



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

Camille Maumet

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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

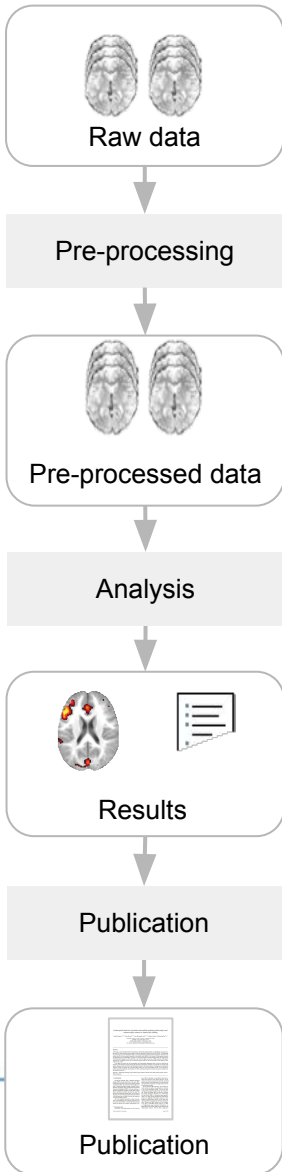
# Agenda

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

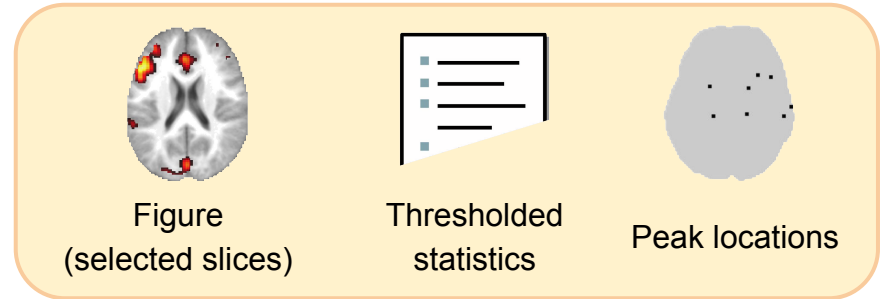
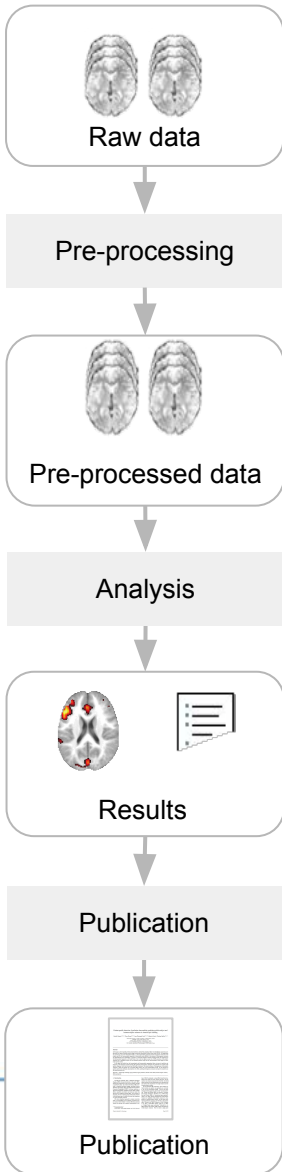


**Background**

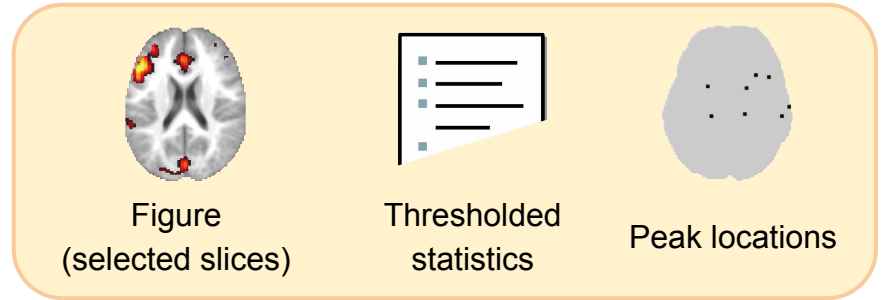
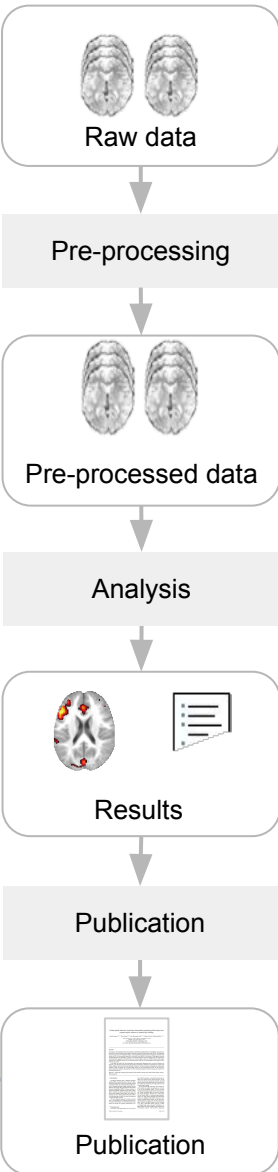
# Reporting of neuroimaging results



# Reporting of neuroimaging results



# Reporting of neuroimaging results



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

# Reproducibility & provenance

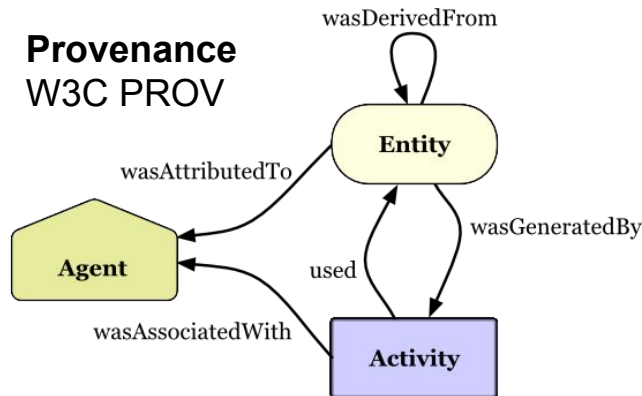
## A reproducibility crisis?



Underpowered studies

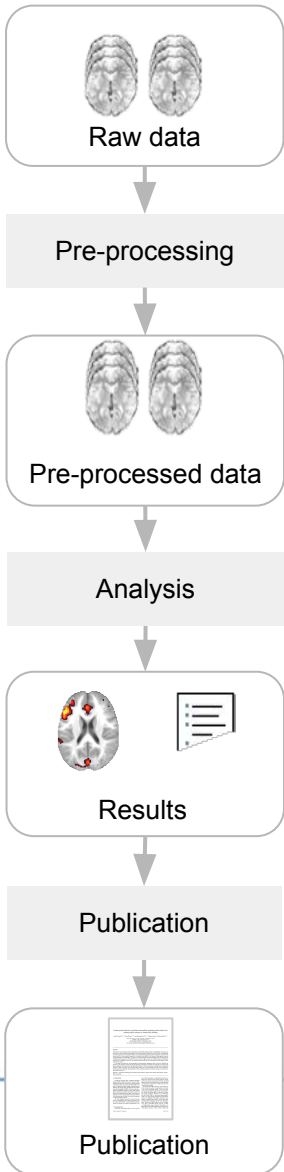


Publication bias

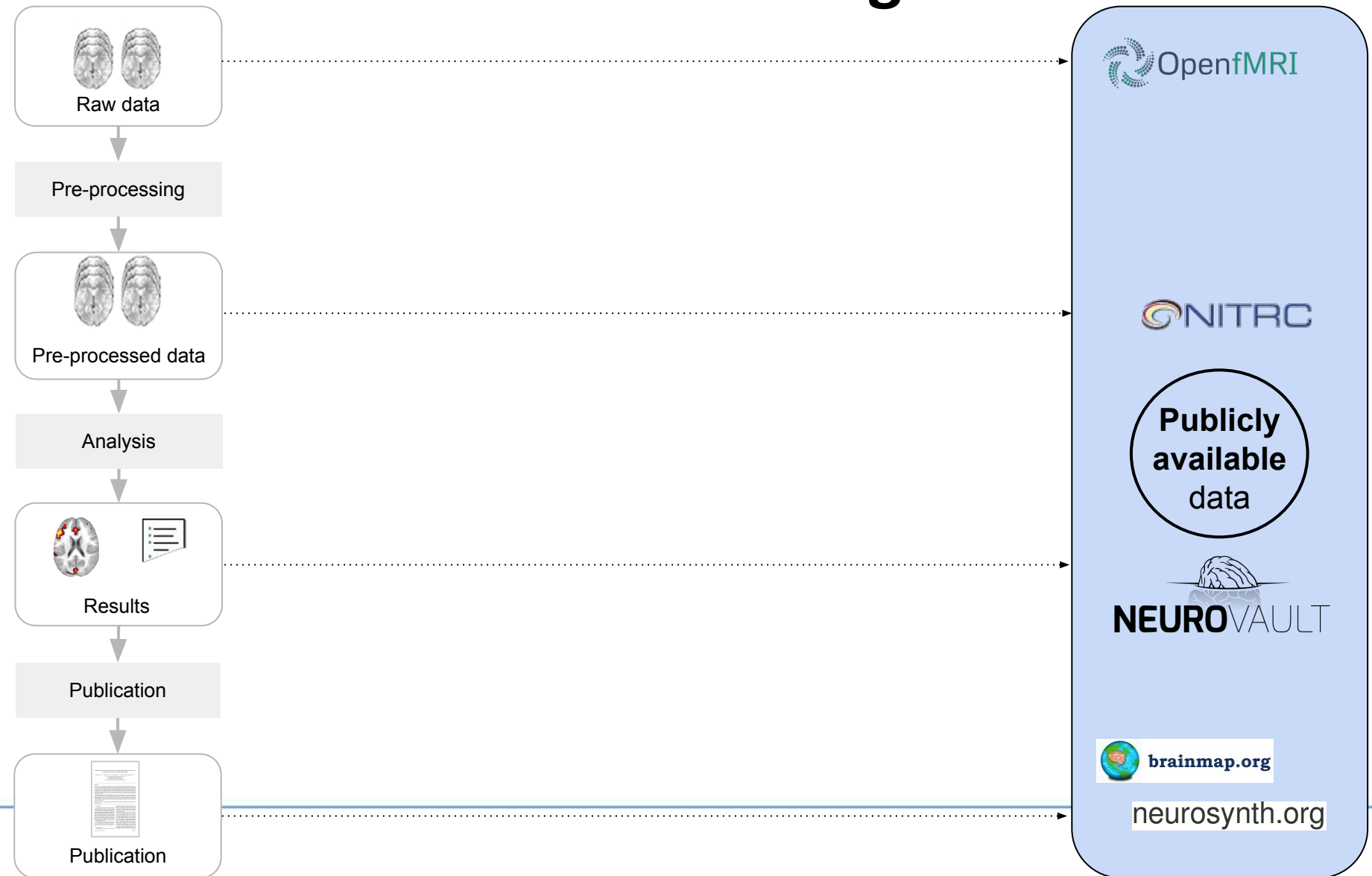




# Data sharing



# Data sharing



# Data sharing

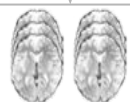
**BUT**

< 5% of data  
shared in public  
repositories



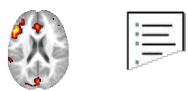
Raw data

Pre-processing



Pre-processed data

Analysis

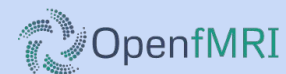


Results

Publication



Publication



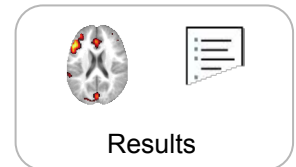
**Publicly  
available  
data**



neurosynth.org

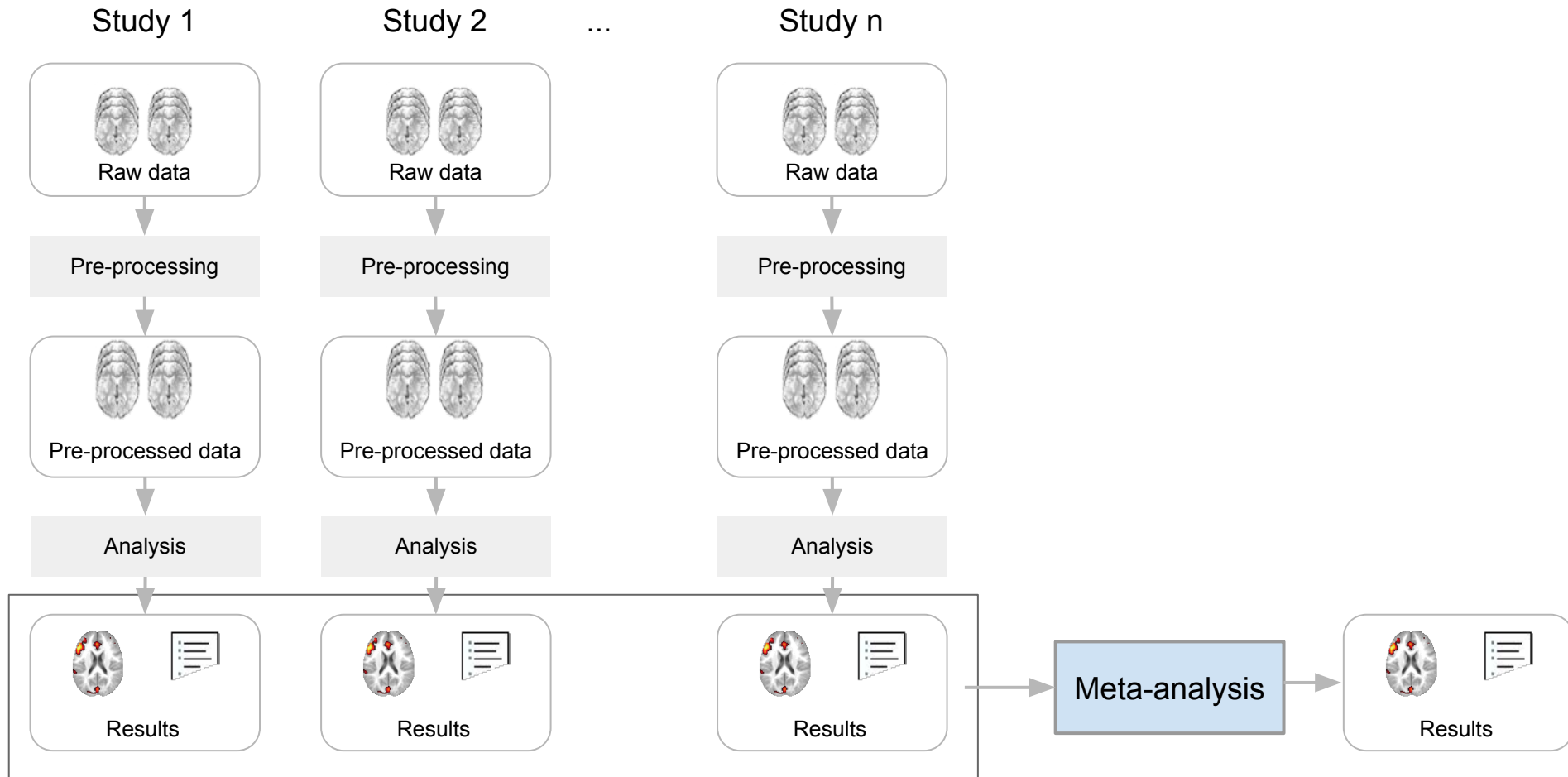
# Data sharing vs results reporting

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



## **Application to meta-analyses**

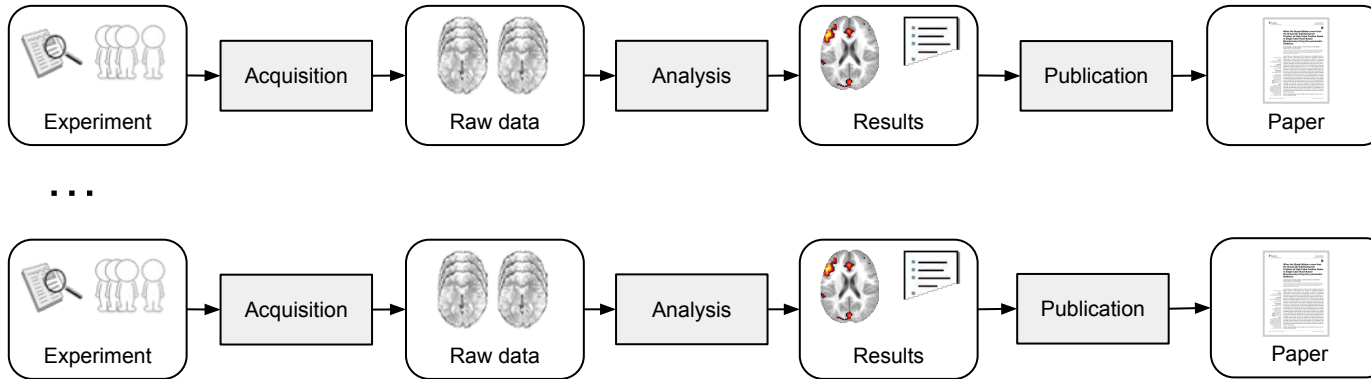
# Meta-analysis



# Neuroimaging meta-analysis

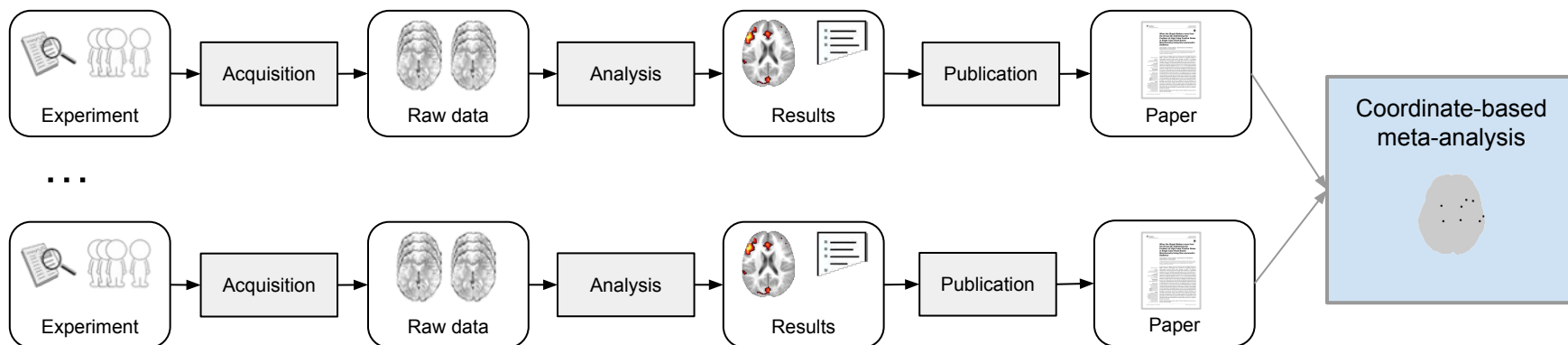
- Rich fMRI literature
  - > 30,000 articles (“fMRI” pubmed)
- Increase statistical power
- Synthesize information across studies

# Coordinate- or Image-Based?





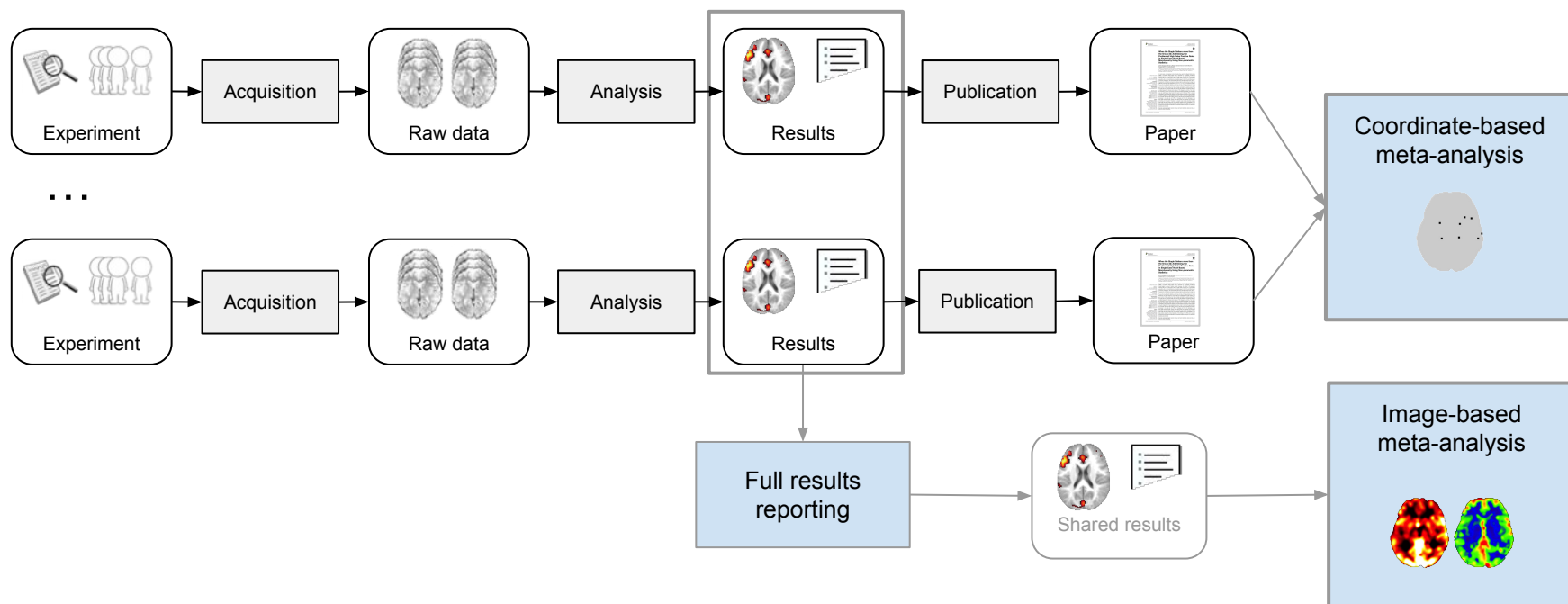
# Coordinate- or Image-Based?



## Coordinate-based meta-analysis



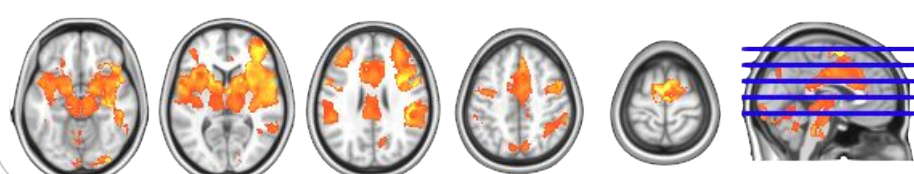
# Coordinate- or Image-Based?



Coordinate-based meta-analysis



Image-based meta-analysis

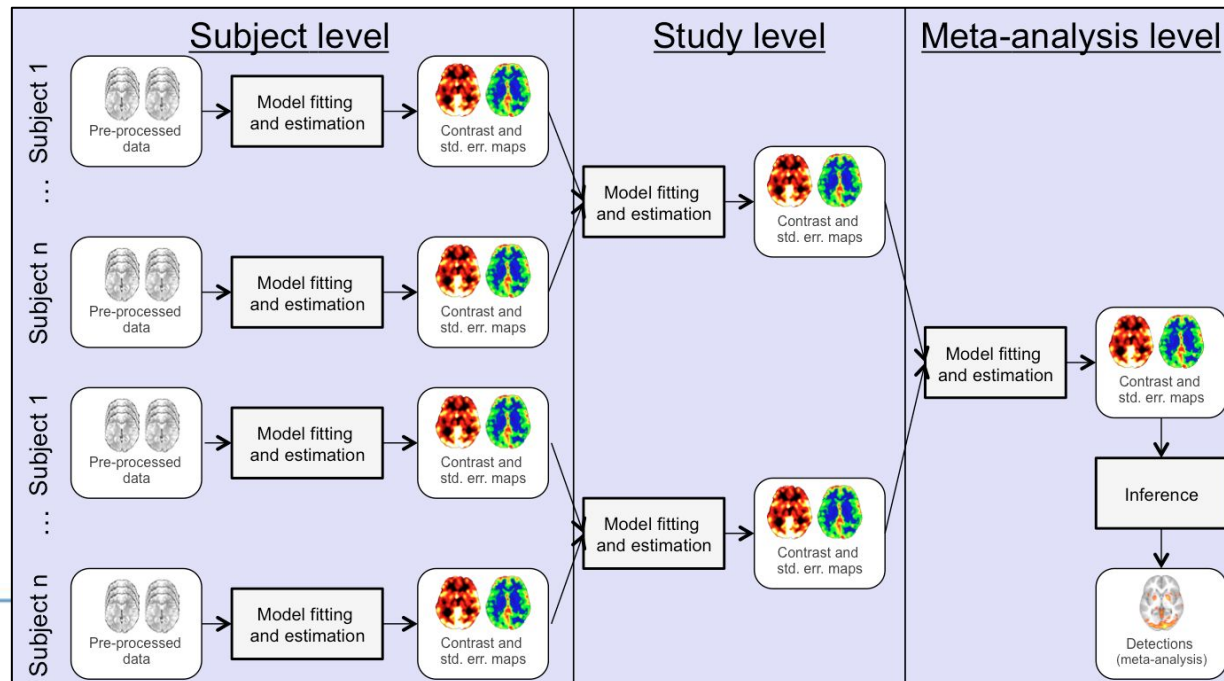
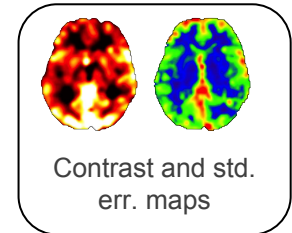


# Image-based meta-analysis

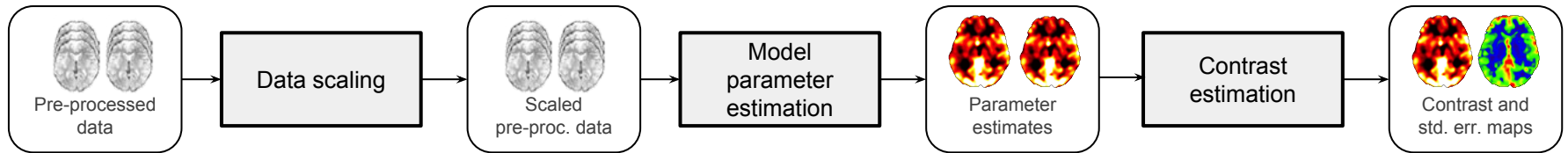
- Gold standard:

## Third-level Mixed-Effects GLM

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

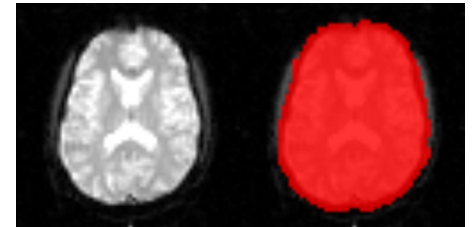


# Units of contrast estimates



Units depend on

- Data scaling  $\text{scaled\_data} = \frac{\text{data} * \text{target}}{\text{est\_mean}}$
- Scaling of the explanatory variables



$$Y = \begin{bmatrix} \text{data} \\ \vdots \\ \text{data} \end{bmatrix} = \begin{bmatrix} \text{X} \\ \vdots \\ \text{X} \end{bmatrix} \beta + \varepsilon$$

- 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**

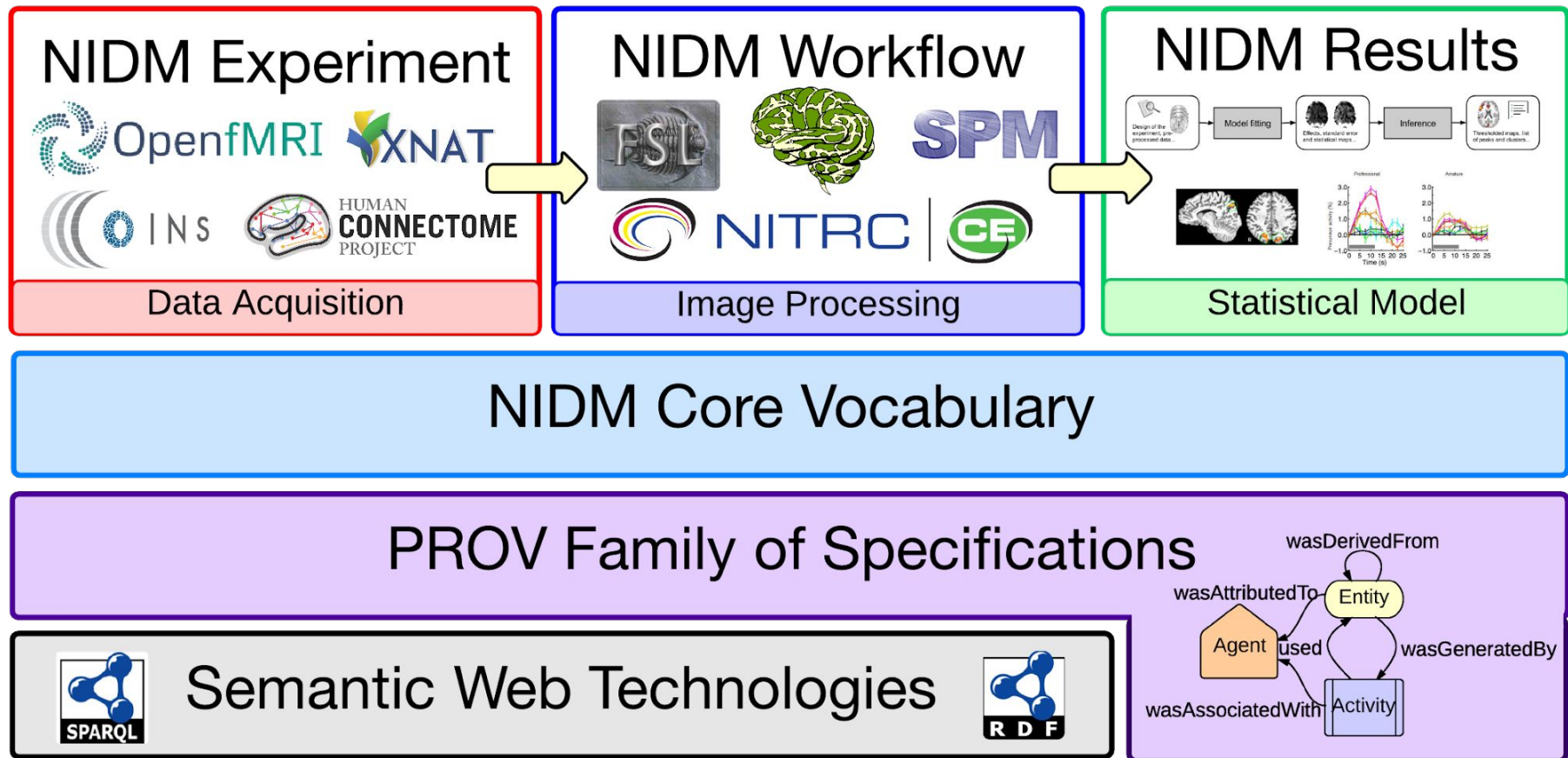
# INCF Neuroimaging Task Force

- International collaboration
  - 13 labs, >12 tools
  - Weekly teleconferences, focused workshops, GitHub
  - Open
- Resources
  - <http://nidm.nidash.org/>
  - <http://github.com/incf-nidash/>

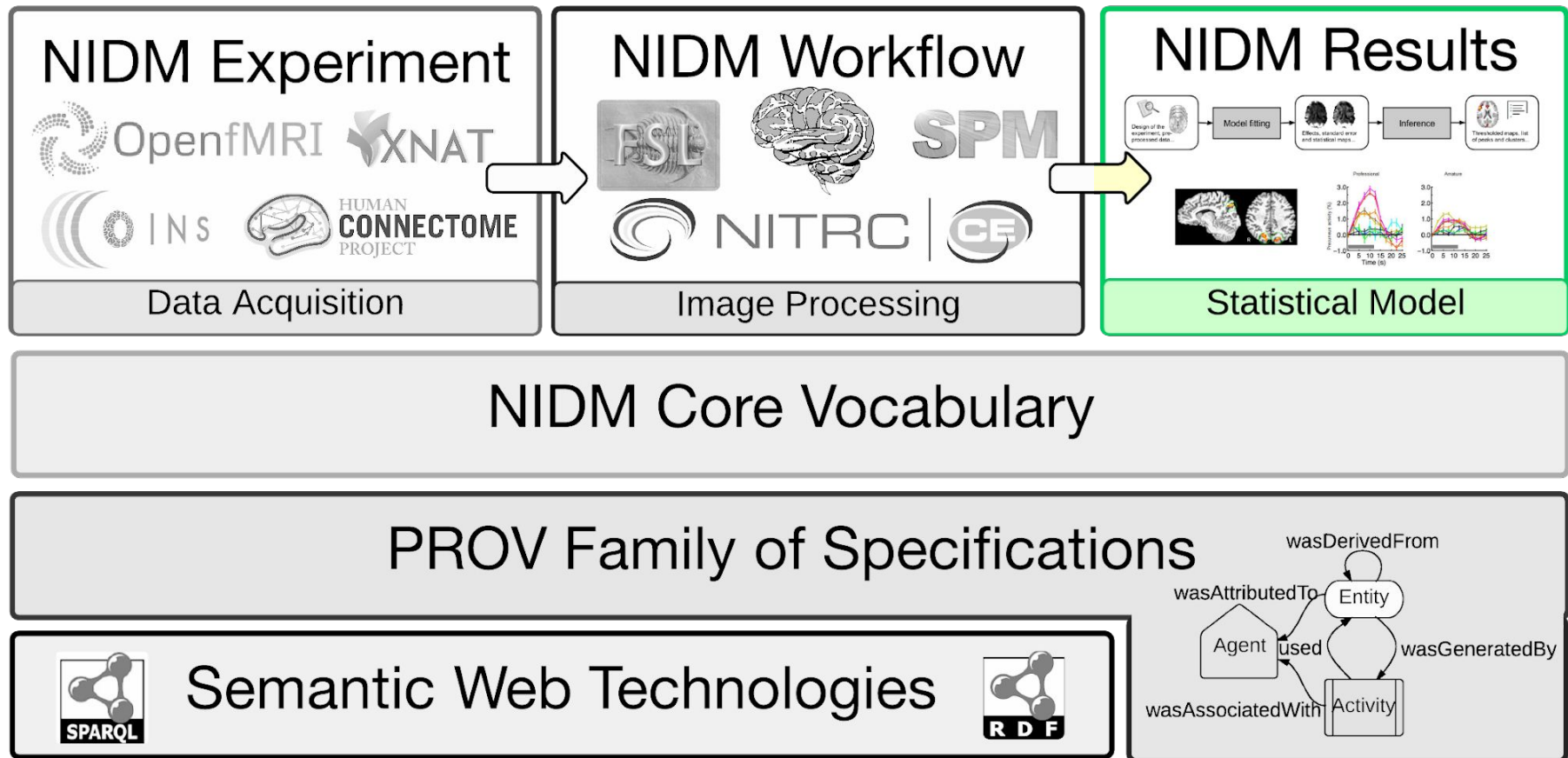




# NIDM: a set of specifications to describe neuroimaging data



# NIDM: a set of specifications to describe neuroimaging data

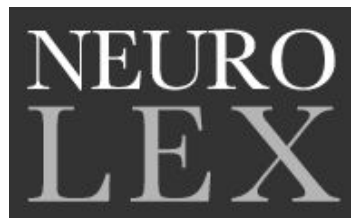
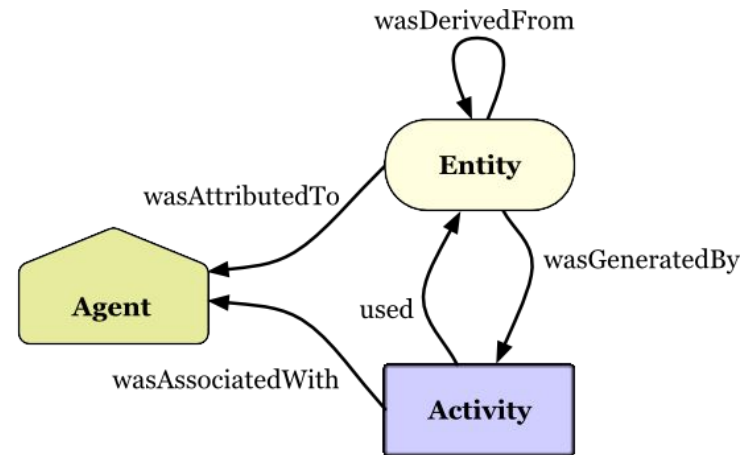


# NIDM-Results

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

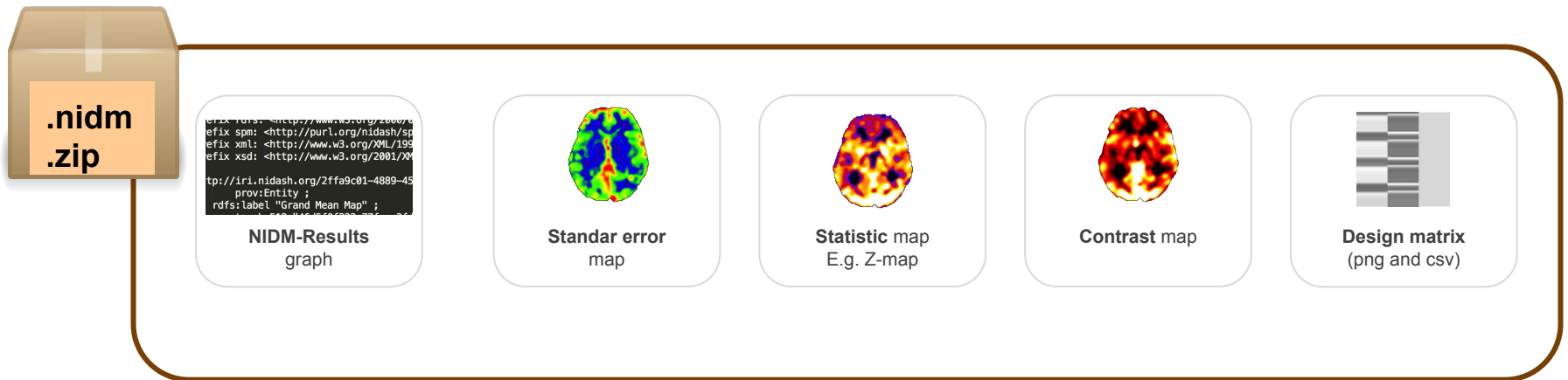
# Model

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

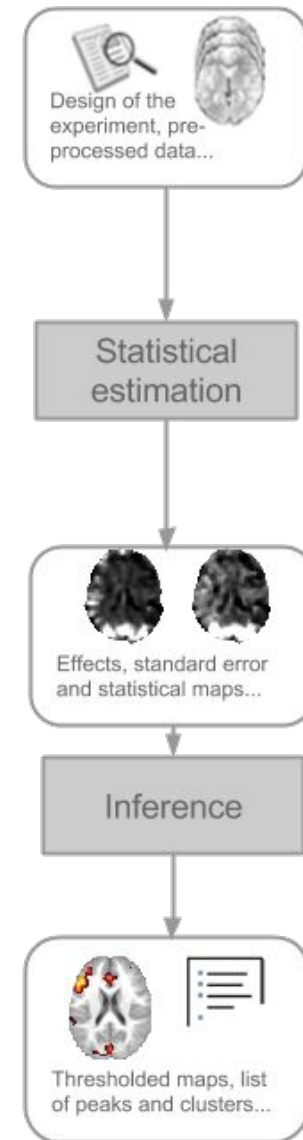
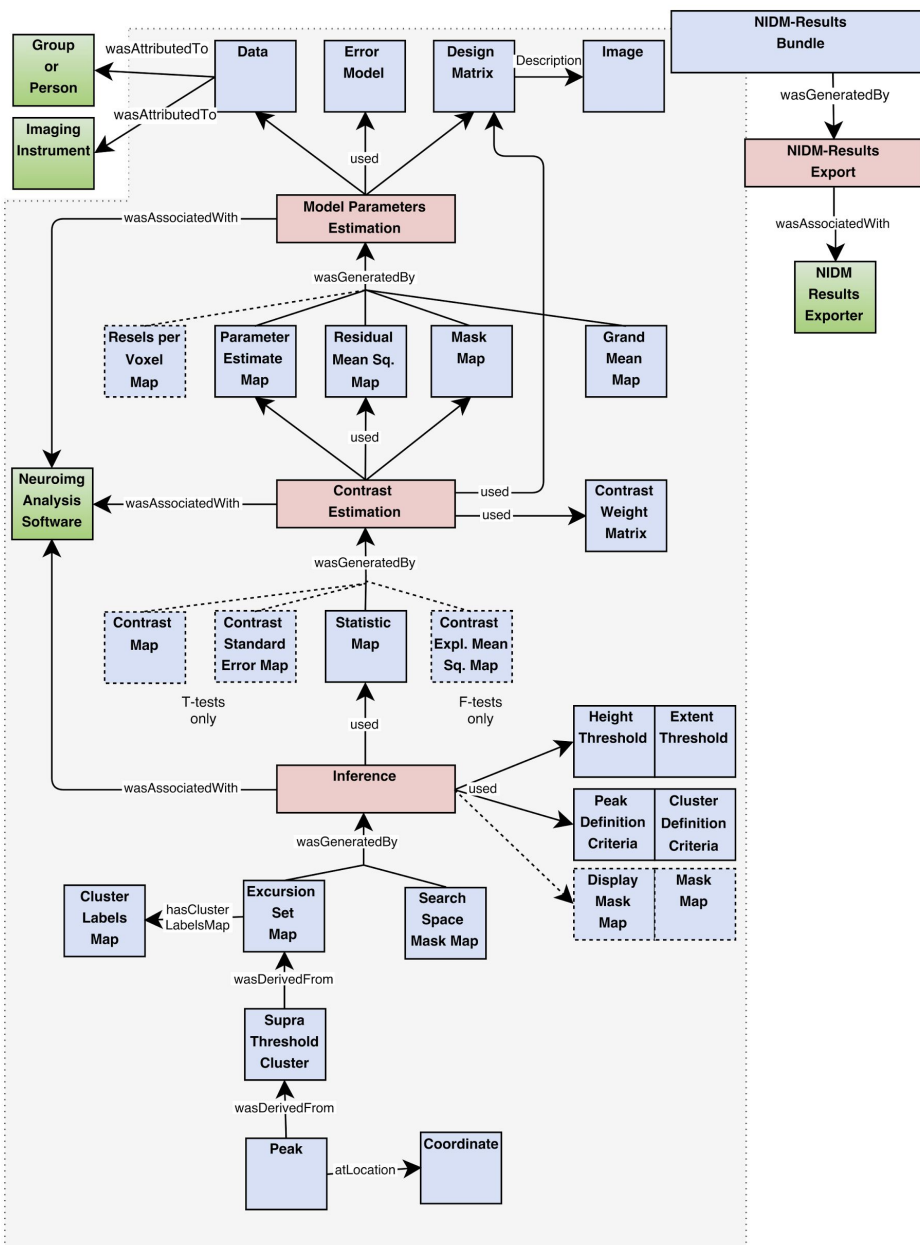


# NIDM-Results

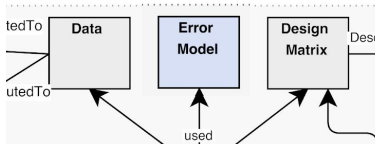
**NIDM-Results pack:** Compressed file containing a NIDM-Results serialization and some or all of the referenced image data files.



# 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 .

```

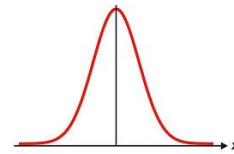
Definition

Attributes

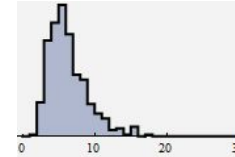
Examples

# Harmonisation across software

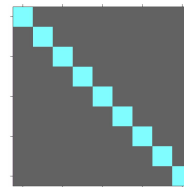
- Model of the error
  - Prob. distribution:
  - Variance:
  - Dependence:



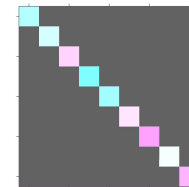
Gaussian



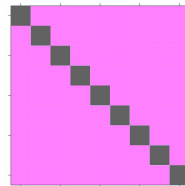
Non-Parametric



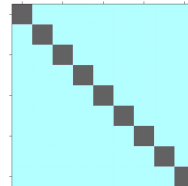
homogeneous



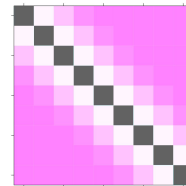
heterogeneous



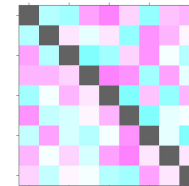
Independent  
noise



Compound  
Symmetry



Serially  
correlated

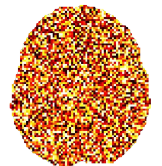


Arbitrarily  
correlated

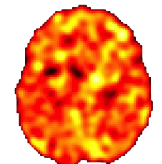
...



global



local



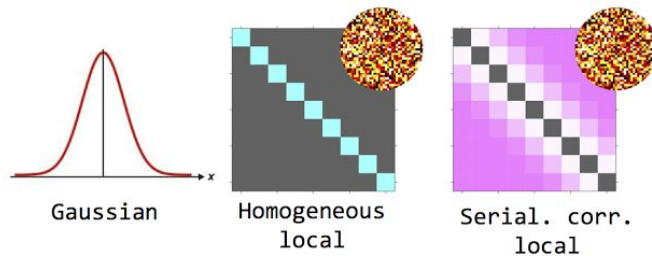
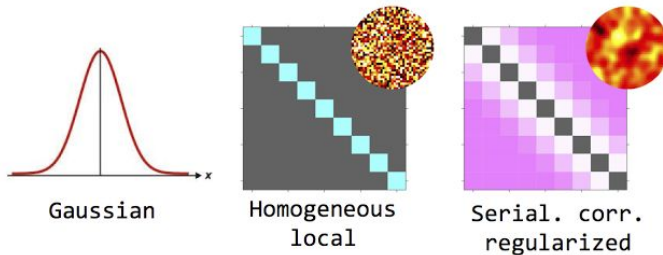
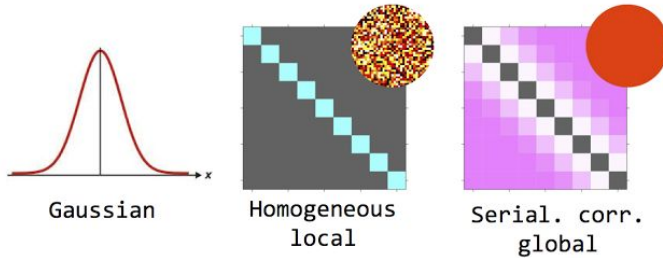
regularized



# Error models: SPM, FSL and AFNI

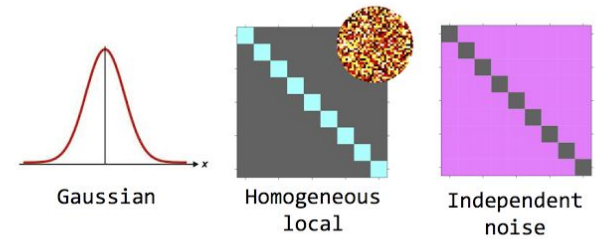
## Subject level

**SPM**

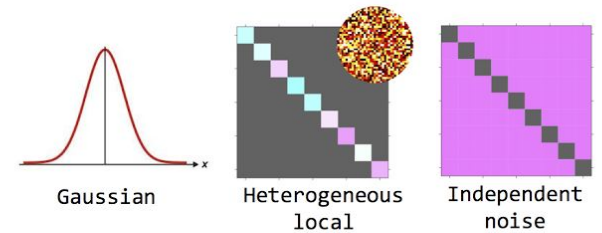


## Group level

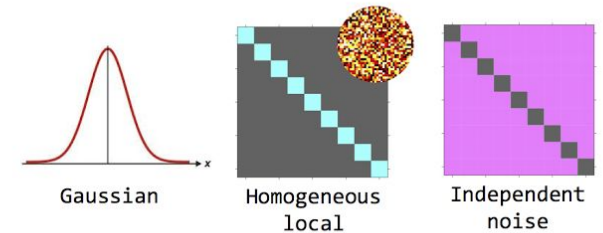
**SPM**  
one sample  
t-test



FLAME 1



3dtttest++

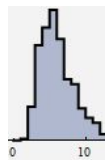


# Error models: non-parametric

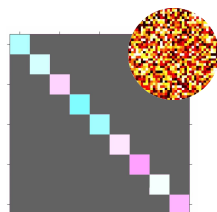
## Group level Sign-flipping



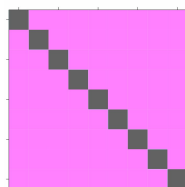
Randomise



NonParametric  
Symmetric

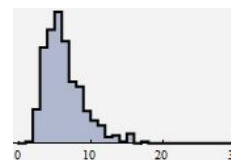


Heterogeneous  
local

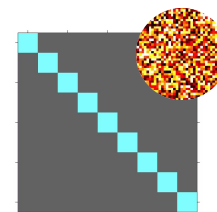


Independent  
noise

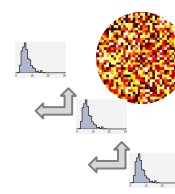
## Group level Label permutation



NonParametric



Homogeneous  
local

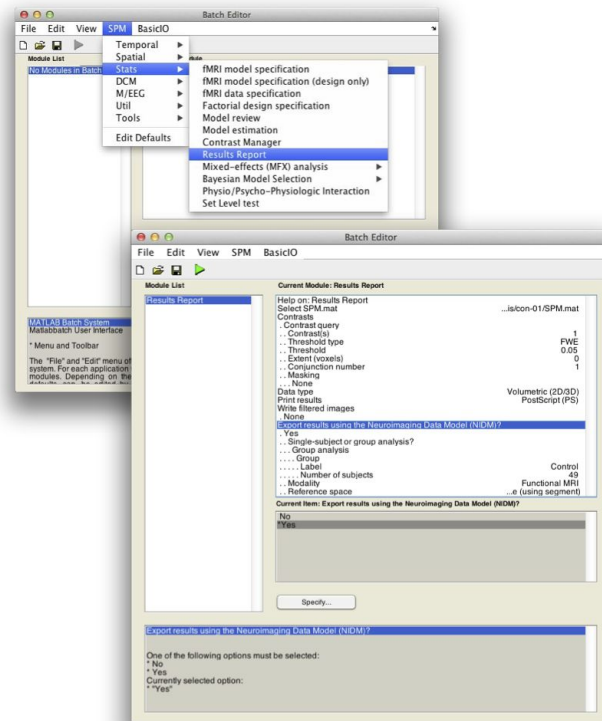


Exchangeable  
noise local

## **Example meta-analysis**

# SPM export

SPM



The screenshot shows the Results window with a table of files. The table has columns for Name, Size, and Kind. The files listed are:

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
```




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

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**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

Q

Log in

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

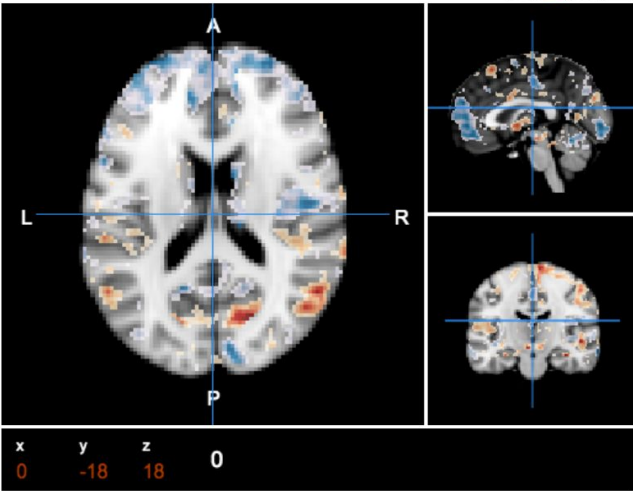
Contributed by ChrisFiloGorgolewski

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



Images Details

Show 7 entries Search:

View	ID	Name	Type
	25	fALFF: Past	Z map
	26	fALFF: Future	Z map
	27	fALFF: Past > Future	Z map
	28	fALFF: Positive	Z map
	29	fALFF: Negative	T map
	30	fALFF: Positive > Negative	Z map
	31	fALFF: Social Cognition	Z map

Showing 1 to 7 of 30 entries

First Previous Next Last

# Upload to NeuroVault

## My NIDM-Results collection

Contributed by cmaumet

[Add image](#) [Edit ▾](#) [Upload ▾](#) [Delete collection](#)

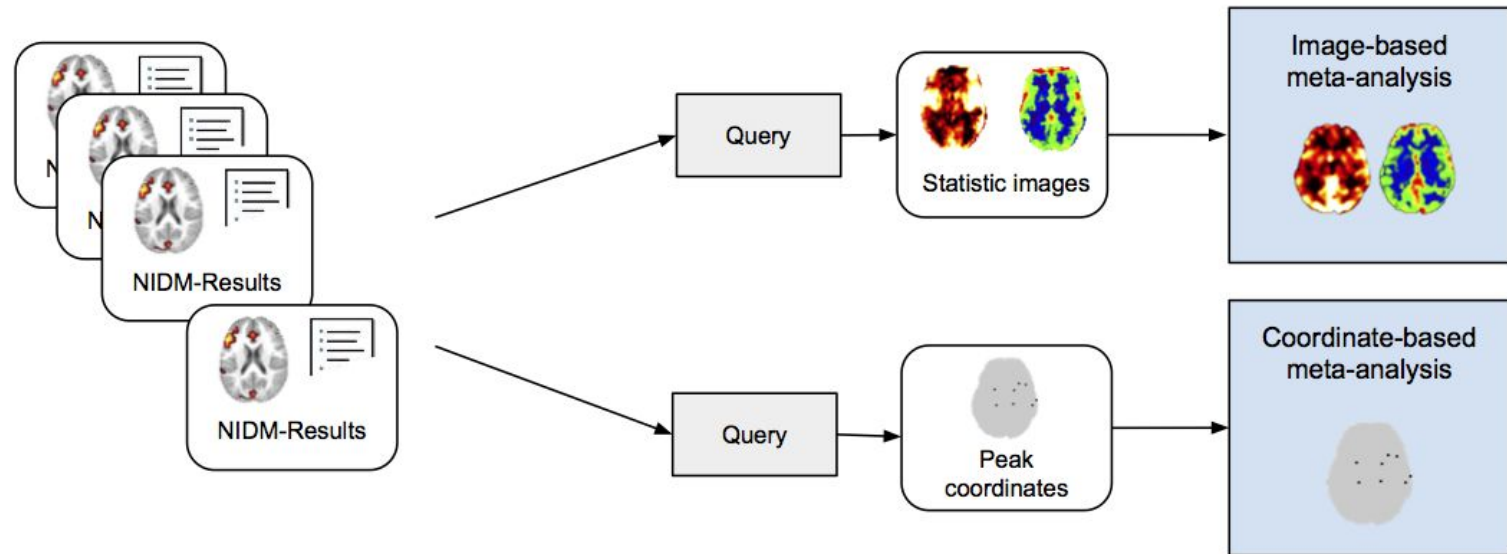
*Private Collection:* To share the link to this collection, please use the private url: </collections/DFSNYVPQ/>

This collection is empty. You can:

<a href="#">Add images one by one</a>
<a href="#">Upload an archive with images (.zip or .tar.gz)</a>
<a href="#">Upload a NIDM-Results file (.nidm.zip)</a>
<a href="#">Upload a folder with images</a>



# 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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## NIDM working group

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# Q & A

## NIDM

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

