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A standard for describing and sharing neuroimaging results Application to image-based meta-analysis

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A standard for describing and sharing neuroimaging results

Application to image-based meta-analysis

Séminaire NeuroSpin - October 3rd, 2016

Camille Maumet

Neuroimaging Statistics, University of Warwick, UK

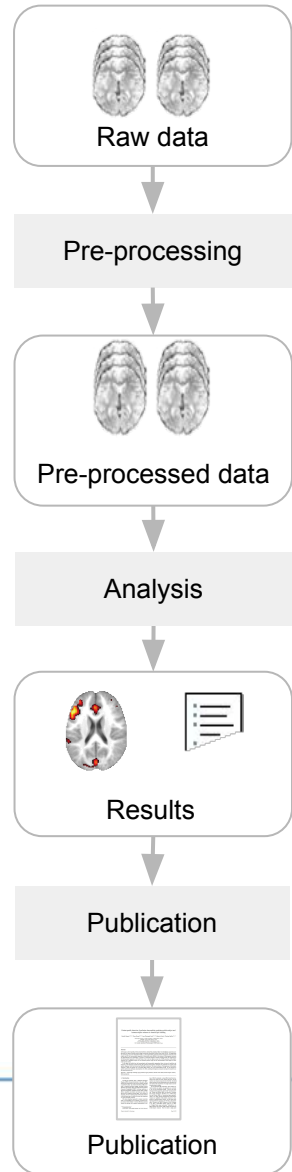
Agenda

- Background
 - Reporting neuroimaging results
 - Meta-analysis
- The NeuroImaging Data Model
- Example of image-based meta-analysis



Background

Reporting of neuroimaging results



Reporting of neuroimaging results

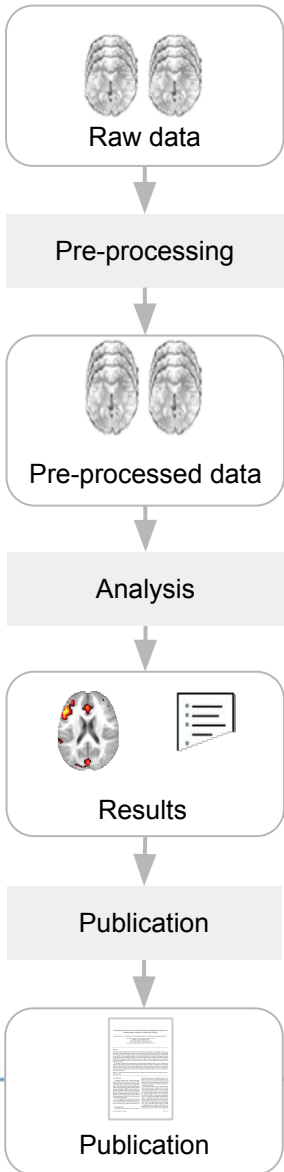
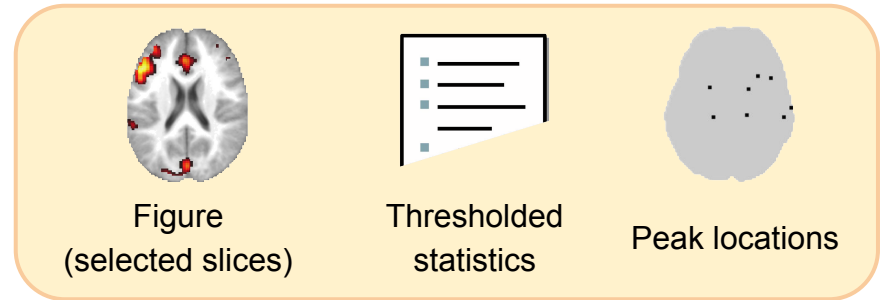
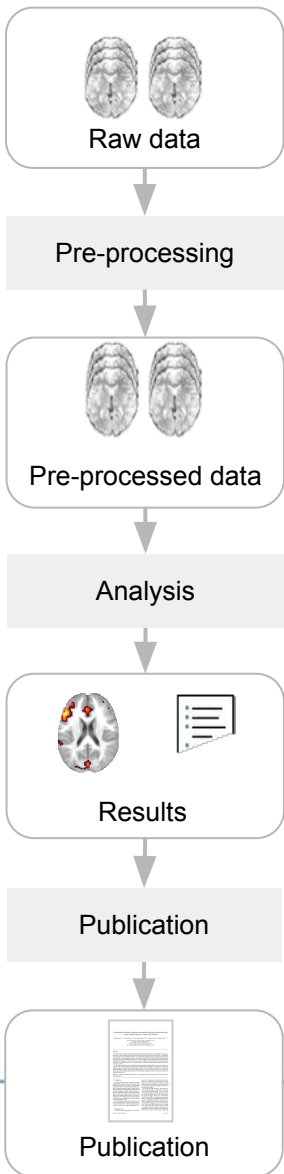


Figure (selected slices) **Thresholded statistics** **Peak locations**

This block contains three key visual outputs of neuroimaging analysis: a brain slice with highlighted clusters, a callout box representing statistical data, and a brain slice with marked peak locations.

Reporting of neuroimaging results



- ✗ Data loss
- ✗ Ambiguous/incomplete reporting
- ✗ Metadata is not searchable

Reproducibility & provenance

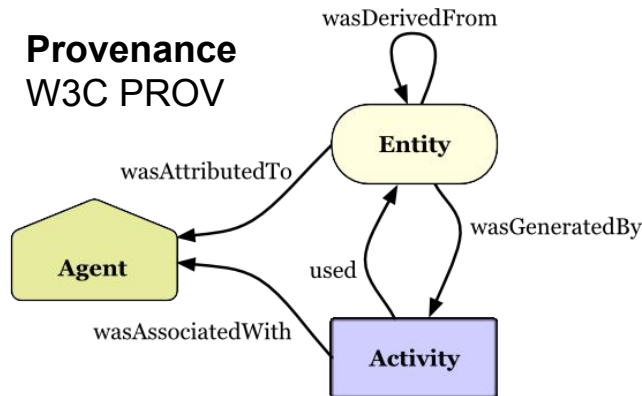
A reproducibility crisis?



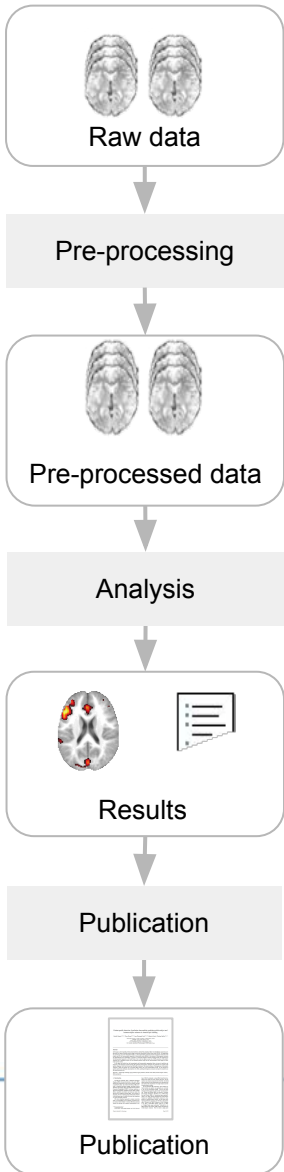
Underpowered studies



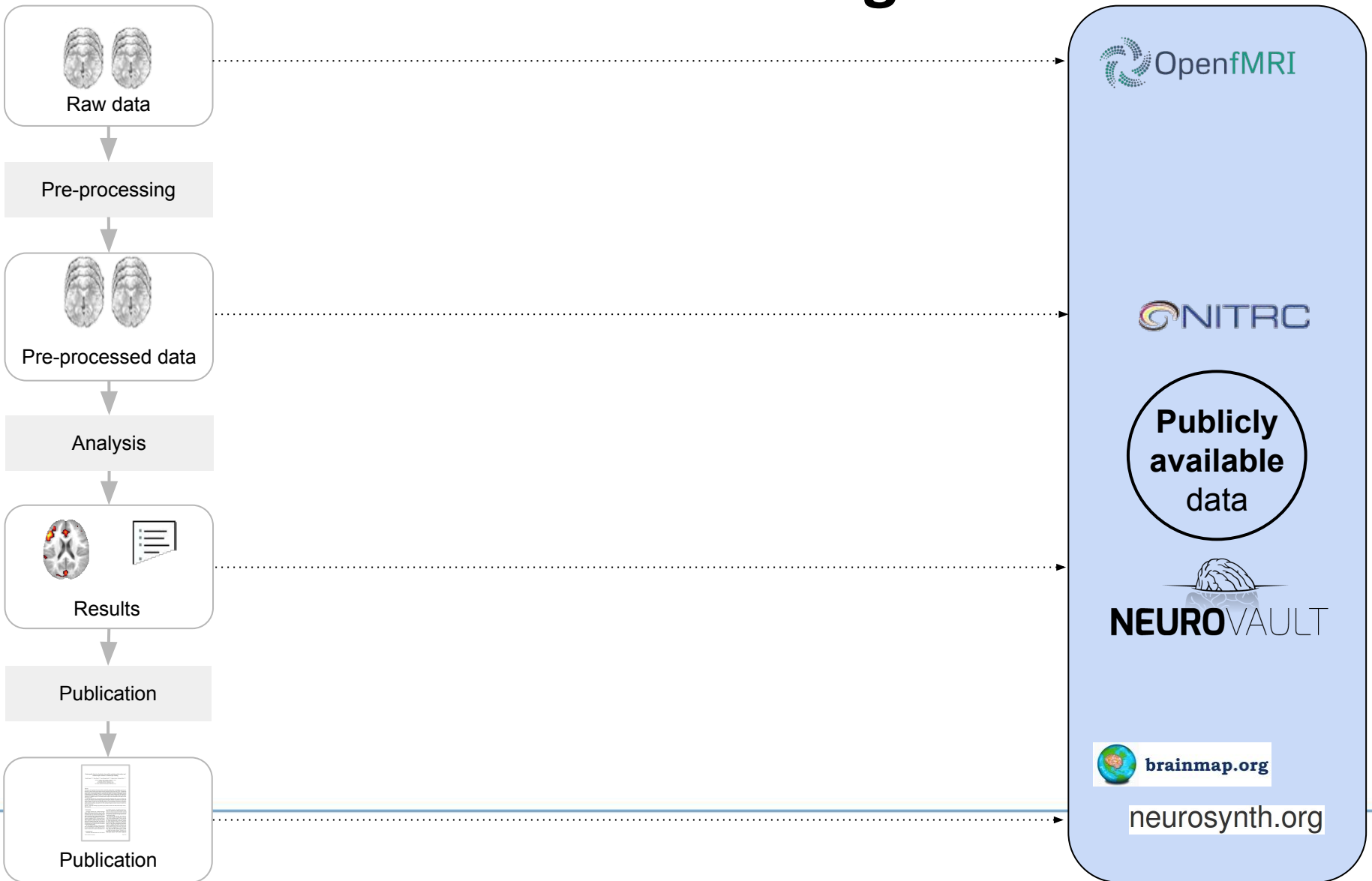
Publication bias



Data sharing



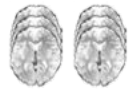
Data sharing



Data sharing

BUT

< 5% of data
shared in public
repositories



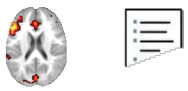
Raw data

Pre-processing



Pre-processed data

Analysis

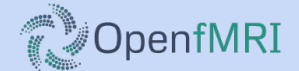


Results

Publication



Publication



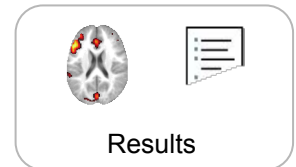
**Publicly
available
data**



neurosynth.org

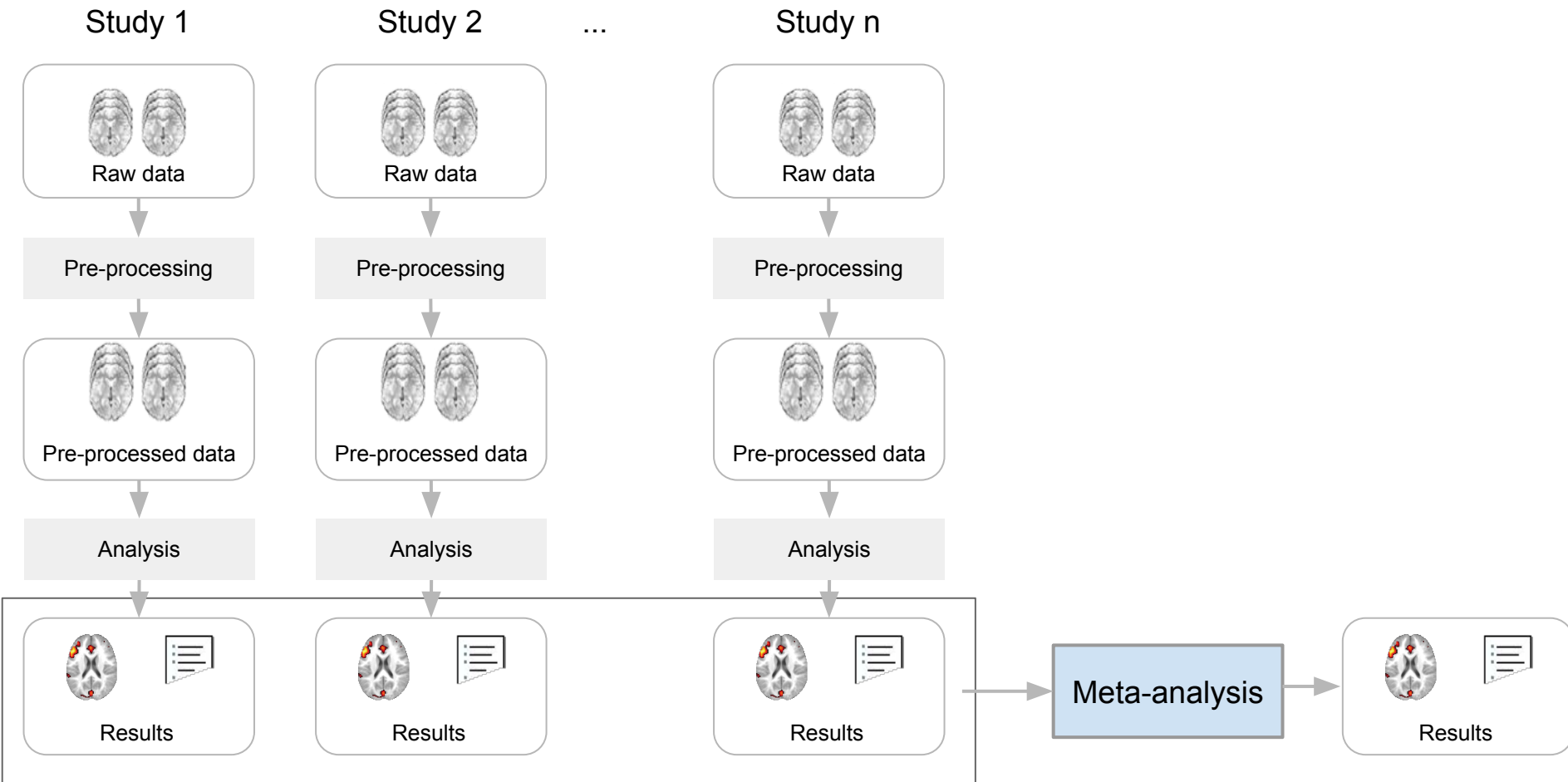
Data sharing vs results reporting

- Impediments
 - **Ethical** considerations
 - **Privacy** issues
 - **Psychological** barriers
 - **Time consuming** process
- **Results sharing** is best practice
 - => **reporting** rather than **data sharing**



Application to meta-analyses

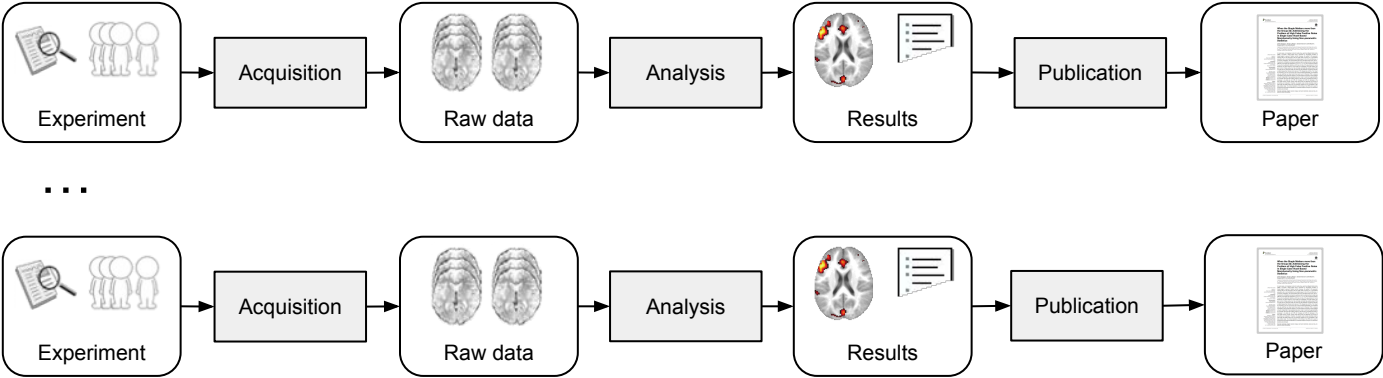
Meta-analysis



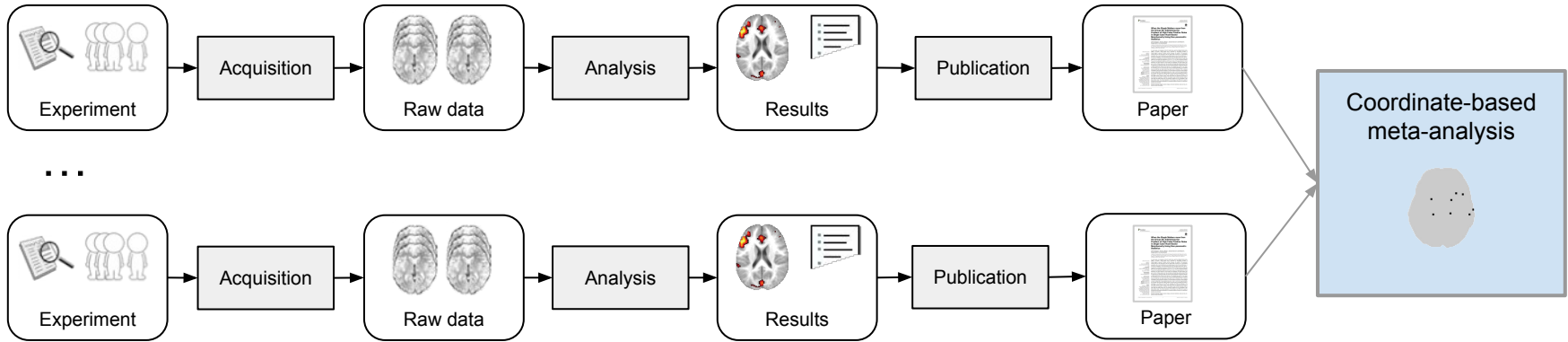
Neuroimaging meta-analysis

- Rich fMRI literature
 - > 30,000 articles (“fMRI” pubmed)
- Increase statistical power
- Synthesize information across studies

Coordinate- or Image-Based?



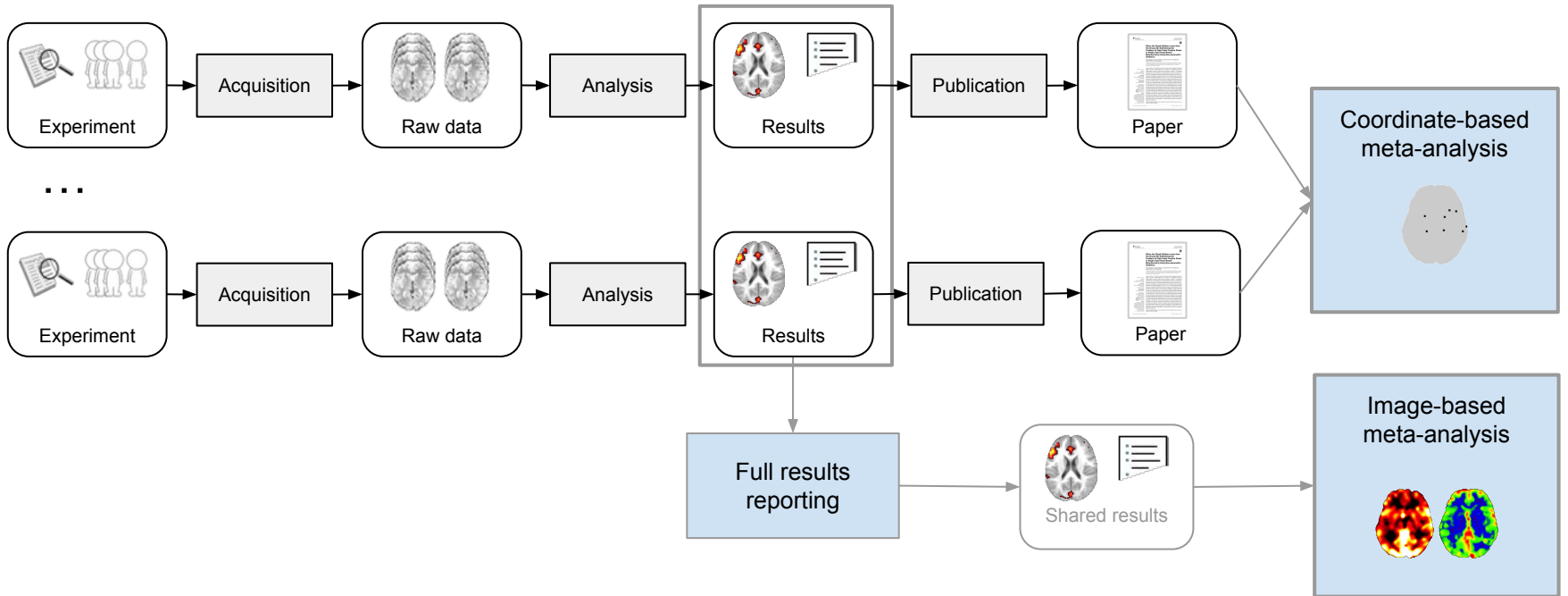
Coordinate- or Image-Based?



Coordinate-based meta-analysis



Coordinate- or Image-Based?



Coordinate-based meta-analysis



Image-based meta-analysis

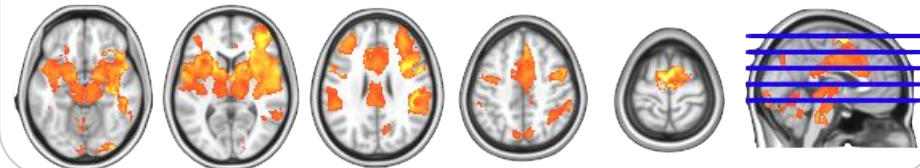
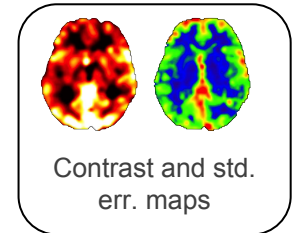


Image-based meta-analysis

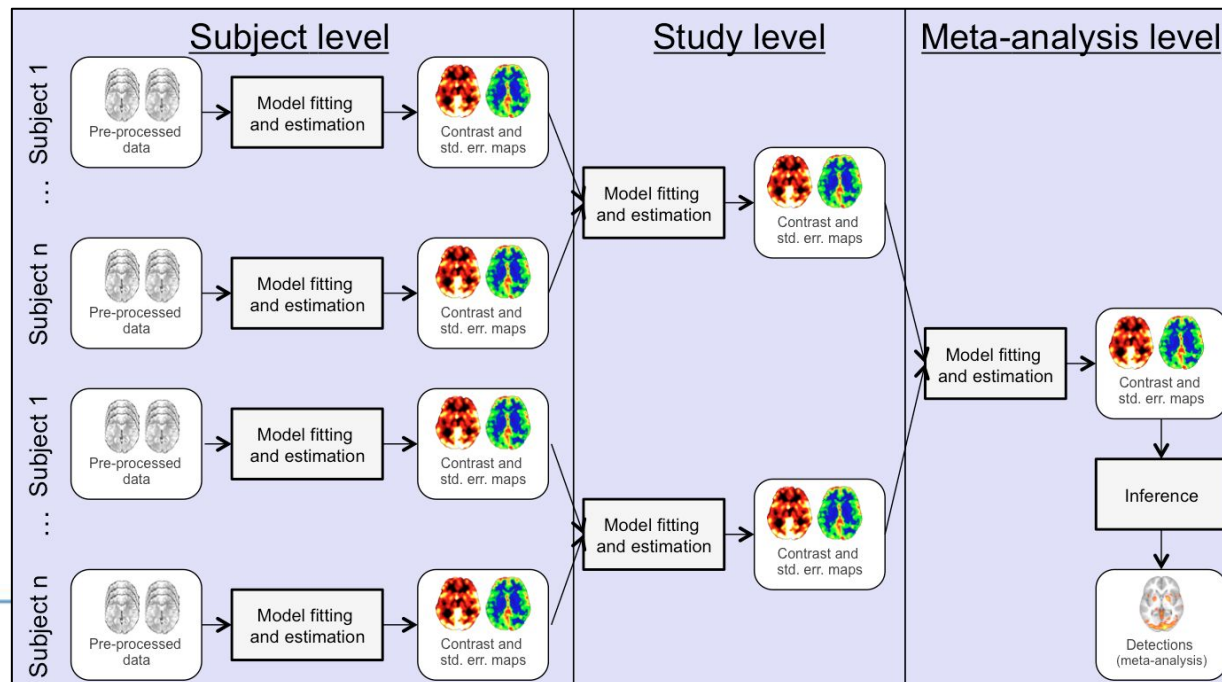
- Gold standard:

Third-level Mixed-Effects GLM

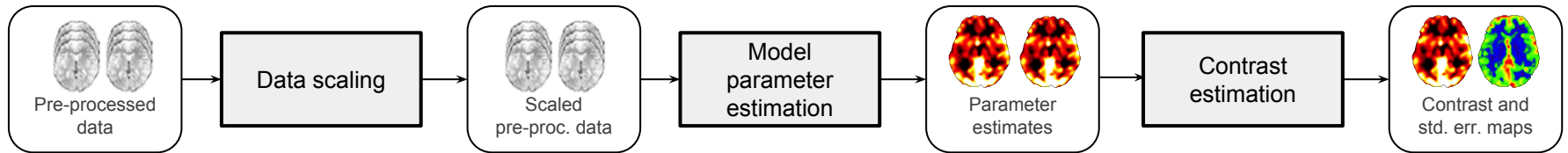


- Requirements

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

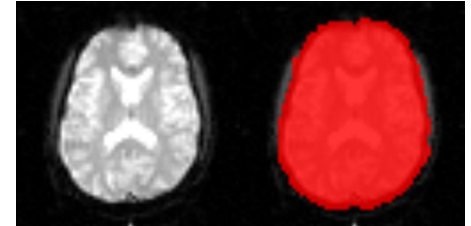


Units of contrast estimates



Units depend on

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



- Scaling of the explanatory variables

$$Y = \begin{bmatrix} \text{---} \\ \text{---} \\ \text{---} \\ \text{---} \\ \text{---} \\ \text{---} \\ \text{---} \\ \text{---} \\ \text{---} \\ \text{---} \end{bmatrix} \beta + \varepsilon$$

- Scaling of the contrast $[1 \ 1 \ 1 \ 1]$ vs. $[\frac{1}{4} \ \frac{1}{4} \ \frac{1}{4} \ \frac{1}{4}]$

Image-Based Meta-Analysis

Other approaches

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	IBMA toolbox

Required for Image-based meta-analysis

- Images
 - Contrast and standard error maps
 - Statistic maps
- Contrast vectors
- Number of subjects per groups
- Neuroimaging software used (data scaling)

The Neuroimaging Data Model

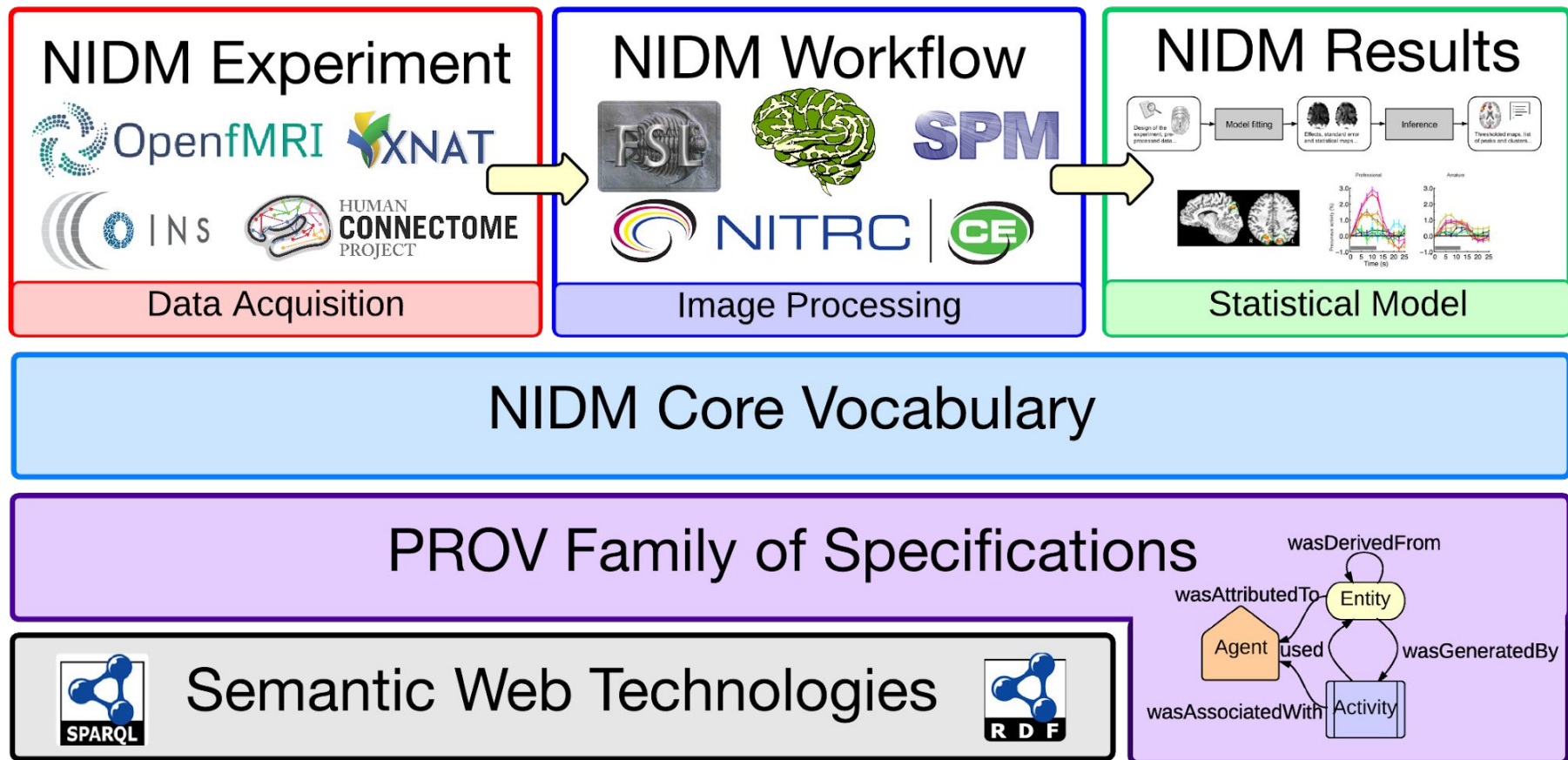
INCF Neuroimaging Task Force

- International collaboration
 - 13 labs, >12 tools
 - Weekly teleconferences, focused workshops, GitHub
 - Open

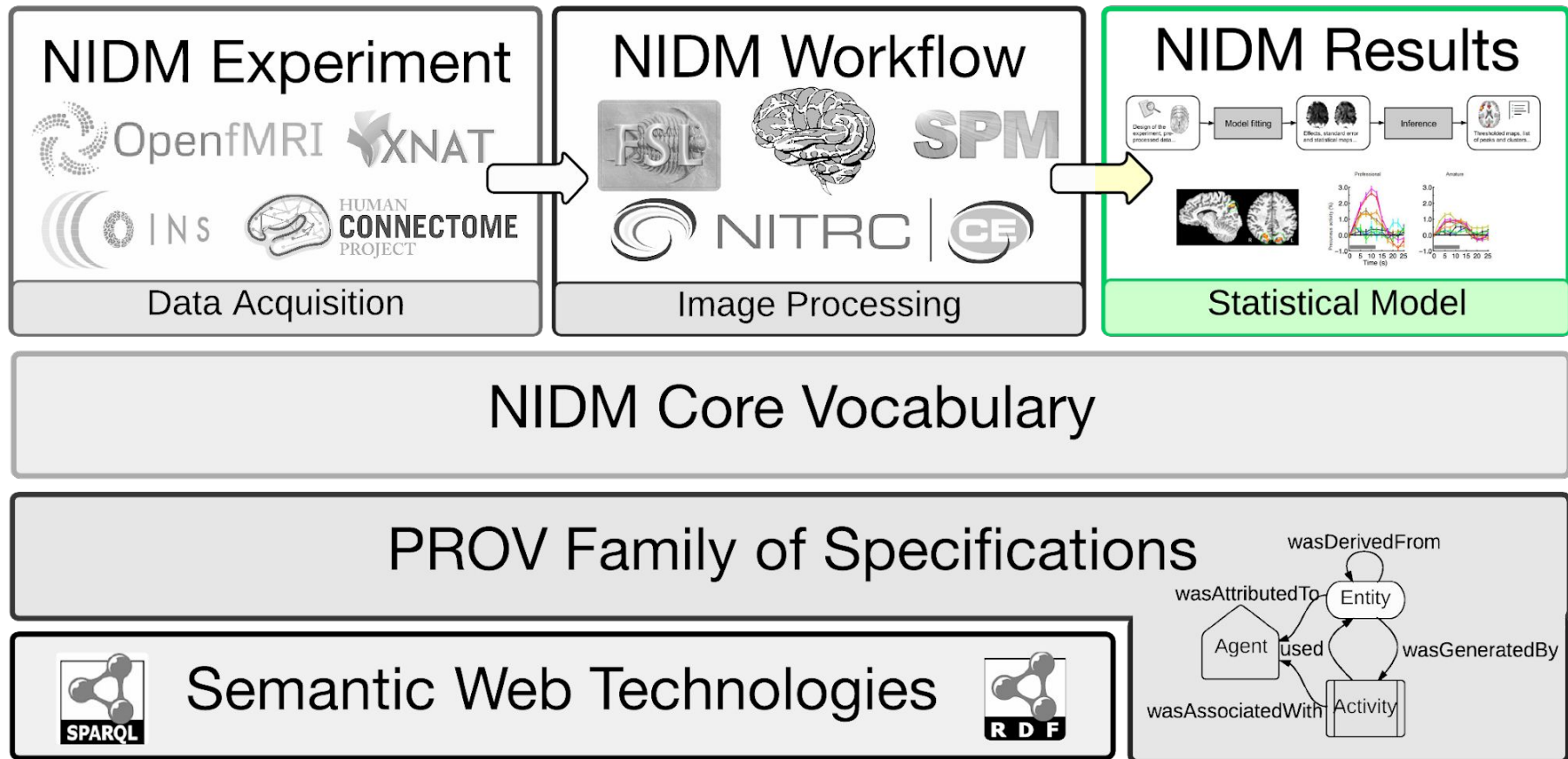
- Resources
 - <http://nidm.nidash.org/>
 - <http://github.com/incf-nidash/>



NIDM: a set of specifications to describe neuroimaging data



NIDM: a set of specifications to describe neuroimaging data

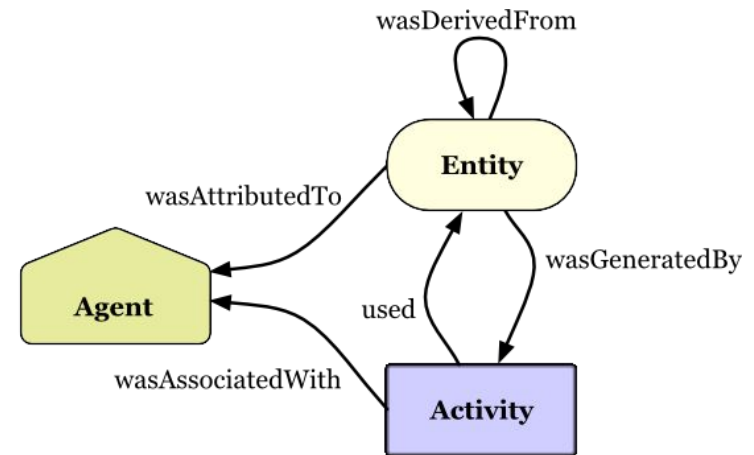


NIDM-Results

- Metadata selected according to
 - Meta-analysis use-case
 - Best practices
 - Neuroimaging software
- **Automatically** retrieved

Model

- Semantic web
- PROV for provenance
- STATO (statistical ontology)
- NeuroLex/RRID (neuroscience lexicon)
- Dublin Core, NEPOMUK file ontology, cryptographic hash functions

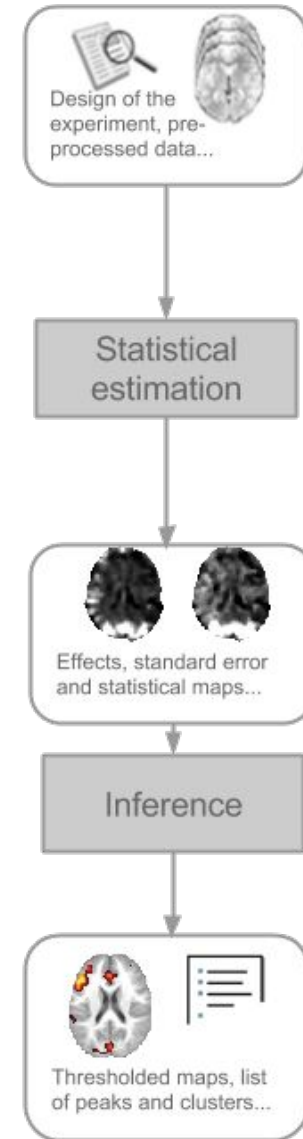
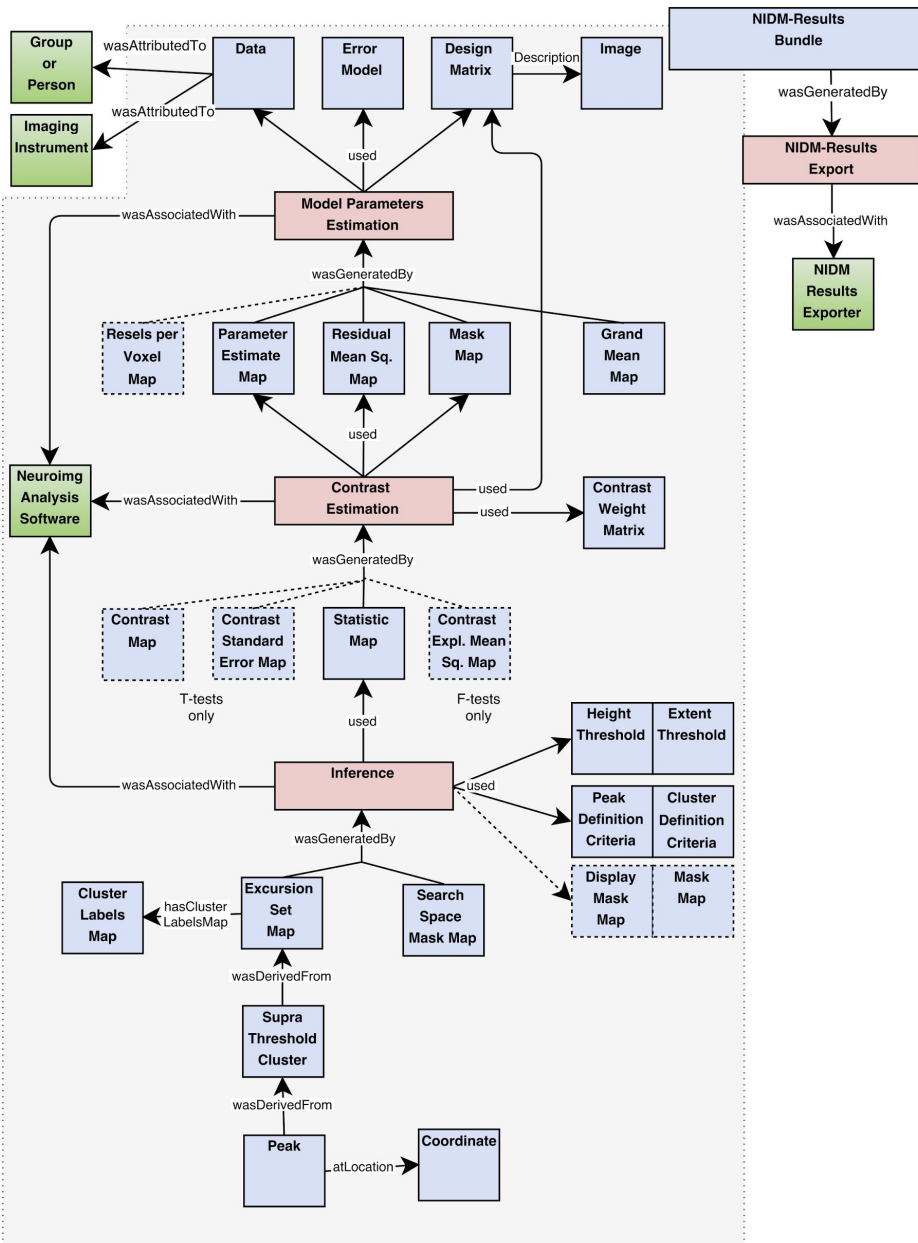


NIDM-Results

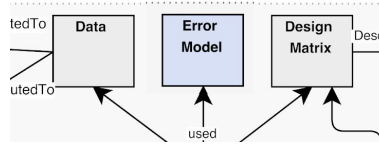
NIDM-Results pack: Compressed file containing a NIDM-Results serialization and some or all of the referenced image data files.



NIDM-Results



Specification



nidm:'Error Model': Model used to describe the random variation of the error term as part of parameter estimation, including specification of the error probability distribution, its variance and dependence both spatially and across observations.

nidm:'Error Model' is a prov:'Entity' used by nidm:'Model Parameter Estimation'.

A nidm:'Error Model' has attributes:

- rdfs:label: (OPTIONAL) Human readable description of the nidm:'Error Model'.
- **nidm:'dependence Map-Wise Dependence'**: (OPTIONAL) Property that associates an 'Error Parameter Map-Wise Dependence' to the dependence of an 'Error Model'. (range nidm:'Error Parameter Map-Wise Dependence' such as nidm:'Constant Parameter', nidm:'Independent Parameter', nidm:'Regularized Parameter').
- **nidm:'error Variance Homogeneous'**: (OPTIONAL) A boolean value reflecting how the variance of the error is modeled during parameter estimation; TRUE for constant variance over all observations in the model, FALSE for heterogeneous variance. (range xsd:boolean).
- **nidm:'has Error Dependence'**: (OPTIONAL) Property that associates a covariance structure representing the dependence structure of the error, used as part of model estimation with an 'Error Model'. (range obo:'covariance structure' such as nidm:'Exchangeable Error', nidm:'Independent Error', obo:'Toeplitz covariance structure', obo:'compound symmetry covariance structure', obo:'unstructured covariance structure').
- **nidm:'has Error Distribution'**: (OPTIONAL) Property that associates a Probability distribution used to model the error with an ErrorModel. (range obo:'probability distribution' such as obo:'continuous probability distribution', obo:'discrete probability distribution').
- **nidm:'variance Map-Wise Dependence'**: (OPTIONAL) Property that associates an 'Error Parameter Map-Wise Dependence' to the variance of an 'Error Model'. (range nidm:'Error Parameter Map-Wise Dependence' such as nidm:'Constant Parameter', nidm:'Independent Parameter', nidm:'Regularized Parameter').

EXAMPLE 19: Error Model: Ordinary least squares

```
@prefix nidm_ErrorModel: <http://purl.org/nidash/nidm#NIDM_0000023> .
@prefix nidm_hasErrorDistribution: <http://purl.org/nidash/nidm#NIDM_0000101> .
@prefix nidm_errorVarianceHomogeneous: <http://purl.org/nidash/nidm#NIDM_0000094> .
@prefix nidm_varianceMapWiseDependence: <http://purl.org/nidash/nidm#NIDM_0000126> .
@prefix nidm_hasErrorDependence: <http://purl.org/nidash/nidm#NIDM_0000100> .
@prefix nidm_dependenceMapWiseDependence: <http://purl.org/nidash/nidm#NIDM_0000089> .
@prefix nidm_IndependentParameter: <http://purl.org/nidash/nidm#NIDM_0000073> .
@prefix nidm_IndependentError: <http://purl.org/nidash/nidm#NIDM_0000048> .
@prefix obo_normaldistribution: <http://purl.obolibrary.org/obo/STATO_0000227> .
```

```
niiri:error_model_id a prov:Entity , nidm_ErrorModel ;
  nidm_hasErrorDistribution: obo_normaldistribution ;
  nidm_errorVarianceHomogeneous: "true"^^xsd:boolean ;
  nidm_varianceMapWiseDependence: nidm_IndependentParameter ;
  nidm_hasErrorDependence: nidm_IndependentError ;
  nidm_dependenceMapWiseDependence: nidm_IndependentParameter ;
```

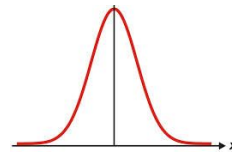
Definition

Attributes

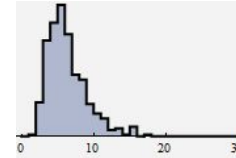
Examples

Harmonisation across software

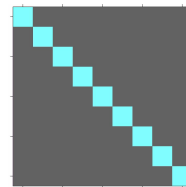
- Model of the error
 - Prob. distribution:
 - Variance:
 - Dependence:



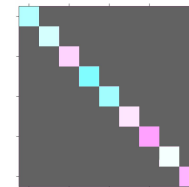
Gaussian



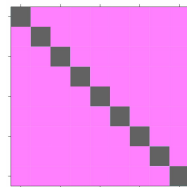
Non-Parametric



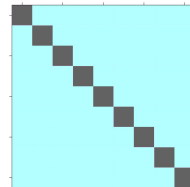
homogeneous



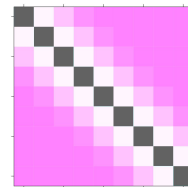
heterogeneous



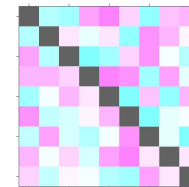
Independent noise



Compound Symmetry

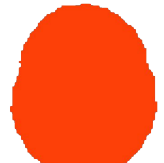


Serially correlated

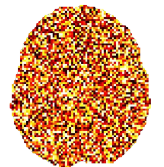


Arbitrarily correlated

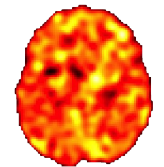
...



global



local

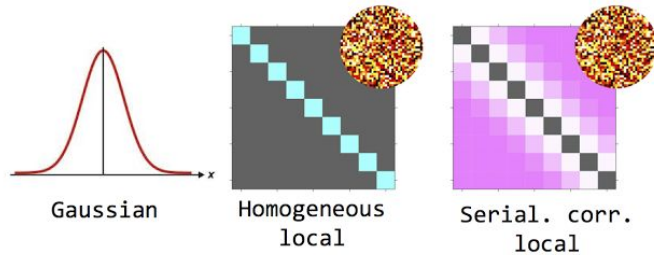
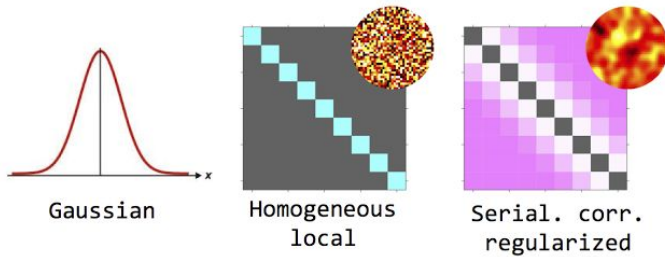
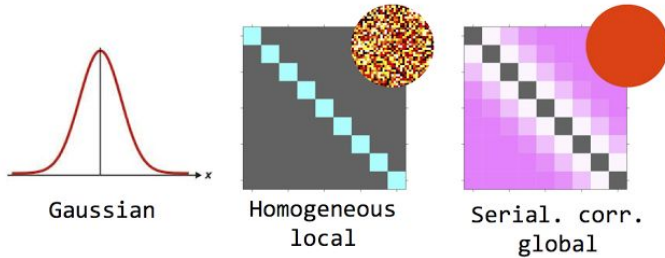


regularized

Error models: SPM, FSL and AFNI

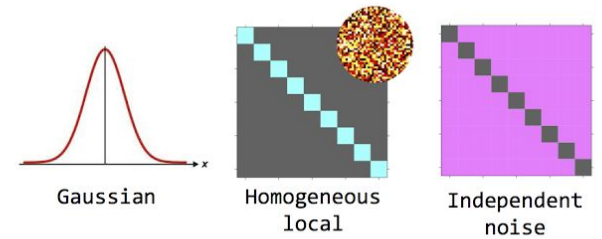
Subject level

SPM

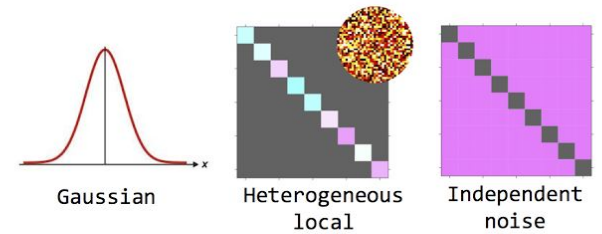


Group level

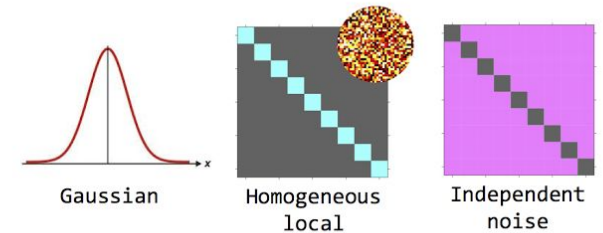
SPM
one sample
t-test



FLAME 1



3dtttest++

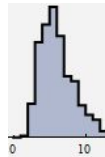


Error models: non-parametric

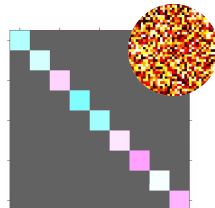
Group level Sign-flipping



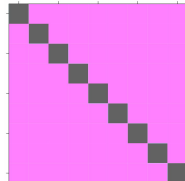
Randomise



NonParametric
Symmetric

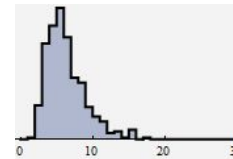


Heterogeneous
local

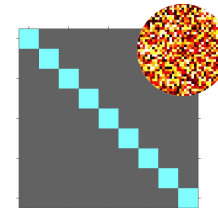


Independent
noise

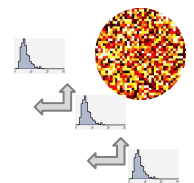
Group level Label permutation



NonParametric



Homogeneous
local

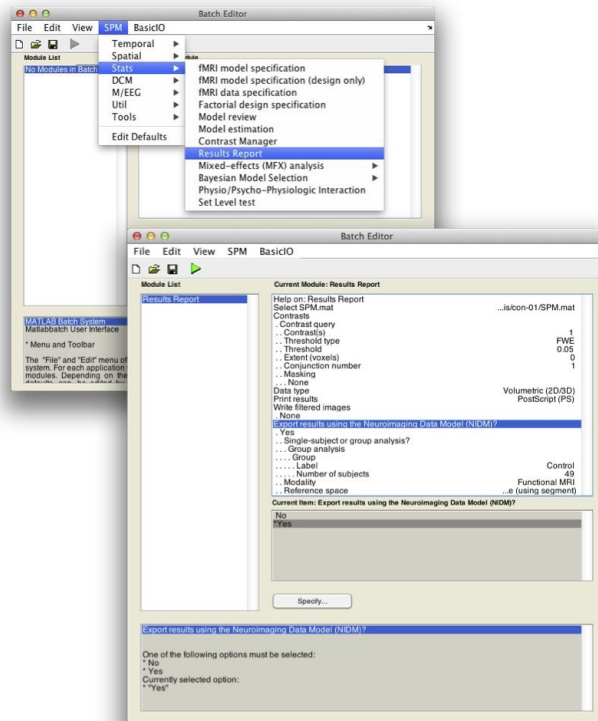


Exchangeable
noise local

Example meta-analysis

SPM export

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

- Available as part of SPM

FSL export



```
$nidmfs1 ds107.gfeat -g Control 49
```

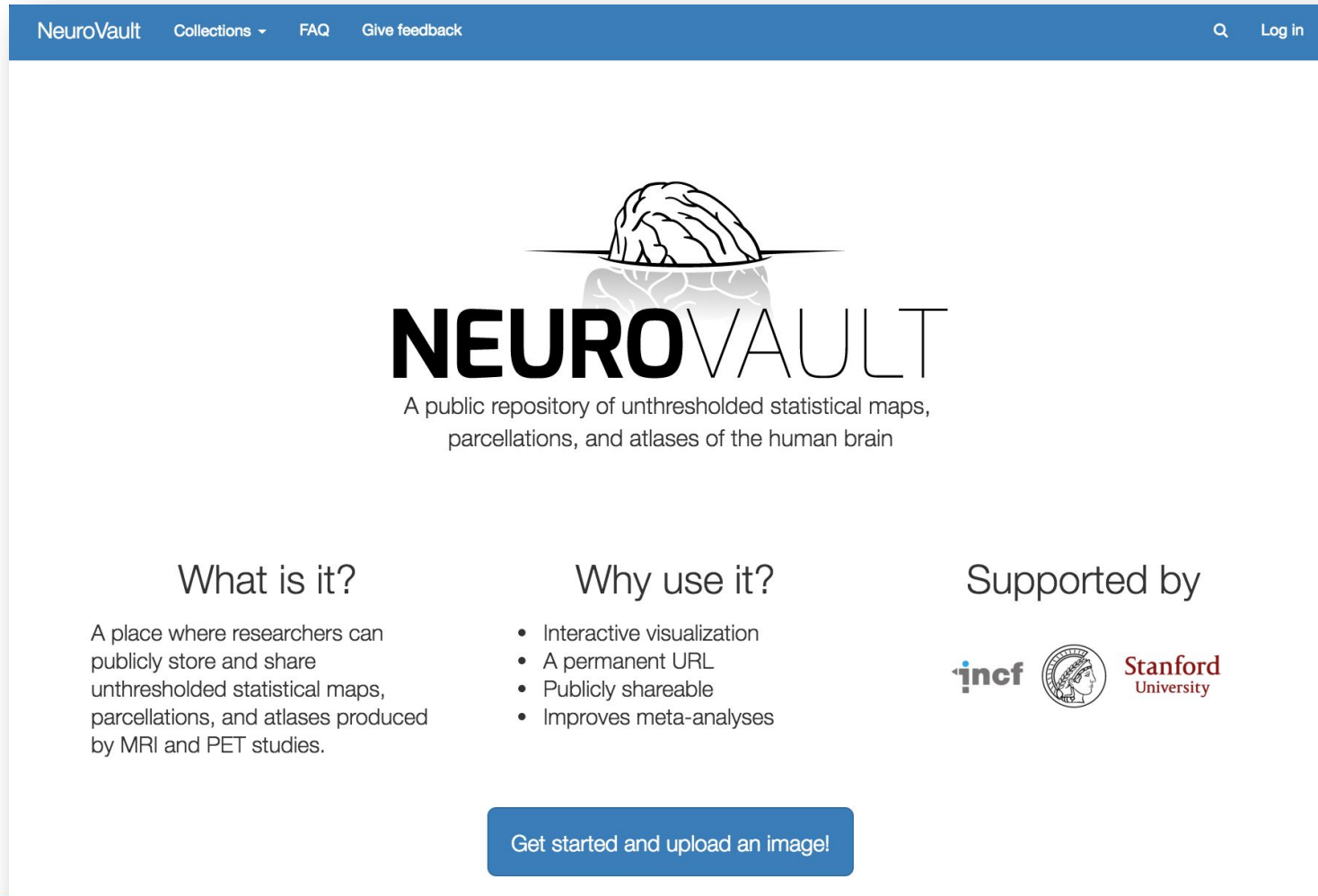


The image shows a file explorer window titled 'fsl_ds107_group' displaying the output of the command. The window contains a table with columns for Name, Size, and Kind.

Name	Size	Kind
design.con	126 bytes	Document
design.fsf	20 KB	Document
design.grp	131 bytes	Document
design.lcon	28 bytes	Document
cope1.feats	--	Folder
cope2.feats	--	Folder
inputreg	--	Folder
logs	--	Folder
bg_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

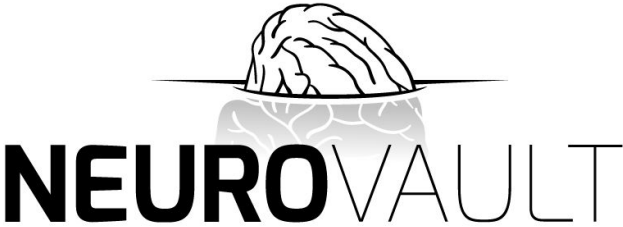
- Installable using pip
- To be included in the next FSL release

Upload to NeuroVault



The screenshot shows the NeuroVault website homepage. At the top is a blue navigation bar with the text "NeuroVault" on the left, "Collections" with a dropdown arrow, "FAQ", and "Give feedback" in the center, and a search icon and "Log in" on the right. The main content area features a central logo consisting of a line drawing of a 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 bullet points: "Interactive visualization", "A permanent URL", "Publicly shareable", and "Improves meta-analyses". The "Supported by" section includes logos for "incf" (International Neuroinformatics Coordinating Framework), the University of California seal, and "Stanford University". At the bottom center is a blue button with the text "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



Get started and upload an image!

Upload to NeuroVault

NeuroVault Collections ▾ FAQ Give feedback 🔍 Log in

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

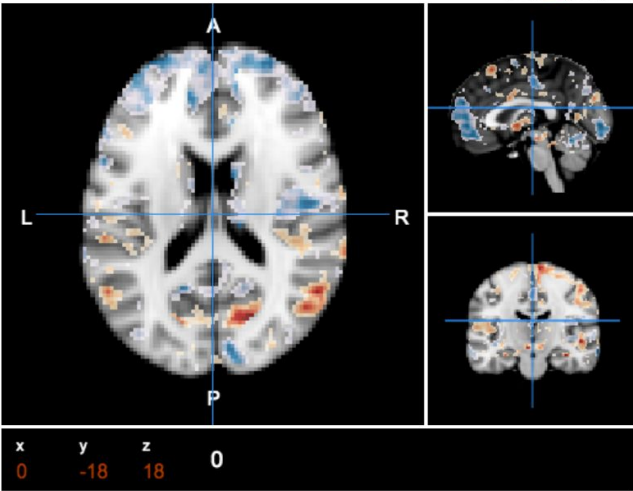
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Krzysztof J. Gorgolewski, Dan Lurie, Sebastian Urchs, Judy A. Kipping, R. Cameron Craddock, Michael P. Milham, Daniel S. Margulies, Jonathan Smallwood

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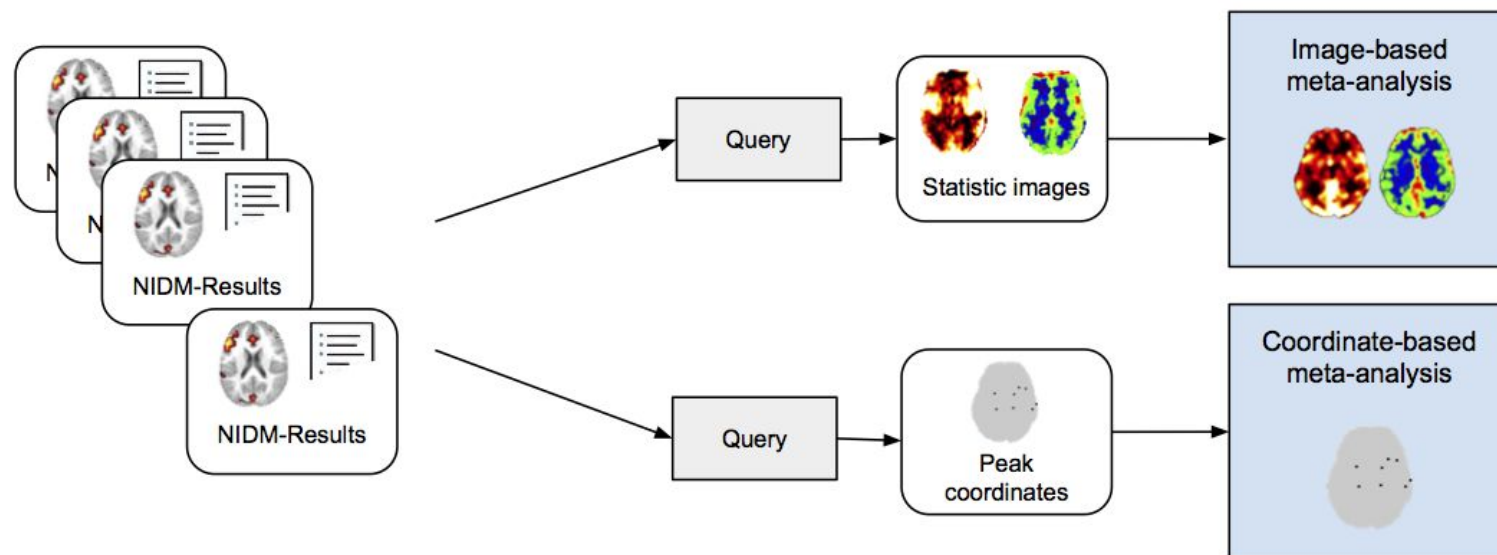
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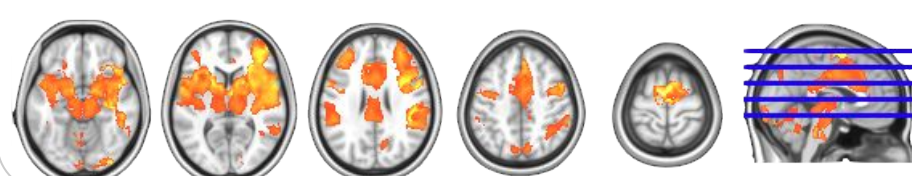
Example of meta-analysis



Coordinate-based meta-analysis



Image-based meta-analysis



Conclusions

Conclusion

NIDM-Results: a model for full reporting of mass-univariate results

Future work:

- Model extensions (e.g. permutation)
- NIDM-Experiment (BIDS)
- NIDM-Workflows
- Ecosystem of tools

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welcometrust



Q & A

NIDM

- Github: <https://github.com/incf-nidash>
- Website: <http://nidm.nidash.org>
- Manuscript: <http://dx.doi.org/10.1101/041798>

