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Practical Intensity Based Meta-Analysis

Camille Maumet

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Submitted on 7 May 2023

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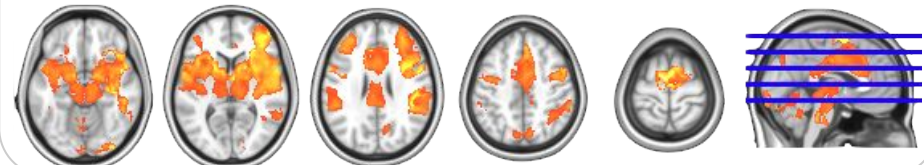
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Practical intensity-based meta-analysis

Coordinate-based meta-analysis



Image-based meta-analysis

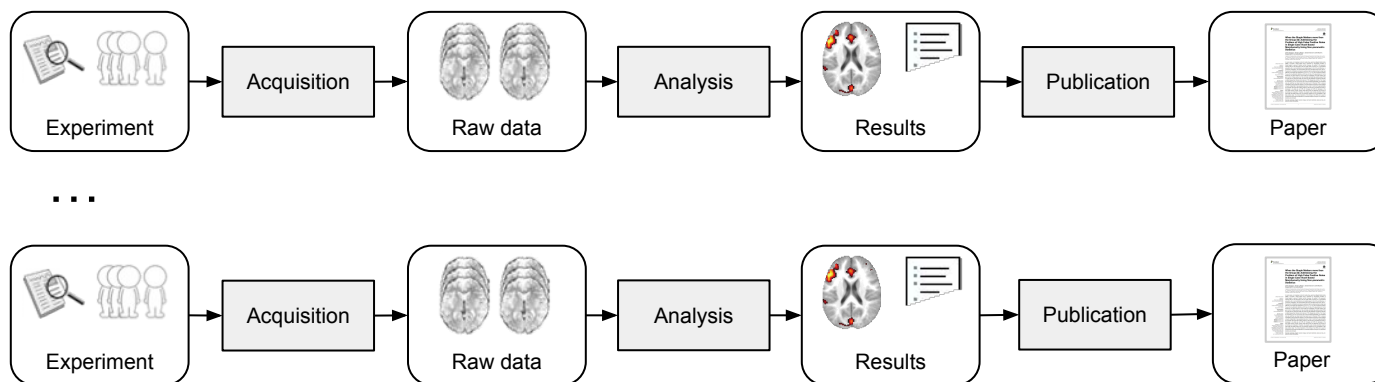


Camille Maumet

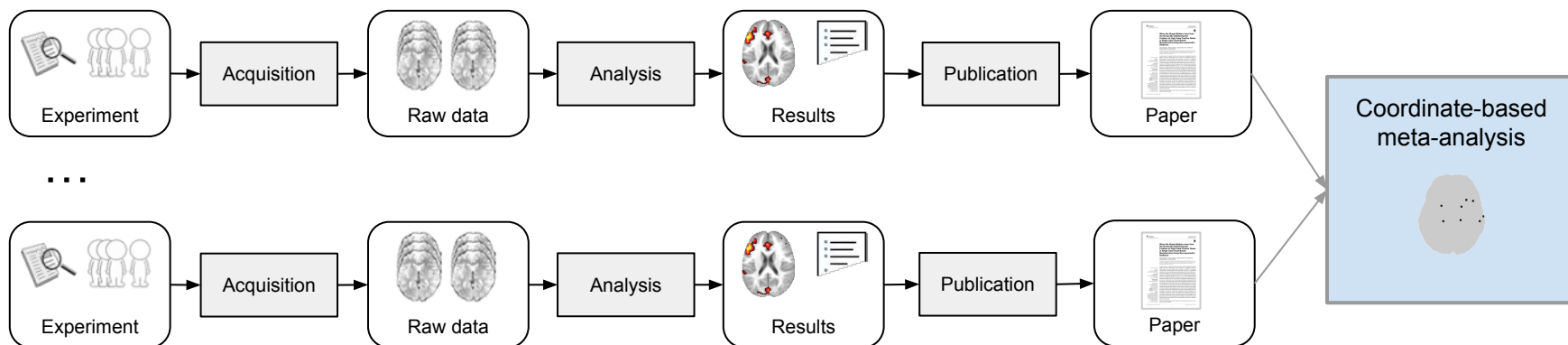
OHBM Neuroimaging Meta-Analysis
Educational course, 25 June 2017

Coordinate-Based & Image-Based Meta-Analyses

Neuroimaging meta-analyses



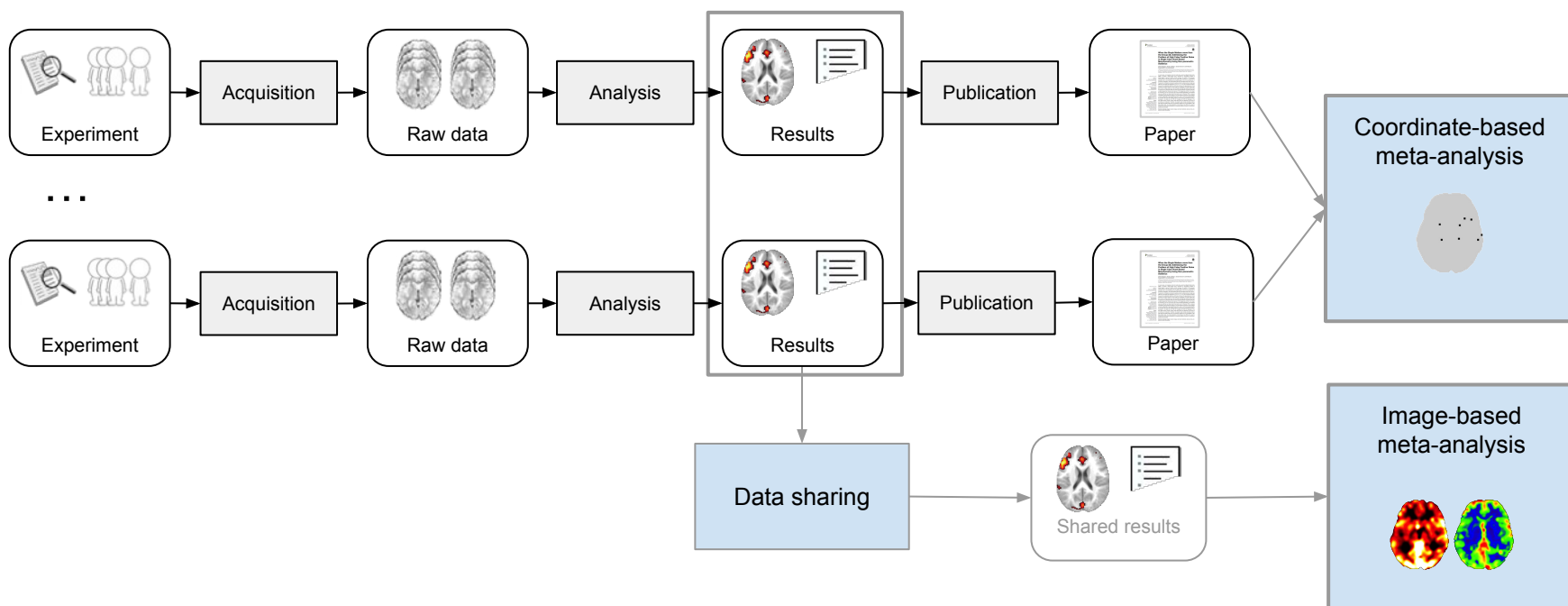
Neuroimaging meta-analyses



Coordinate-based meta-analysis



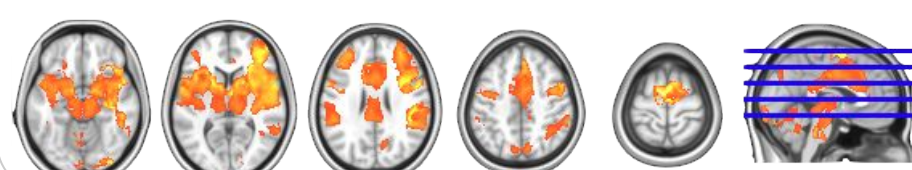
Neuroimaging meta-analyses



Coordinate-based meta-analysis



Image-based meta-analysis



How to perform an image-based
meta-analysis?

Image-based meta-analysis

Subject 1

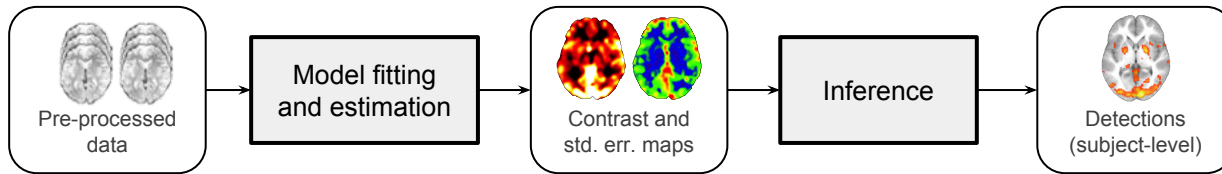
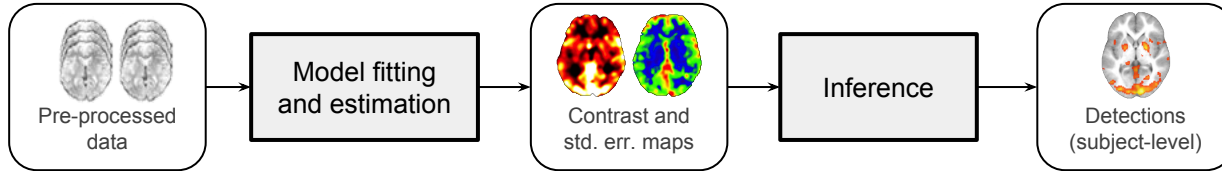


Image-based meta-analysis

Subject 1
...



Subject n

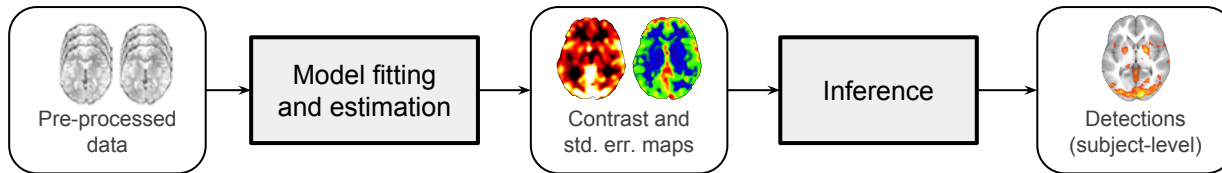


Image-based meta-analysis

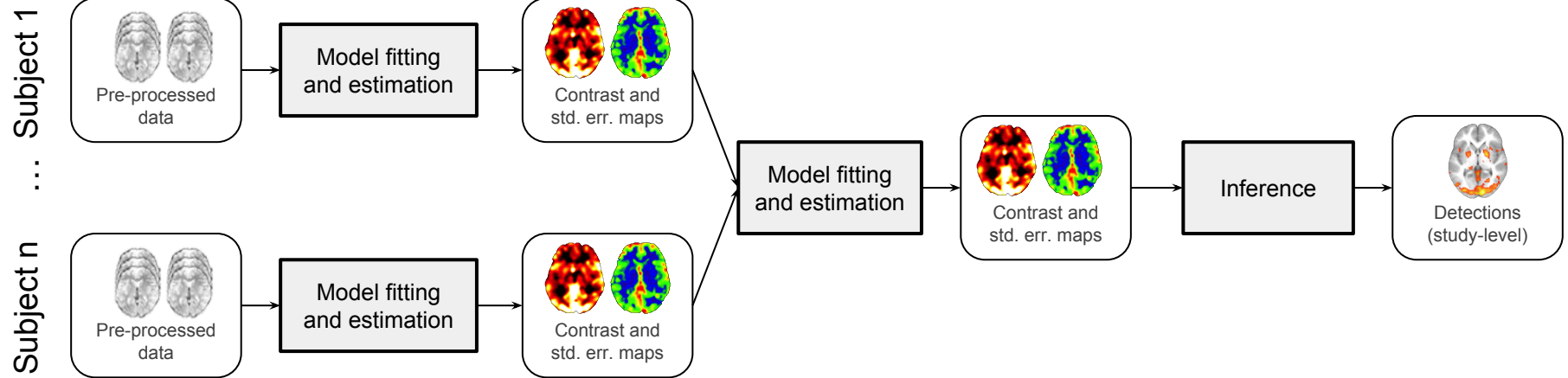


Image-based meta-analysis

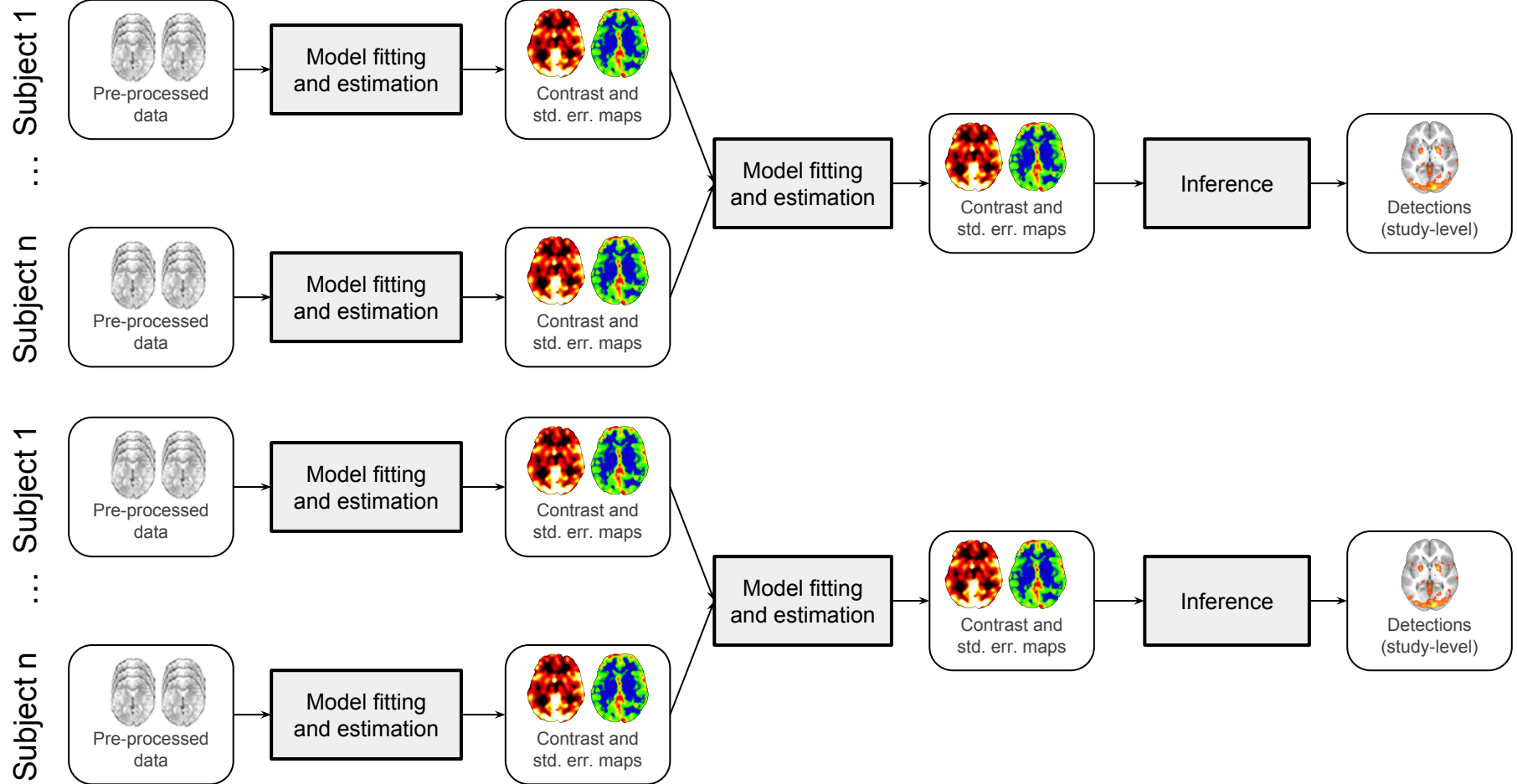


Image-based meta-analysis

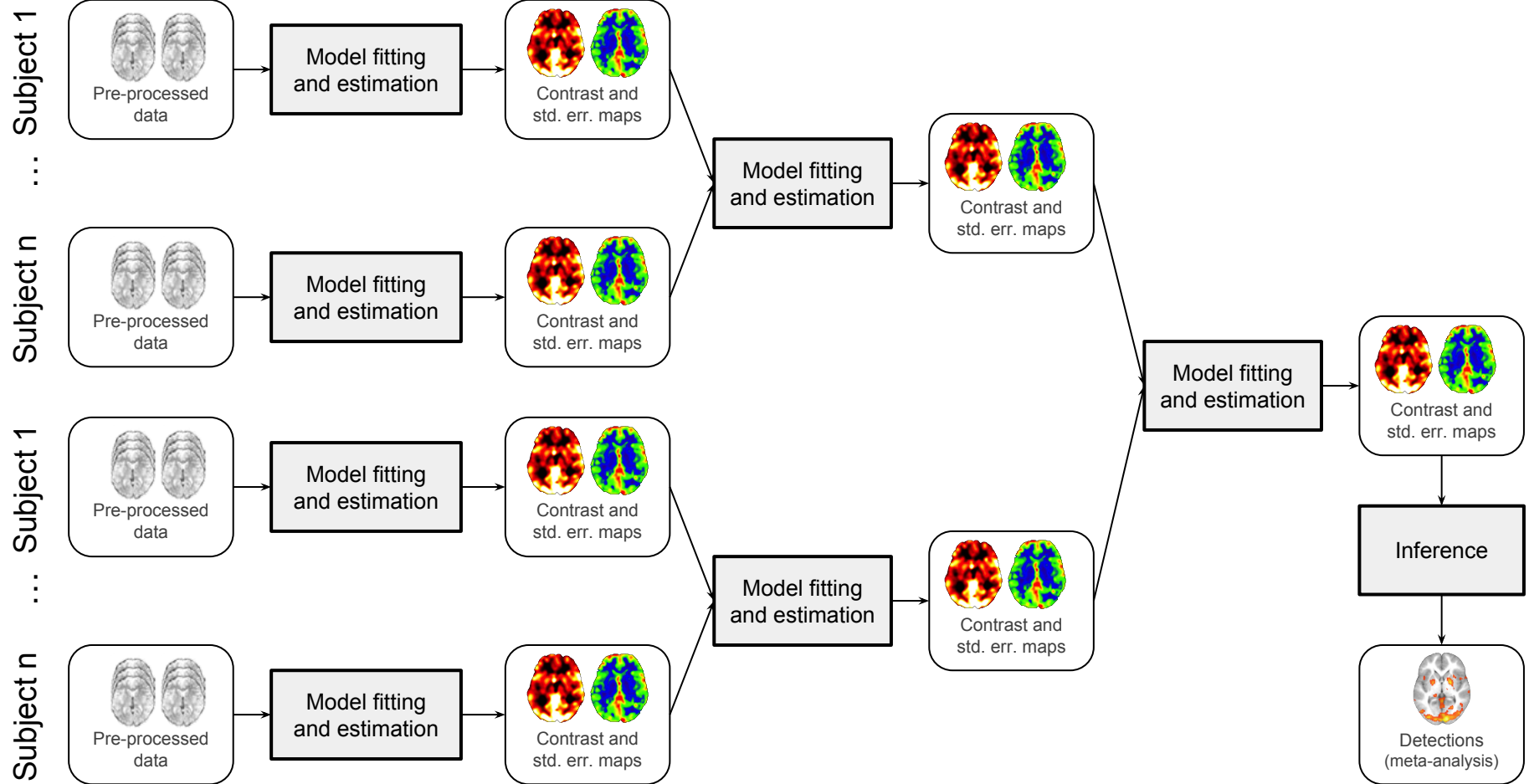


Image-based meta-analysis

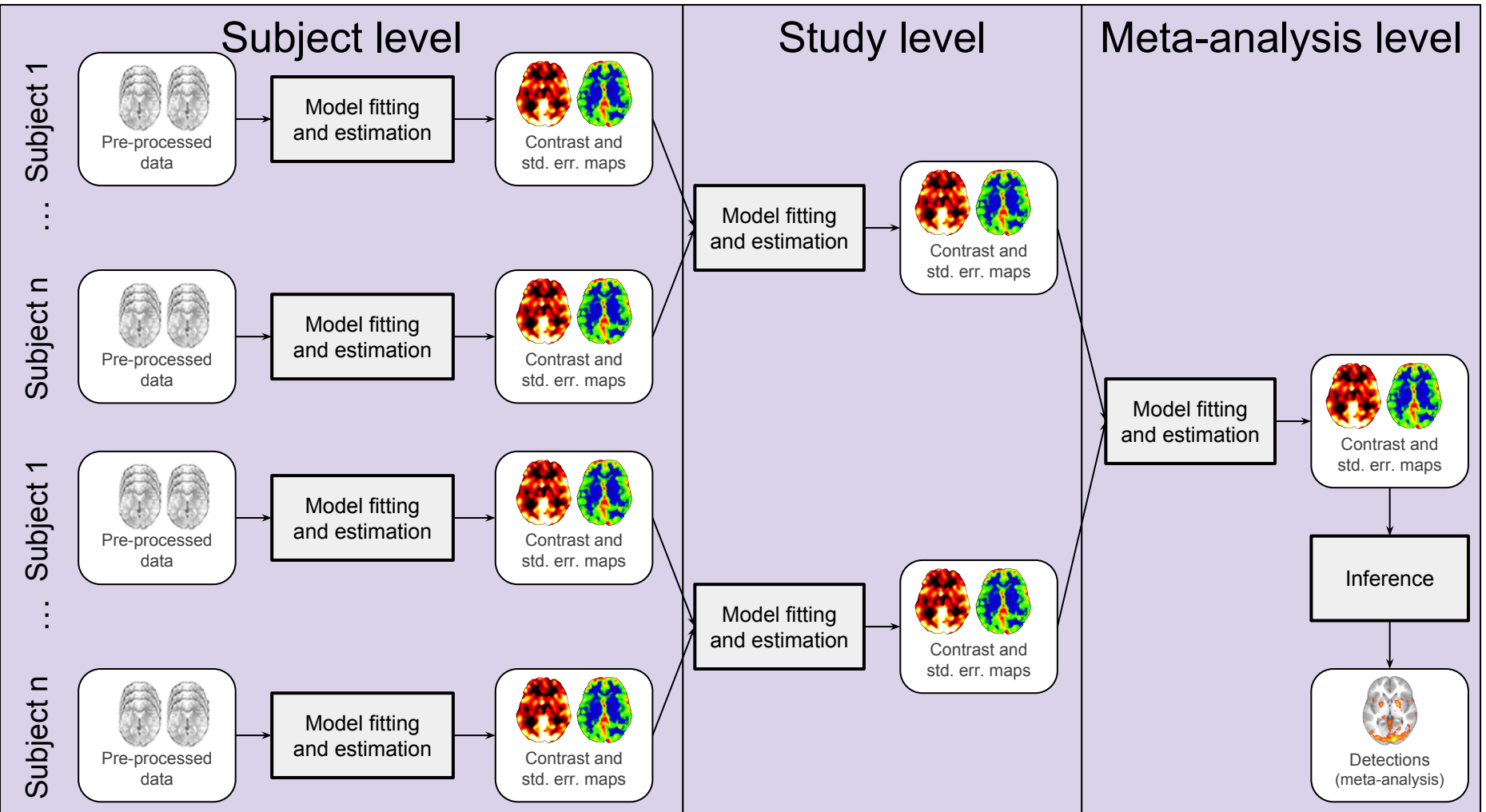
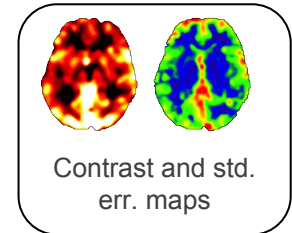


Image-based meta-analysis

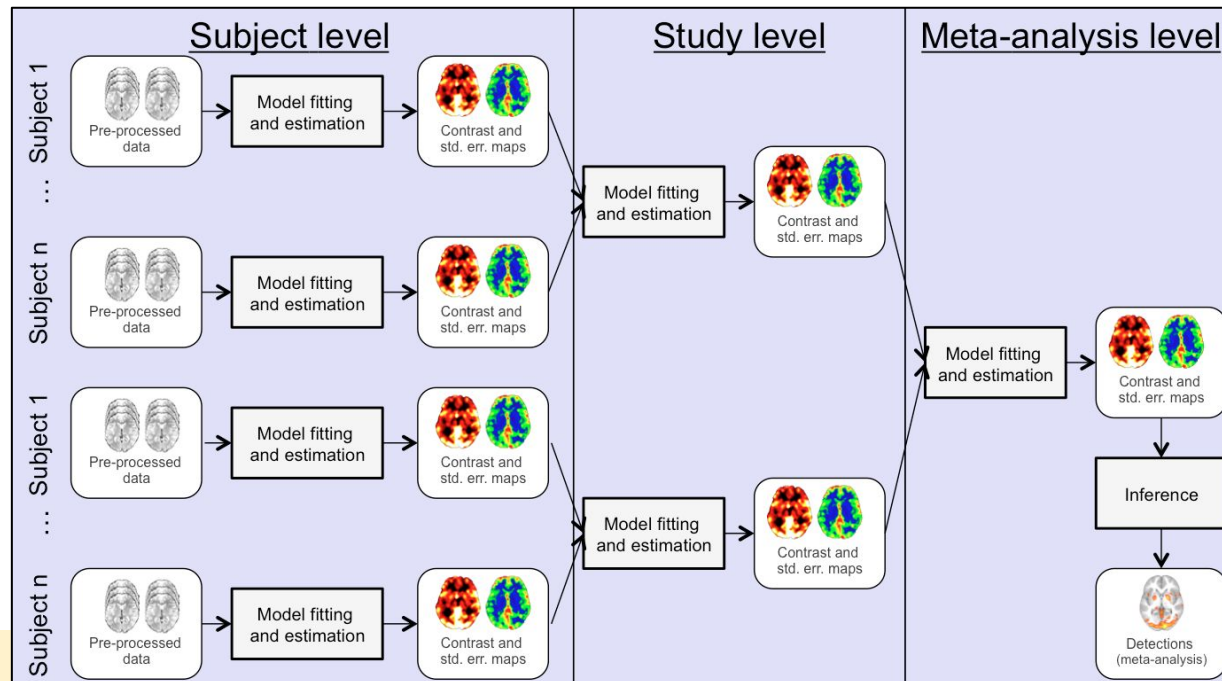
- Gold standard:

Third-level Mixed-Effects GLM

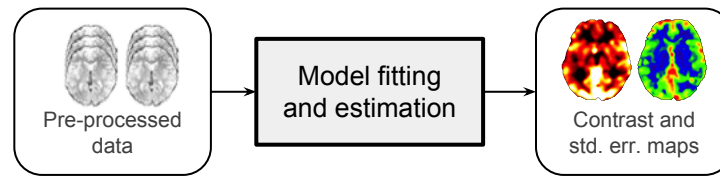


- Requirements

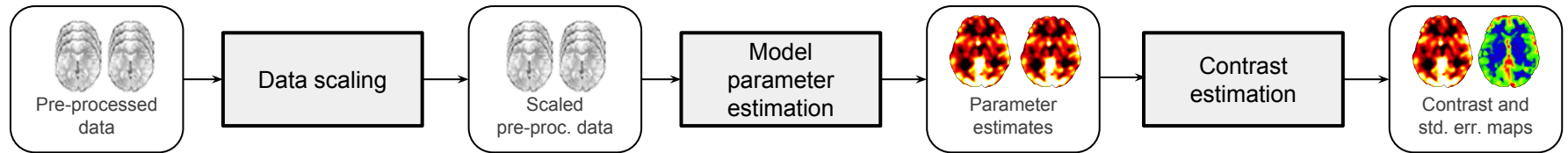
- study-level **Contrast estimates** and **Standard error maps.**
- **Same units**



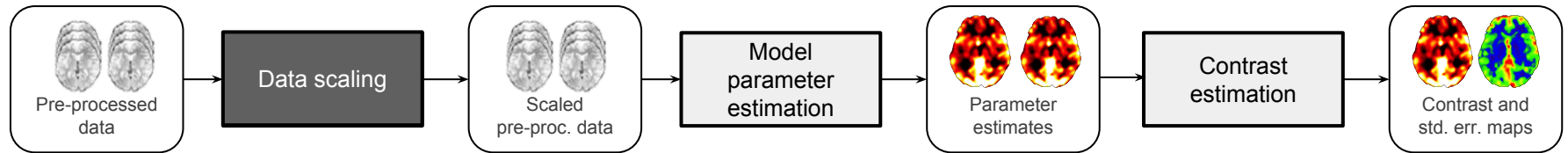
Units of contrast estimates



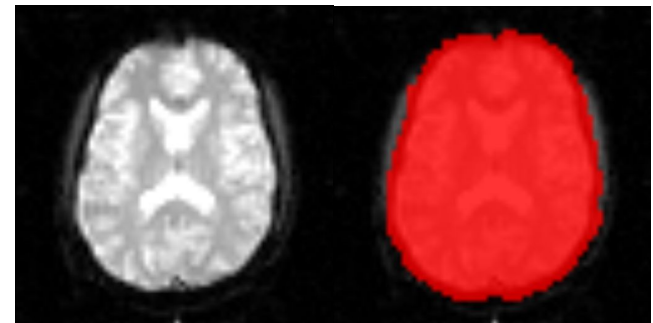
Units of contrast estimates



Units of contrast estimates

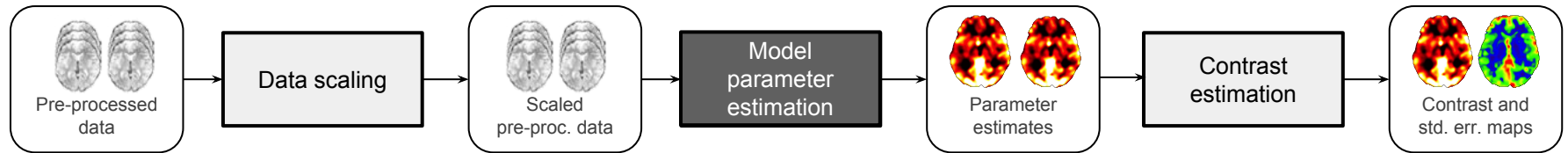


$$\text{scaled_data} = \frac{\text{data} * \text{target}}{\text{est_mean}}$$



Units depend on **mean estimation** and **scaling target**.

Units of contrast estimates

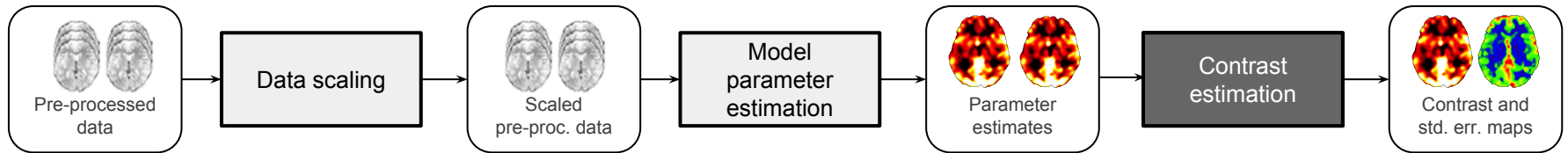


$$Y = \begin{matrix} \text{[Matrix of 10 rows and 2 columns]} \end{matrix} \beta + \epsilon$$

The matrix is a 10x2 grid of gray squares, representing the design matrix for the linear model. The first column contains varying shades of gray, while the second column is a uniform light gray.

Units depend on **scaling** of **explanatory variables**

Units of contrast estimates



- **Contrast Estimation**

- Linear combination of parameter estimates
- Final statistics invariant to scale
 - e.g. $[1 \ 1 \ 1 \ 1]$ gives same T's & P's as $[\frac{1}{4} \ \frac{1}{4} \ \frac{1}{4} \ \frac{1}{4}]$

Units depend on **contrast vector**

- Rule for contrasts to preserve units
 - Positive elements sum to 1
 - Negative elements sum to -1

Units of contrast estimates

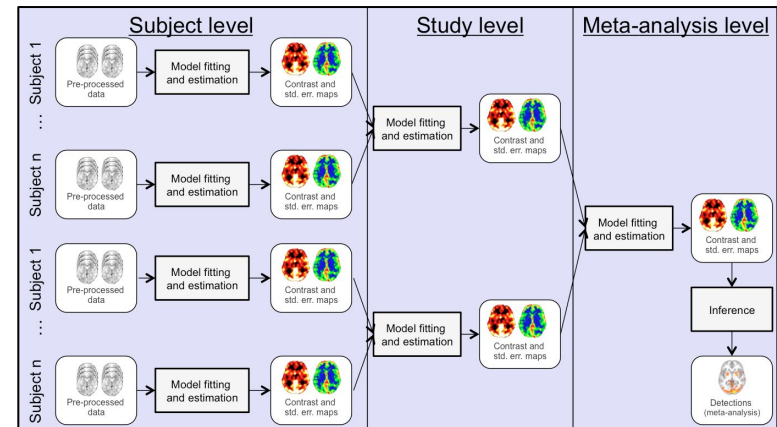
- Gold standard:
Third-level Mixed-Effects GLM

- But...

– Units will depend on:

- The scaling of the data (subject-level)
- The scaling of the predictor(s) (subject- and study-level)
- The scaling of the contrast (subject- and study-level).

– Contrast estimates and standard error maps are rarely shared...

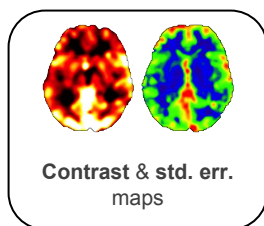


Which images for IBMA?

SPM

FSL

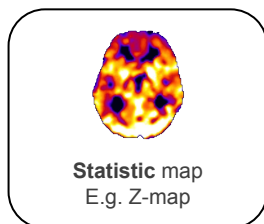
AFNI



con_0001.nii
[SPM.mat]

cope1.nii
varcope1.nii (*squared*)

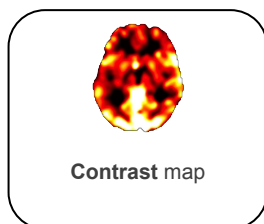
3dMEMA_result+tlrc.BRIK[[0]]
[from contrast & stat maps]



spmT_0001.nii

tstat1.nii.gz
zstat1.nii.gz

3dMEMA_result+tlrc.BRIK[[1]]

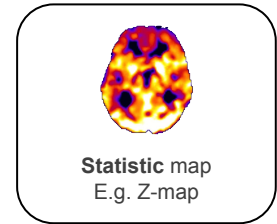


con_0001.nii

cope1.nii

3dMEMA_result+tlrc.BRIK[[0]]

IBMA on Z maps



- Fisher's

$$-2 \sum_k \log P_k \sim \chi_{2k}^2$$

- Sum of $-\log$ P-values (from T/Z's converted to P's)

- Stouffer's

$$\sqrt{K} \times \frac{1}{K} \sum_k Z_k \sim \mathcal{N}(0, 1)$$

- Average Z, rescaled to $\mathcal{N}(0,1)$

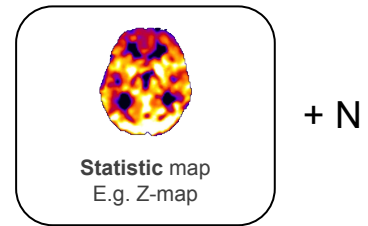
- “Stouffer's Random Effects (RFX)”

$$\sqrt{K} \times \frac{1}{K} \sum_k Z_k \sim \mathcal{N}(0, \sigma_{RFX}^2)$$

- Submit Z's to one-sample t-test

(Slide adapted from Thomas Nichols, OHBM 2015)

IBMA on Z maps + N



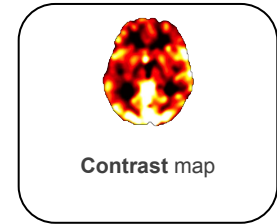
- Weighted Stouffer's

$$\sum_k w_k Z_k \sim \mathcal{N}(0, 1), \quad w_k \propto \sqrt{N_k}$$

- Z's from bigger studies get bigger weights

(Slide adapted from Thomas Nichols, OHBM 2015)

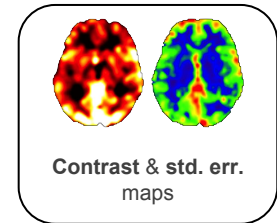
IBMA on Contrast maps



- Random Effects (RFX) GLM

$$\frac{1}{K} \sum_k c\hat{\beta}_k \sim \mathcal{N}(0, \sigma_{\text{RFX}}^2)$$

- Analyze per-study contrasts as “data”



Contrast + standard error maps

- Fixed-Effects (FFX) GLM

$$\frac{1}{K} \sum_k \hat{\theta}_k \sim \mathcal{N}(0, \sum_k \sigma_{\text{FFX},k}^2 / K^2)$$

- *Don't* estimate variance, just take from first level

(Slide adapted from Thomas Nichols, OHBM 2015)

Implementations

- Not all of these options are easily used

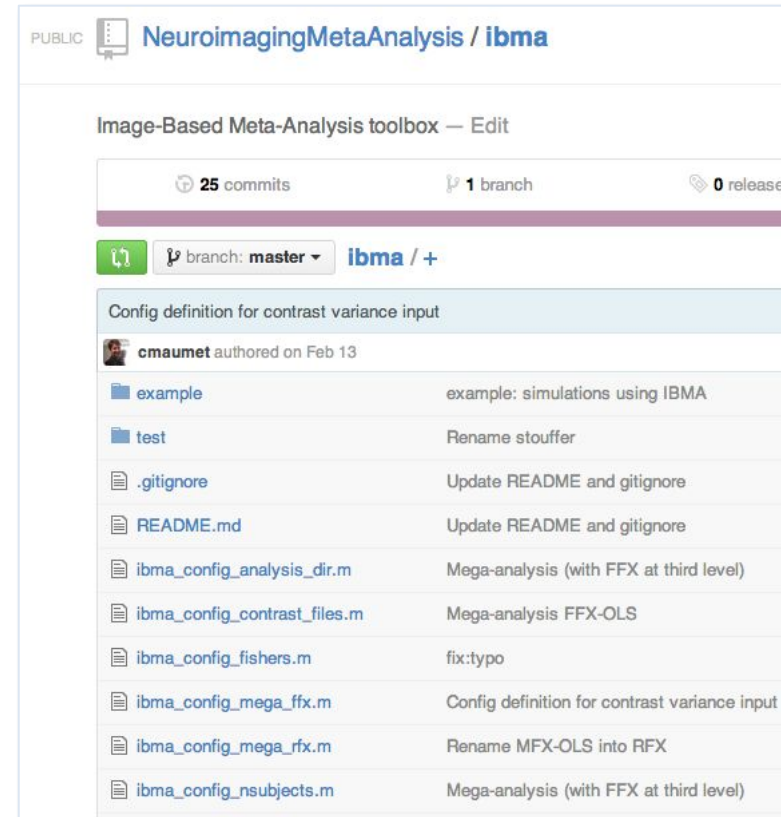
Meta-Analysis Method	Inputs	Neuroimaging Implementation
'Gold Standard' MFX	Con's + SE's	FSL's FEAT SPM spm_mfx AFNI 3dMEMA
RFX GLM Stouffer's RFX	Con's Z's	FSL, SPM, AFNI, etc...
FFX GLM Fisher's Stouffer's Stouffer's Weighted	Con's +SE's Z's Z's Z's + N's	n/a

(Slide from Thomas Nichols, OHBM 2015)

Self Promotion Alert: IBMA toolbox

- SPM Extension
- Still in beta!
 - But welcome all feedback
- Available on GitHub

<https://github.com/NeuroimagingMetaAnalysis/ibma>



Meta-analysis of 21 pain studies

- Results
 - GLM methods similar
 - Z-based methods similar
 - But FFX Z methods more sensitive (as expected)

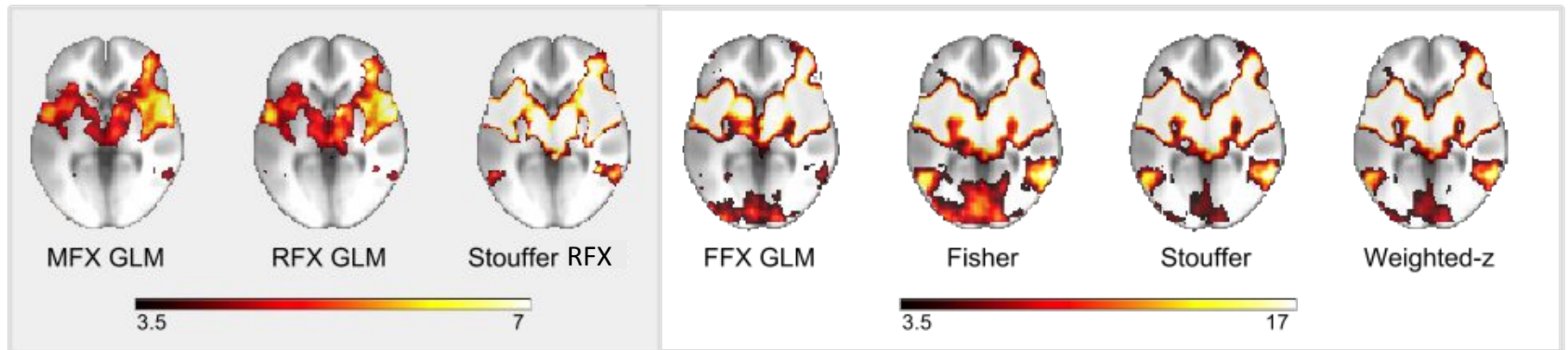
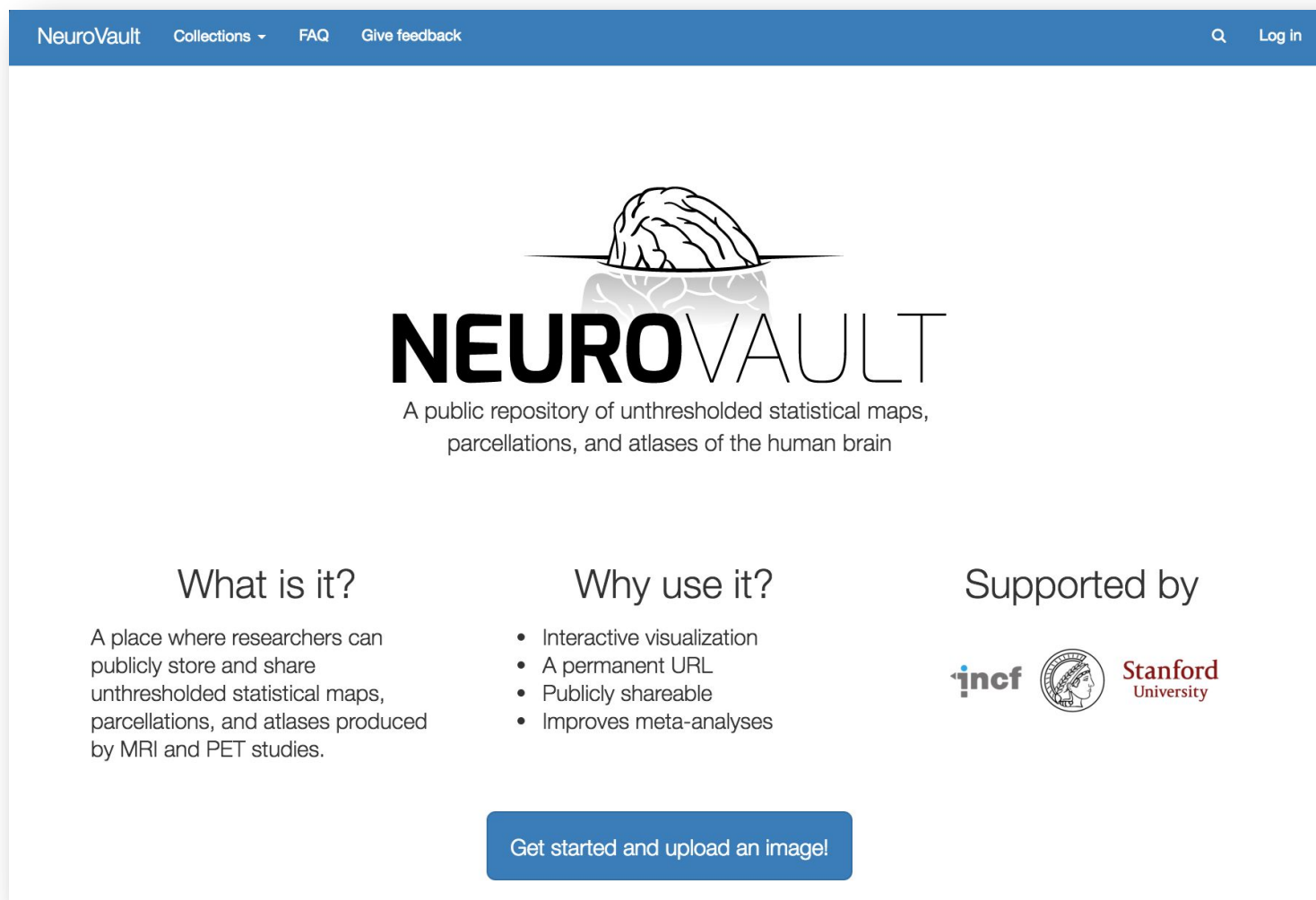


Fig. 1: Result of a meta-analysis of 21 pain studies for 4 fixed-effects (FFX GLM, Fisher, Stouffer, weighted-z) and 2 random-effects (RFX GLM, Stouffer MFX) meta-analytic approaches compared to the reference (MFX GLM) at a threshold of $p < 0.05$ FDR corrected.

Data: Tracey pain group, FMRI, Oxford.

How to publish your statistic maps?

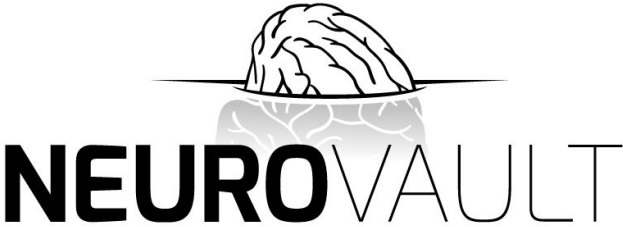
Share your statistic maps



The screenshot shows the NeuroVault website homepage. At the top is a blue navigation bar with the text "NeuroVault", "Collections", "FAQ", and "Give feedback" on the left, and a search icon and "Log in" on the right. The main content area features a central logo consisting of a stylized brain with the text "NEUROVAULT" below it. Underneath the logo is the tagline: "A public repository of unthresholded statistical maps, parcellations, and atlases of the human brain". Below this are three columns of text: "What is it?", "Why use it?", and "Supported by". The "What is it?" section describes the repository as a place for researchers to store and share unthresholded statistical maps, parcellations, and atlases produced by MRI and PET studies. The "Why use it?" section lists four benefits: interactive visualization, a permanent URL, public shareability, and improved meta-analyses. The "Supported by" section includes logos for INCF and Stanford University. At the bottom center is a blue button that says "Get started and upload an image!".

NeuroVault Collections FAQ Give feedback

Q Log in



NEUROVAULT

A public repository of unthresholded statistical maps, parcellations, and atlases of the human brain



What is it?

A place where researchers can publicly store and share unthresholded statistical maps, parcellations, and atlases produced by MRI and PET studies.

Why use it?

- Interactive visualization
- A permanent URL
- Publicly shareable
- Improves meta-analyses

Supported by



Stanford University

Get started and upload an image!

<http://neurovault.org>

Share your statistic maps

NeuroVault Collections ▾ FAQ Give feedback Q Log in

A Correspondence between Individual Differences in the Brain's Intrinsic Functional Architecture and the Content and Form of Self-Generated Thoughts

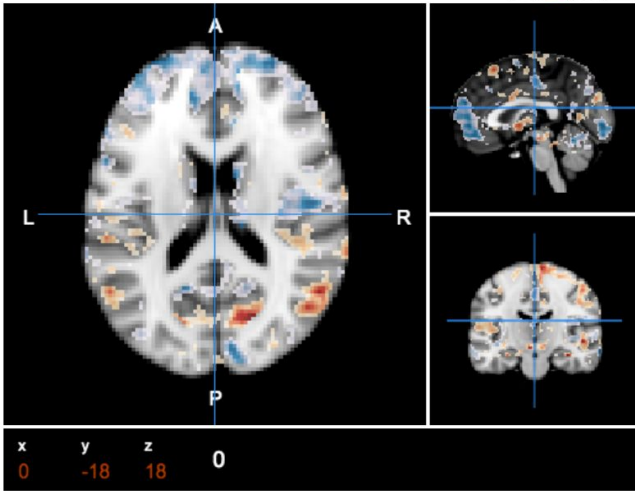
Contributed by ChrisFiloGorgolewski

Krzysztof J. Gorgolewski, Dan Lurie, Sebastian Urchs, Judy A. Kipping, R. Cameron Craddock, Michael P. Milham, Daniel S. Margulies, Jonathan Smallwood

[Link to the paper](#)

[3D View](#)

File View Options ■ ■ ■ 🌐 🗨



x y z 0
0 -18 18 0

[Images](#) [Details](#)

Show entries Search:

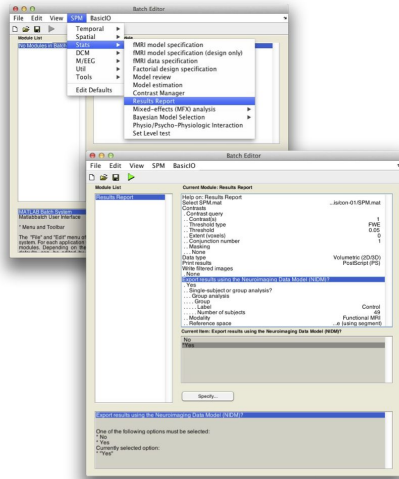
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<input type="checkbox"/>	26	fALFF: Future	Z map
<input type="checkbox"/>	27	fALFF: Past > Future	Z map
<input type="checkbox"/>	28	fALFF: Positive	Z map
<input type="checkbox"/>	29	fALFF: Negative	T map
<input type="checkbox"/>	30	fALFF: Positive > Negative	Z map
<input type="checkbox"/>	31	fALFF: Social Cognition	Z map

Showing 1 to 7 of 30 entries [First](#) [Previous](#) [Next](#) [Last](#)

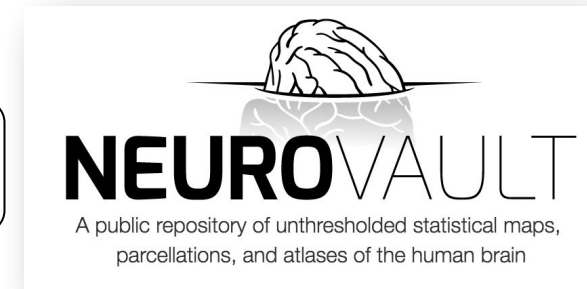
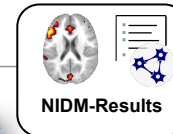
<http://neurovault.org>

From SPM & FSL

SPM



Name	Size	Kind
beta_0001.nii	2.4 MB	NIFTI
con_0001.nii	2.4 MB	NIFTI
mask.nii	593 KB	NIFTI
nidm_001.nidm.zip	4.1 MB	ZIP archive
ResMS.nii	4.7 MB	NIFTI
RPV.nii	4.7 MB	NIFTI
SPM.mat	484 KB	MATLAB Data
spmT_0001.nii	2.4 MB	NIFTI

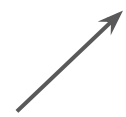


FSL

```
$ nidmfsl fsl_ds107_group 49 -g Control
```



Name	Size	Kind
design.con	126 bytes	Document
design.fsf	20 KB	Document
design.grp	131 bytes	Document
design.icon	28 bytes	Document
cope1.feaf	--	Folder
cope2.feaf	--	Folder
inputreg	--	Folder
logs	--	Folder
lq_image.nii.gz	3.4 MB	gzip compressed archive
mask.nii.gz	15 KB	gzip compressed archive
mean_func.nii.gz	2.8 MB	gzip compressed archive
report_firstlevel.html	10 KB	HTML document
report_log.html	55 KB	HTML document
report_reg.html	17 KB	HTML document
report_stats.html	495 bytes	HTML document
report.html	922 bytes	HTML document
design.mat	732 bytes	MATLAB Data
design_cov.ppm	6 KB	OpenOffice.app Document
design.ppm	219 KB	OpenOffice.app Document
design_cov.png	106 bytes	Portable Network Graphics image
design.png	1 KB	Portable Network Graphics image
fsl_ds107_group.nidm.zip	13.6 MB	ZIP archive



<http://nidm.nidash.org/getting-started/>

Conclusions

- When data available, **Image-Based** preferred to **Coordinate-Based** meta-analysis

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- Few tools for Z-based IBMA, but underway...

Conclusions

- When data available, **Image-Based** preferred to **Coordinate-Based** meta-analysis
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- When only contrast estimates are available, **RFX GLM** is a practical & valid approach
- Few tools for Z-based IBMA, but underway...
- Data sharing tools: **NeuroVault**, NIDM-Results

Thank you!

This work is supported by

