

# NIDM-Results: a model to share brain mapping statistical results

CBU Open Science Workshop 2016, Nov. 22<sup>nd</sup>

Camille Maumet

Neuroimaging Statistics, University of Warwick, UK

# Agenda

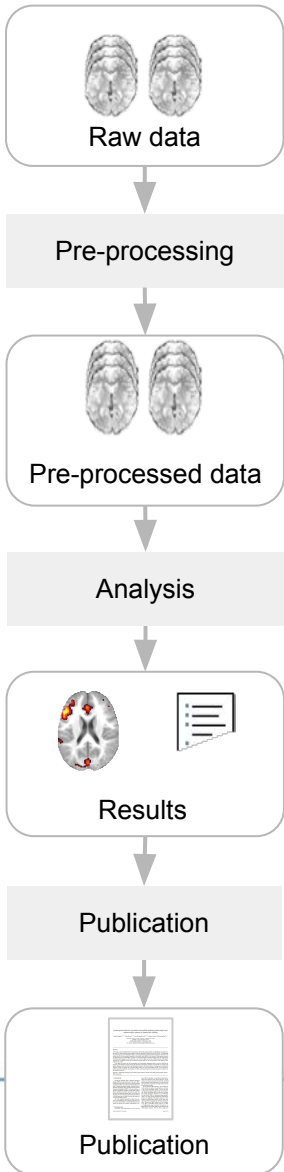
- Background
  - Reporting of neuroimaging results
  - Neuroimaging meta-analyses
- The NeuroImaging Data Model
- Example of image-based meta-analysis



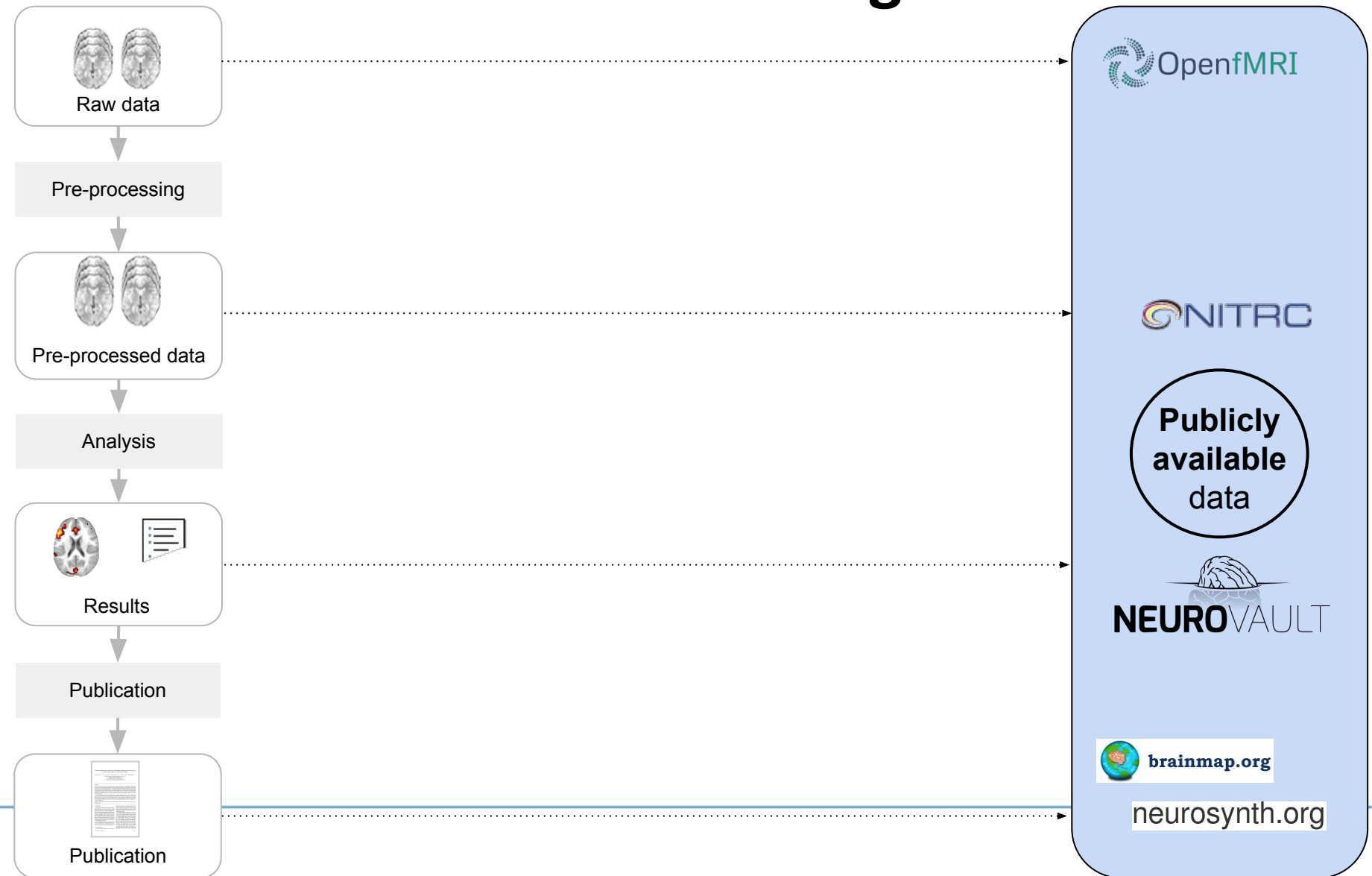
## **Background**

Reporting of neuroimaging results

# Data sharing



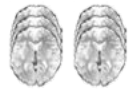
# Data sharing



# Data sharing

**BUT**

< 5% of data  
shared in public  
repositories



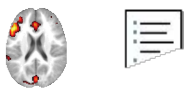
Raw data

Pre-processing



Pre-processed data

Analysis

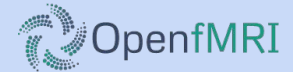


Results

Publication



Publication



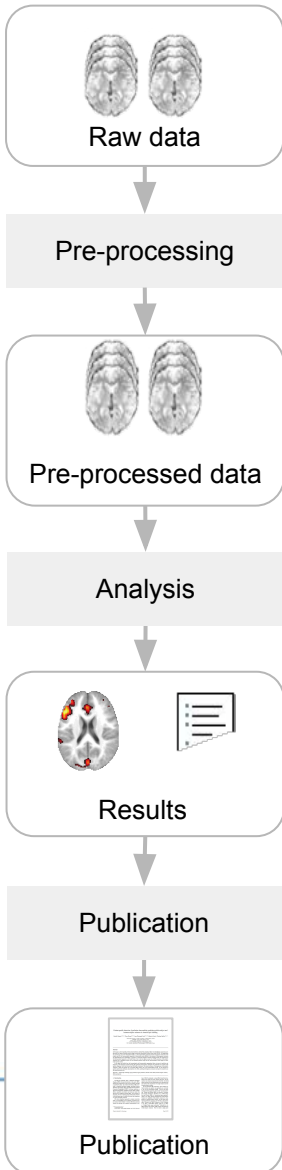
**Publicly  
available  
data**



neurosynth.org

# Data sharing

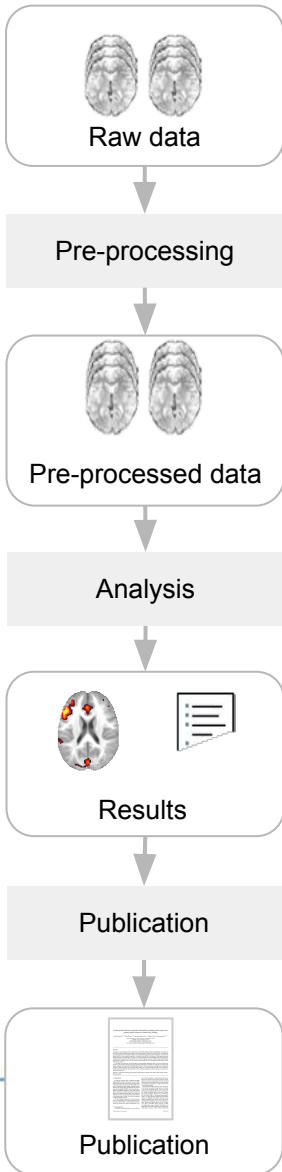
- Barriers to neuroimaging data sharing
  - **Ethical** considerations
  - **Privacy** issues
  - **Psychological** barriers
  - **Time consuming** process



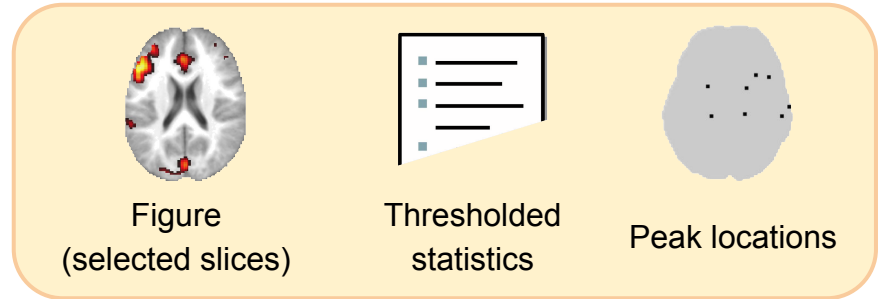
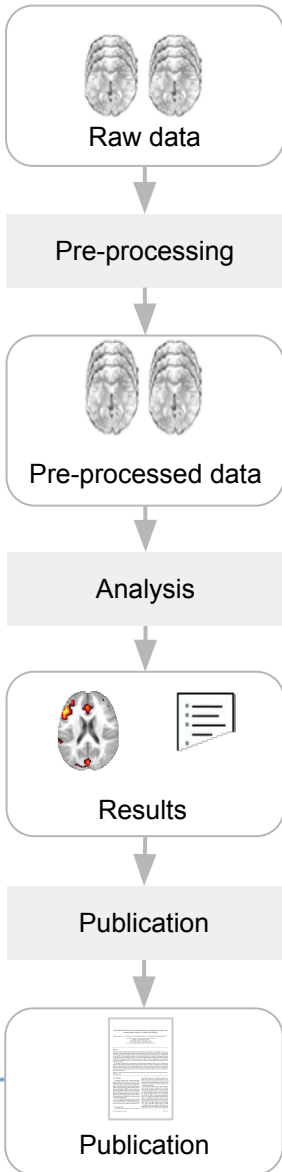
# Data sharing

- Barriers to neuroimaging data sharing
  - **Ethical** considerations
  - **Privacy** issues
  - **Psychological** barriers
  - **Time consuming** process
- “Reporting” rather than “sharing”

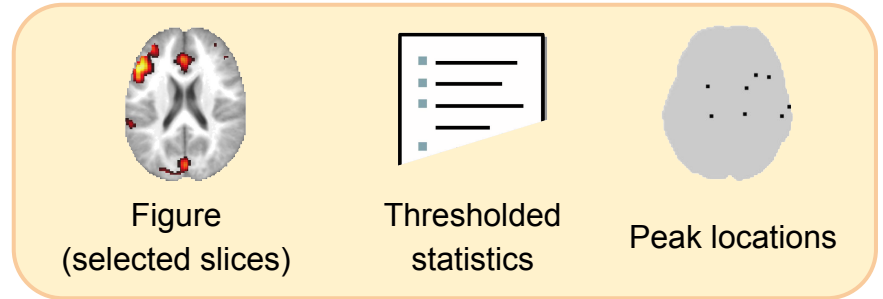
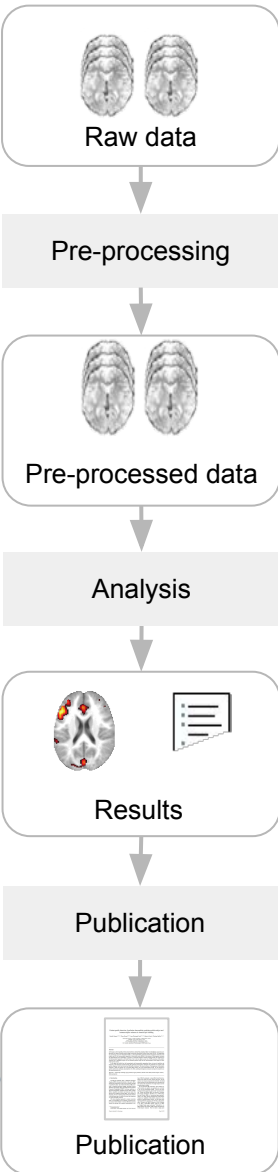
# Reporting of neuroimaging results



# Reporting of neuroimaging results



# Reporting of neuroimaging results

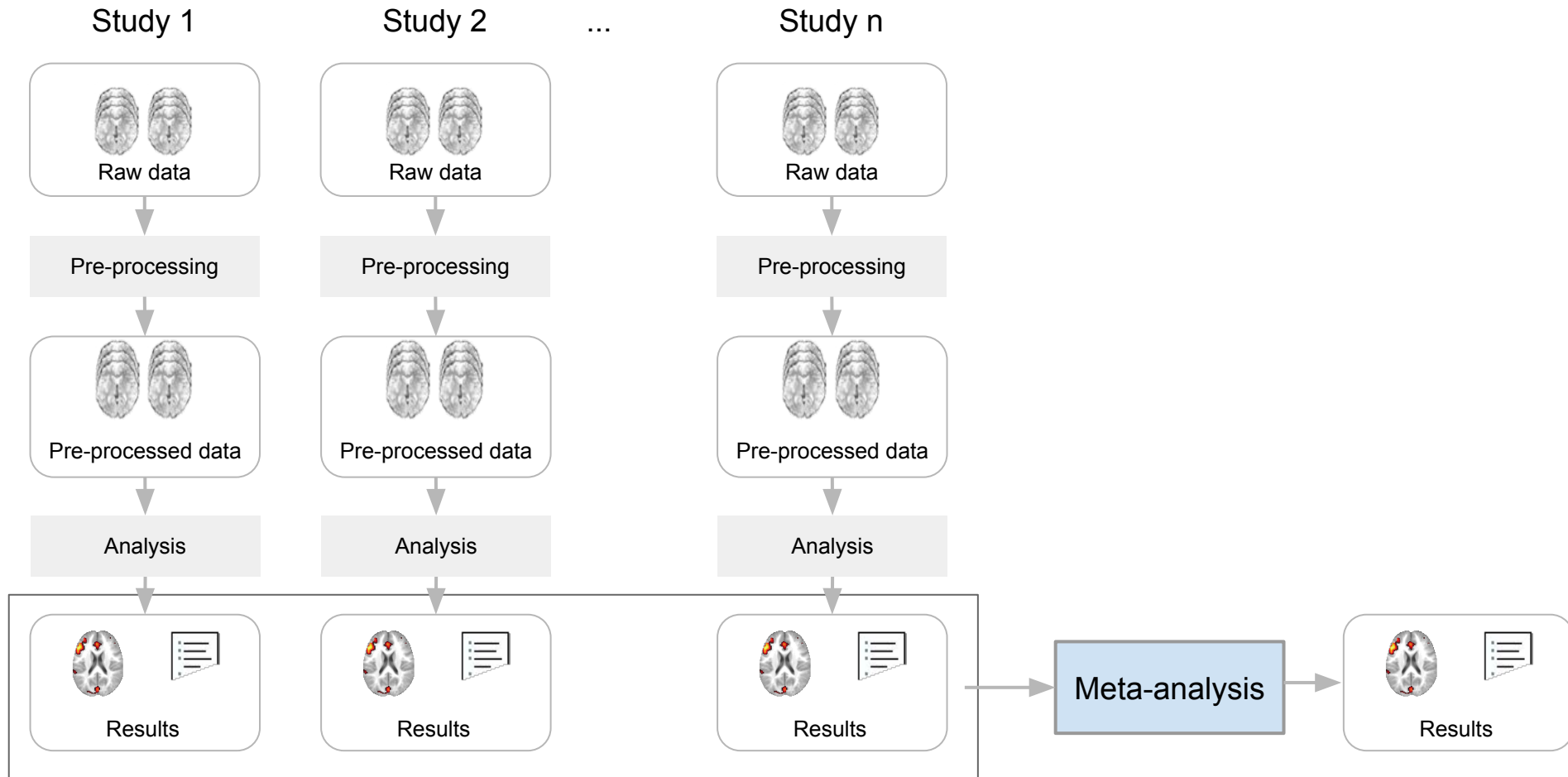


- ✗ Incomplete statistical results
- ✗ Ambiguous/incomplete methods
- ✗ Metadata is not searchable

# **Background**

Neuroimaging meta-analyses

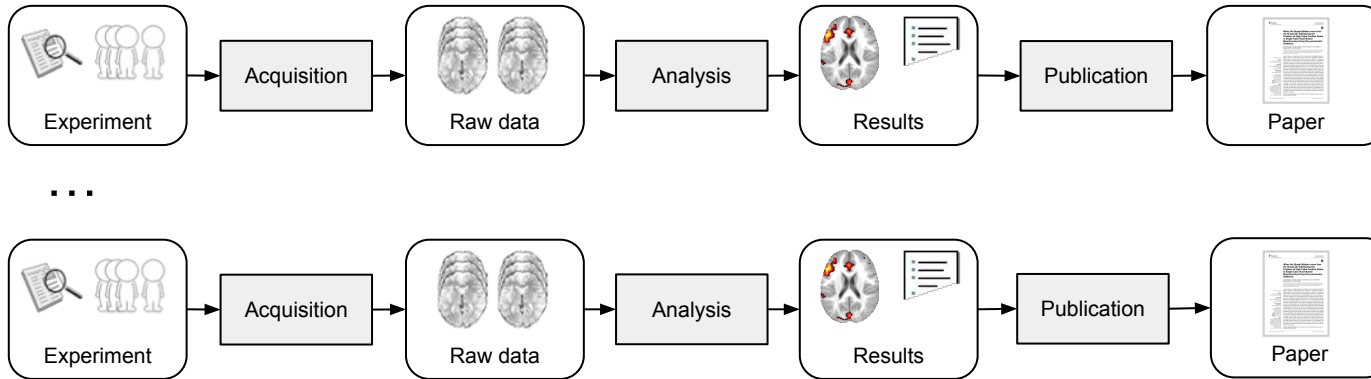
# Meta-analysis



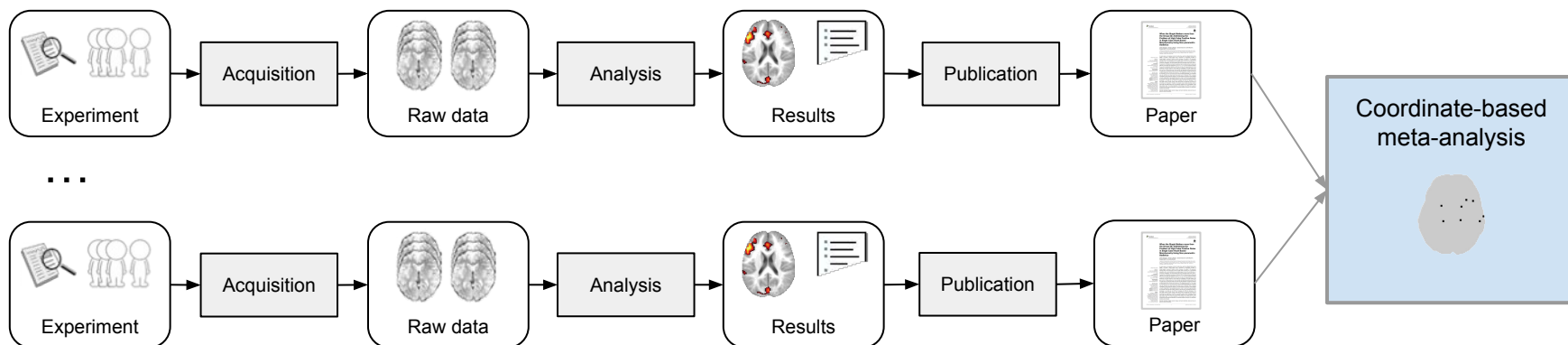
# Neuroimaging meta-analysis

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

# Coordinate- or Image-Based?



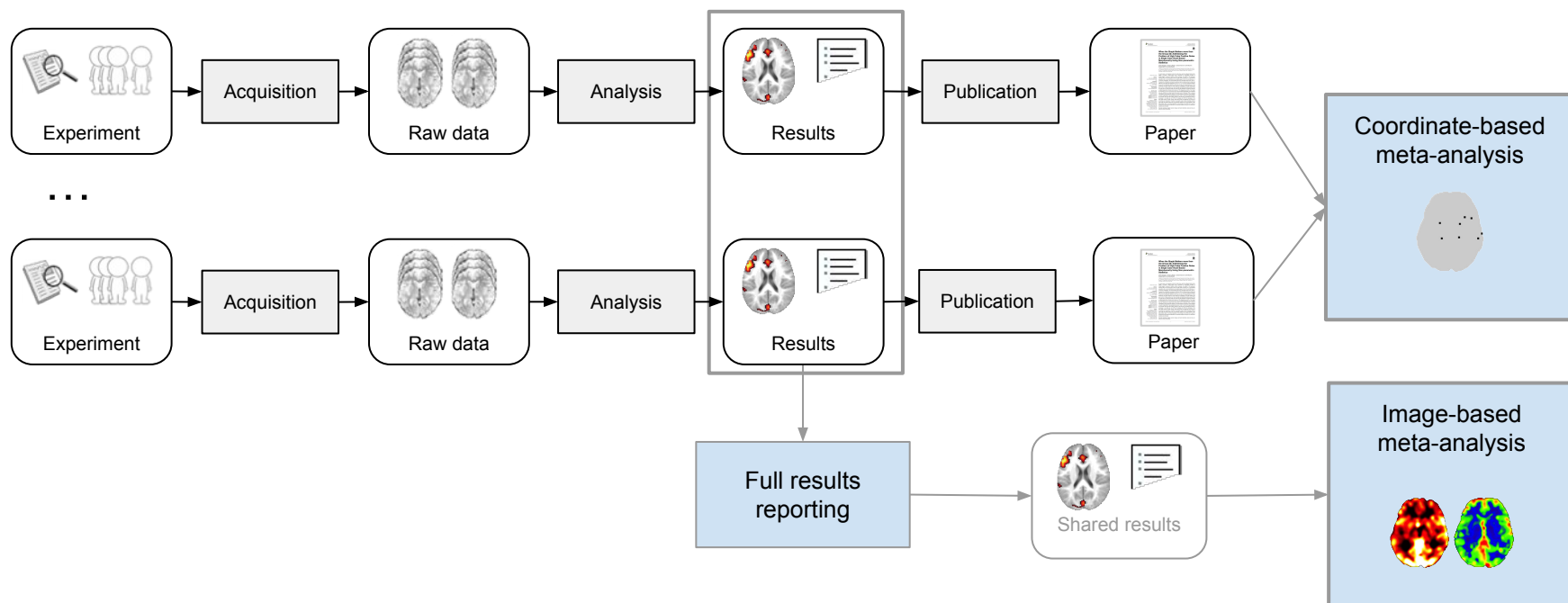
# Coordinate- or Image-Based?



## Coordinate-based meta-analysis



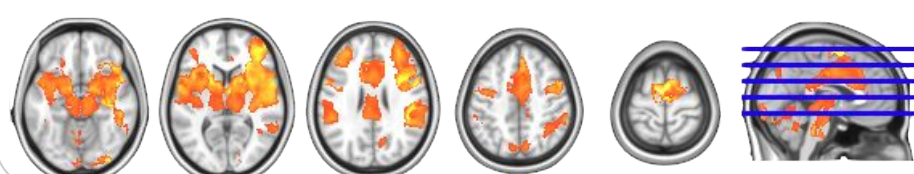
# Coordinate- or Image-Based?



Coordinate-based meta-analysis



Image-based meta-analysis



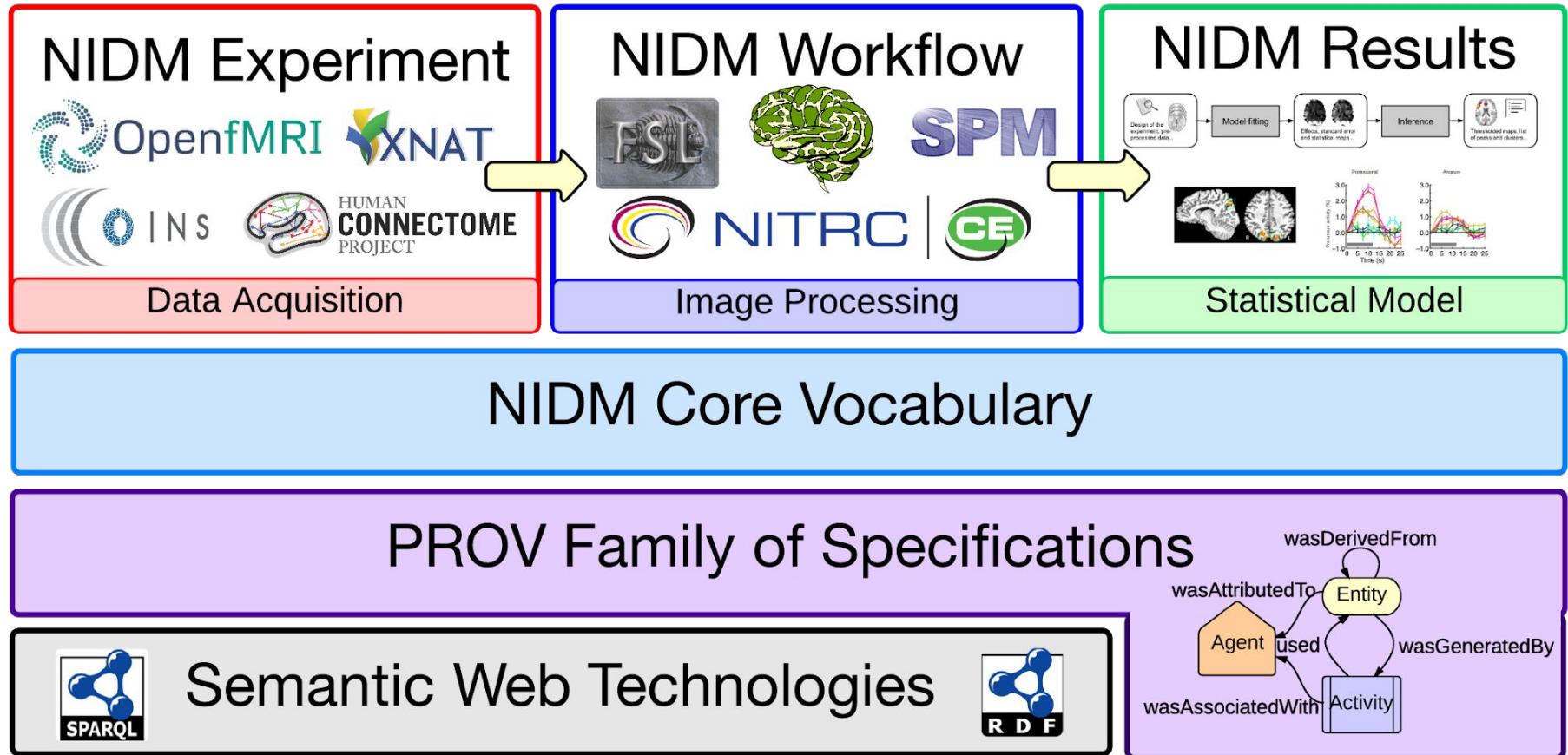
# **The Neuroimaging Data Model (NIDM)**

# INCF Neuroimaging Task Force

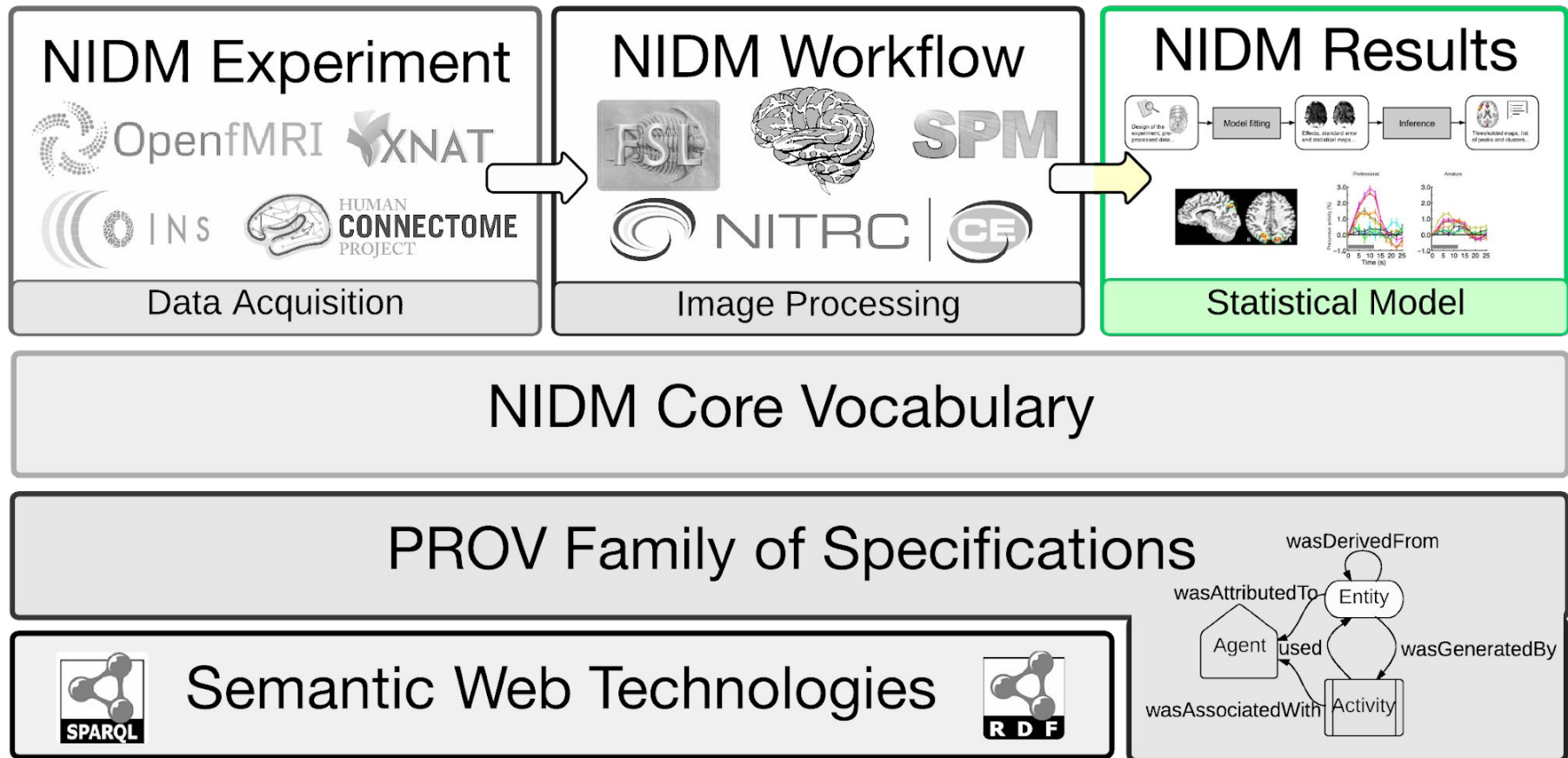
- International collaboration
  - 13 labs, >12 tools
  - Weekly teleconferences, focused workshops, GitHub
  - Open



# NIDM: a set of specifications to describe neuroimaging data



# NIDM: a set of specifications to describe neuroimaging data

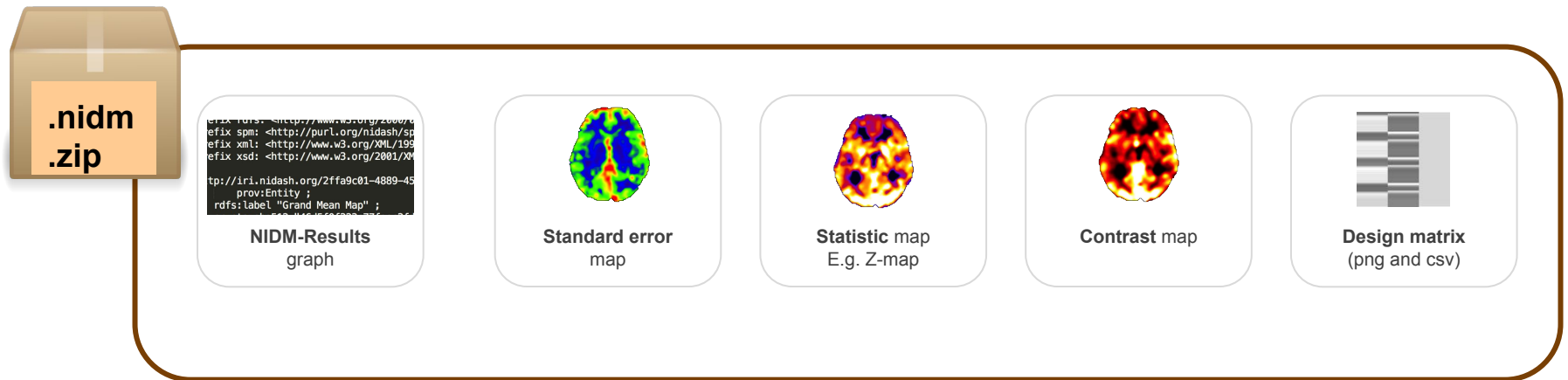


# NIDM-Results

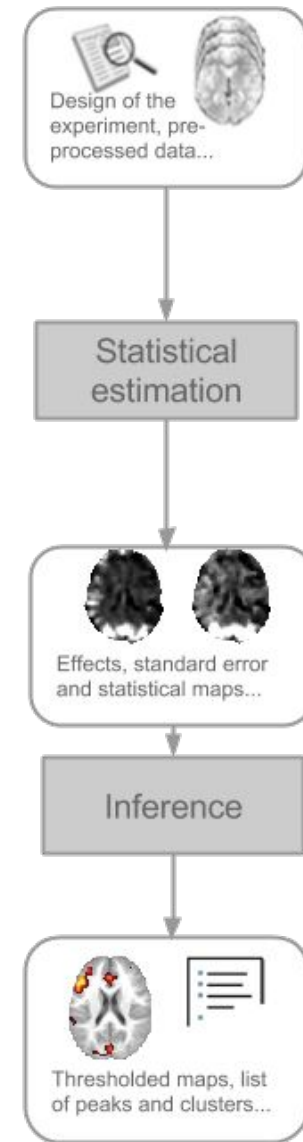
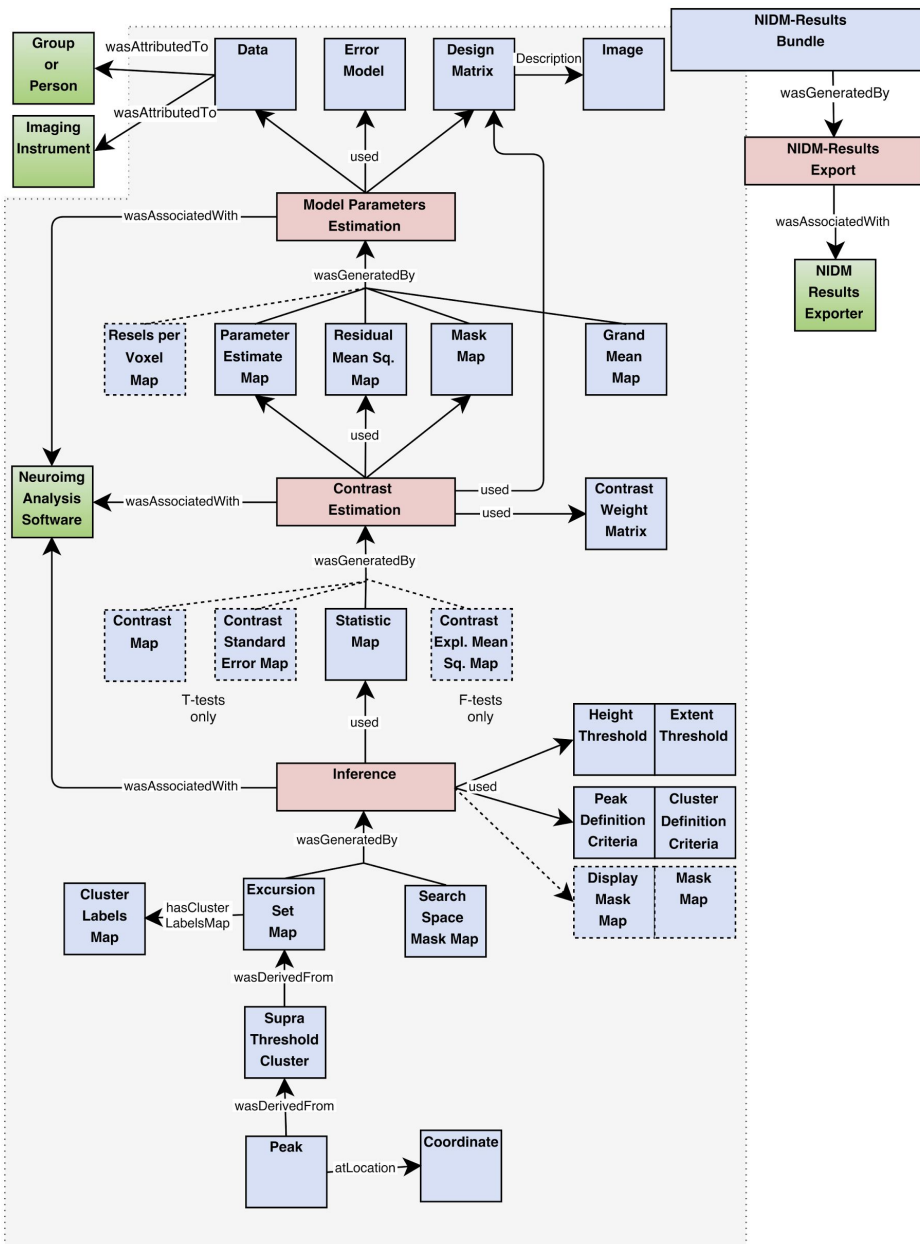
- Metadata selected according to
  - Meta-analysis use-case
  - Best practices
  - Neuroimaging software
- **Automatically** generated by the neuroimaging software packages.

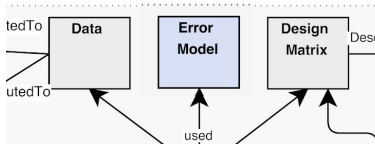
# NIDM-Results

**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 .

```

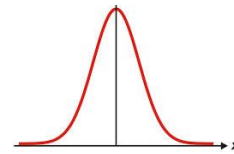
Definition

Attributes

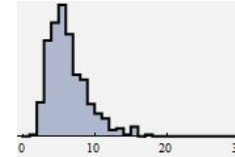
Examples

# Harmonisation across software

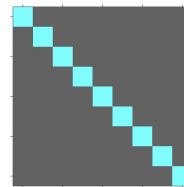
- Model of the error
  - Prob. distribution:
  - Variance:
  - Dependence:



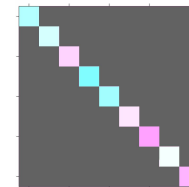
Gaussian



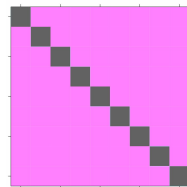
Non-Parametric



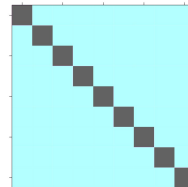
homogeneous



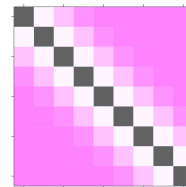
heterogeneous



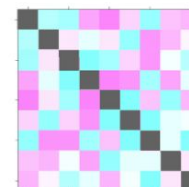
Independent  
noise



Compound  
Symmetry



Serially  
correlated

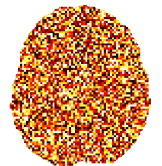


Arbitrarily  
correlated

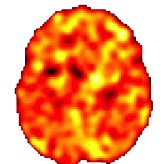
...



global



local

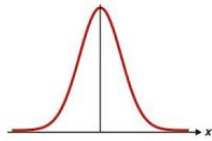


regularized

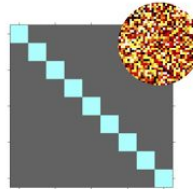
# Error models: SPM, FSL and AFNI

## Subject level

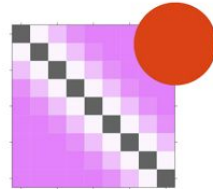
**SPM**



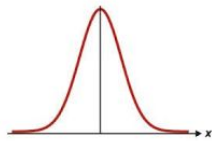
Gaussian



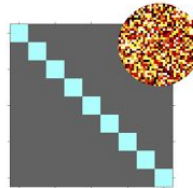
Homogeneous  
local



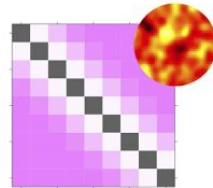
Serial. corr.  
global



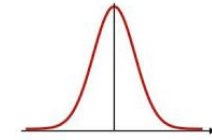
Gaussian



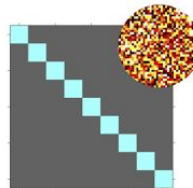
Homogeneous  
local



Serial. corr.  
regularized



Gaussian



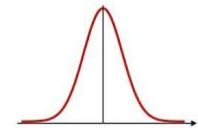
Homogeneous  
local



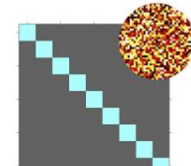
Serial. corr.  
local

## Group level

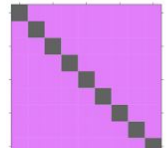
**SPM**  
one sample  
t-test



Gaussian



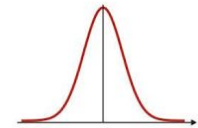
Homogeneous  
local



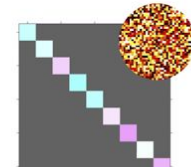
Independent  
noise



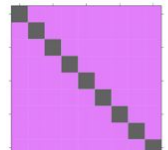
FLAME 1



Gaussian



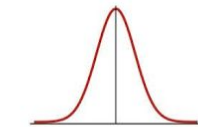
Heterogeneous  
local



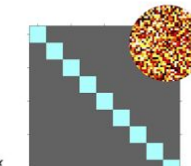
Independent  
noise



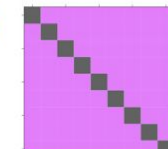
3dtttest++



Gaussian



Homogeneous  
local

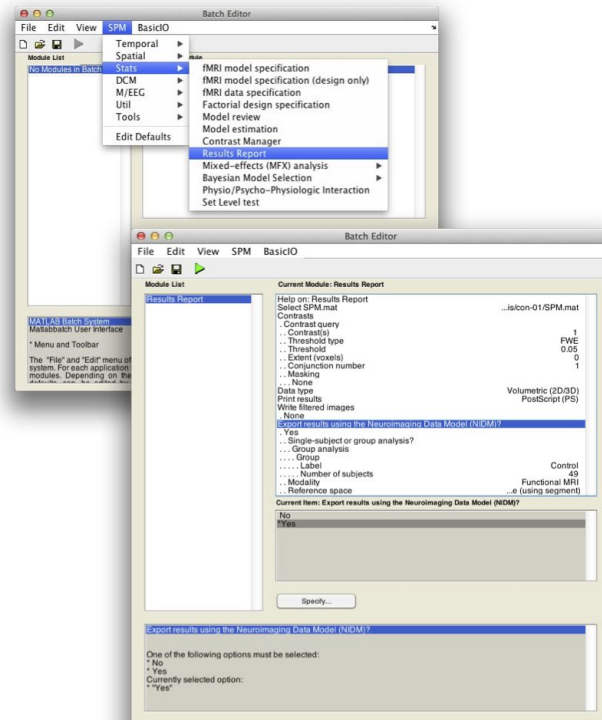


Independent  
noise

# **An image-based meta-analysis with NIDM-Results**

# SPM export to NIDM

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: 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), and spmT\_0001.nii (2.4 MB, NIFTI).

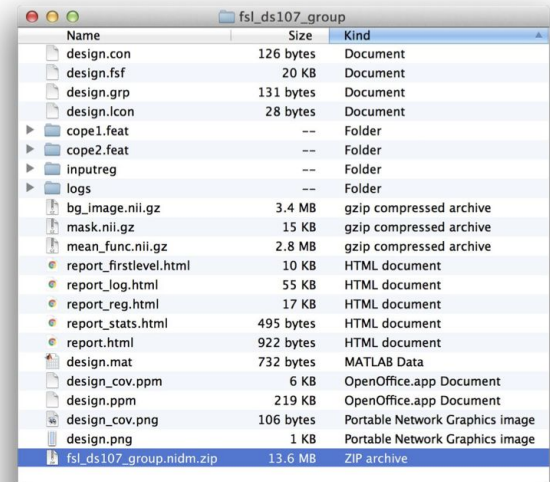
| Name              | Size   | Kind        |
|-------------------|--------|-------------|
| beta_0001.nii     | 2.4 MB | NIFTI       |
| con_0001.nii      | 2.4 MB | NIFTI       |
| mask.nii          | 593 KB | NIFTI       |
| nidm_001.nidm.zip | 4.1 MB | ZIP archive |
| ResMS.nii         | 4.7 MB |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

- Available as part of SPM12

# FSL export to NIDM



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

A screenshot of a macOS file explorer window titled 'fsl\_ds107\_group'. It displays a list of files and folders with columns for Name, Size, and Kind. The files include design.con, design.fsf, design.grp, design.lcon, cope1.feaf, cope2.feaf, inputreg, logs, bg\_image.nii.gz, mask.nii.gz, mean\_func.nii.gz, report\_firstlevel.html, report\_log.html, report\_reg.html, report\_stats.html, report.html, design.mat, design\_cov.ppm, design.ppm, design\_cov.png, design.png, and fsl\_ds107\_group.nidm.zip. The last file is highlighted in blue.

| Name                     | Size      | Kind                            |
|--------------------------|-----------|---------------------------------|
| design.con               | 126 bytes | Document                        |
| design.fsf               | 20 KB     | Document                        |
| design.grp               | 131 bytes | Document                        |
| design.lcon              | 28 bytes  | Document                        |
| cope1.feaf               | --        | Folder                          |
| cope2.feaf               | --        | 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                     |

- Install via pip
- To be included in the next FSL release

# Upload to NeuroVault

[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

Q

Log in

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

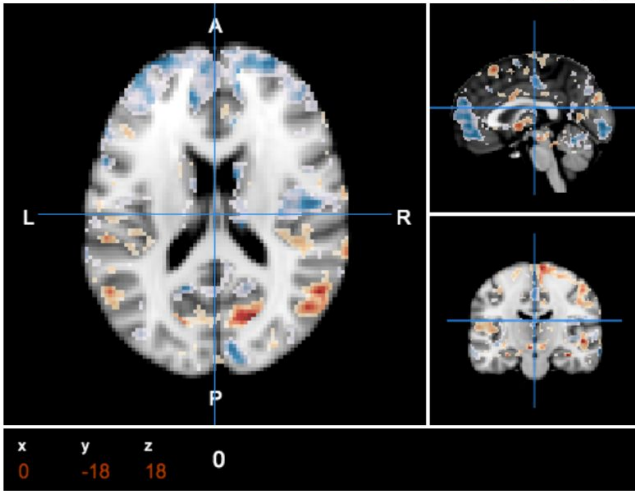
Contributed by ChrisFiloGorgolewski

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

NeuroVault

Collections ▾

FAQ

Give feedback



cmaumet ▾

## 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:

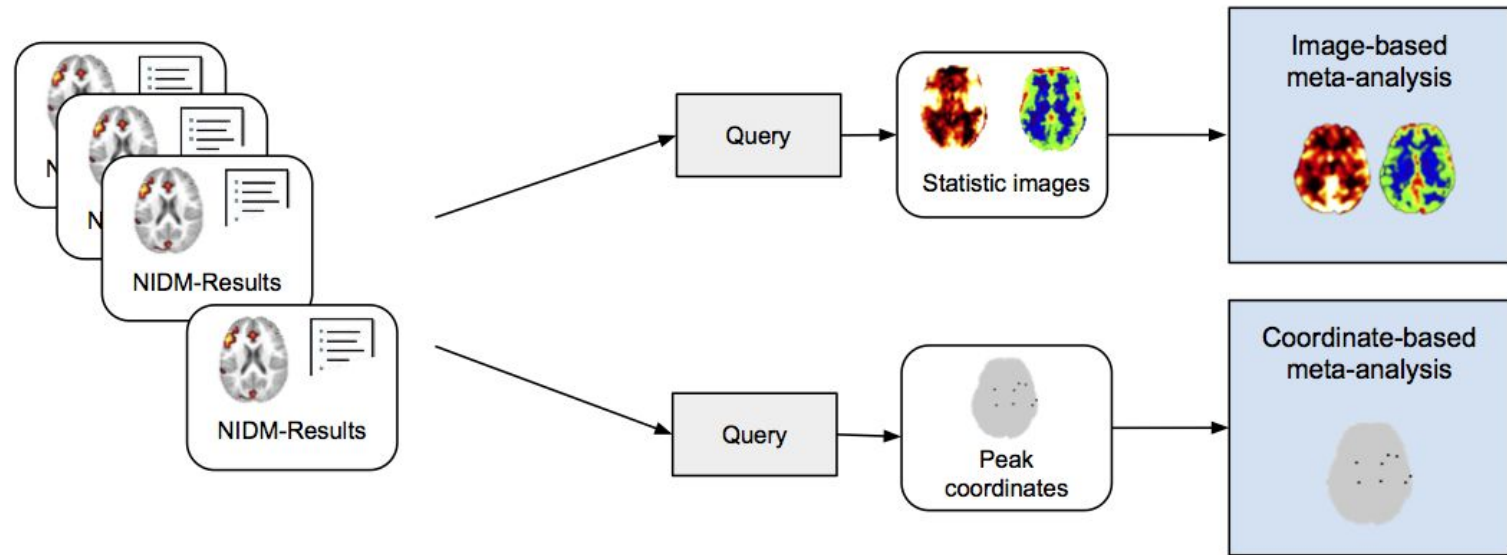
[Add images one by one](#)

[Upload an archive with images \(.zip or .tar.gz\)](#)

[Upload a NIDM-Results file \(.nidm.zip\)](#)

[Upload a folder with images](#)

# Example of meta-analysis



Coordinate-based meta-analysis



Image-based meta-analysis



## **Conclusion**

# Conclusion

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

Future work

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

# Acknowledgements

Thank you! To all the INCF  
NIDASH task force members.

**Warwick neurodata sharing** Tom Nichols, Alex Bowring, Ruth Pauli, Peter Williams, Tom Maullin-Sapey.

**NIDM working group** Tibor Auer, Samir Das, Fariba Fana, Guillaume Flandin, Satra Ghosh, Tristan Glatard, Chris Gorgolewski, Karl Helmer, David Keator, Nolan Nichols, Jean-Baptiste Poline, Vanessa Sochat, Jason Steffener, Jessica Turner.

**SPM** Guillaume Flandin.

**FSL** Mark Jenkinson, Matthew Webster, Paul McCarthy, Eugene Duff, Steve Smith.

**AFNI** Gang Chen, Richard Reynolds, Ziad Saad, Robert Cox.

**Meta-analysis dataset** Tracey group at FMRIb.

This work is supported by the

**wellcome**trust



# Q & A

Maumet, C. et al. Sharing brain mapping statistical results with the neuroimaging data model. *Sci. Data* 3:160102  
doi: [10.1038/sdata.2016.102](https://doi.org/10.1038/sdata.2016.102) (2016).



<https://github.com/incf-nidash>

<http://nidm.nidash.org>

