

Supporting image-based meta-analysis with NIDM: Standardized reporting of neuroimaging results

INCF NIDASH Task force

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WARWICK

Agenda

- Context
 - NIDM and the INCF NIDASH Task force
 - Meta-analysis use-case
 - Data sharing environment
- NIDM for meta-analysis
 - NIDM-Results
 - Implementation
 - Future directions
- Conclusions

CONTEXT



CONTEXT

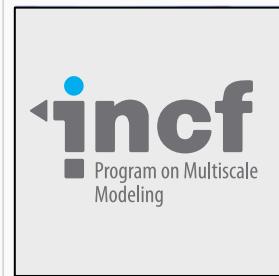
INCF NIDASH Task Force

International Neuroinformatics Coordinating Facility



Digital Brain Atlasing

Coordinates and improves the impact of brain atlasing projects



Multiscale Modeling

Improves interoperability and reproducibility of neural simulations



Ontologies of Neural Structures

Establishes consistent naming and classification for all neural structures



Standards for Data Sharing

Develops metadata and data standards for reproducible research



2 Task Forces

- Neuroimaging (NIDASH)
- Electrophysiology

NIDM working group

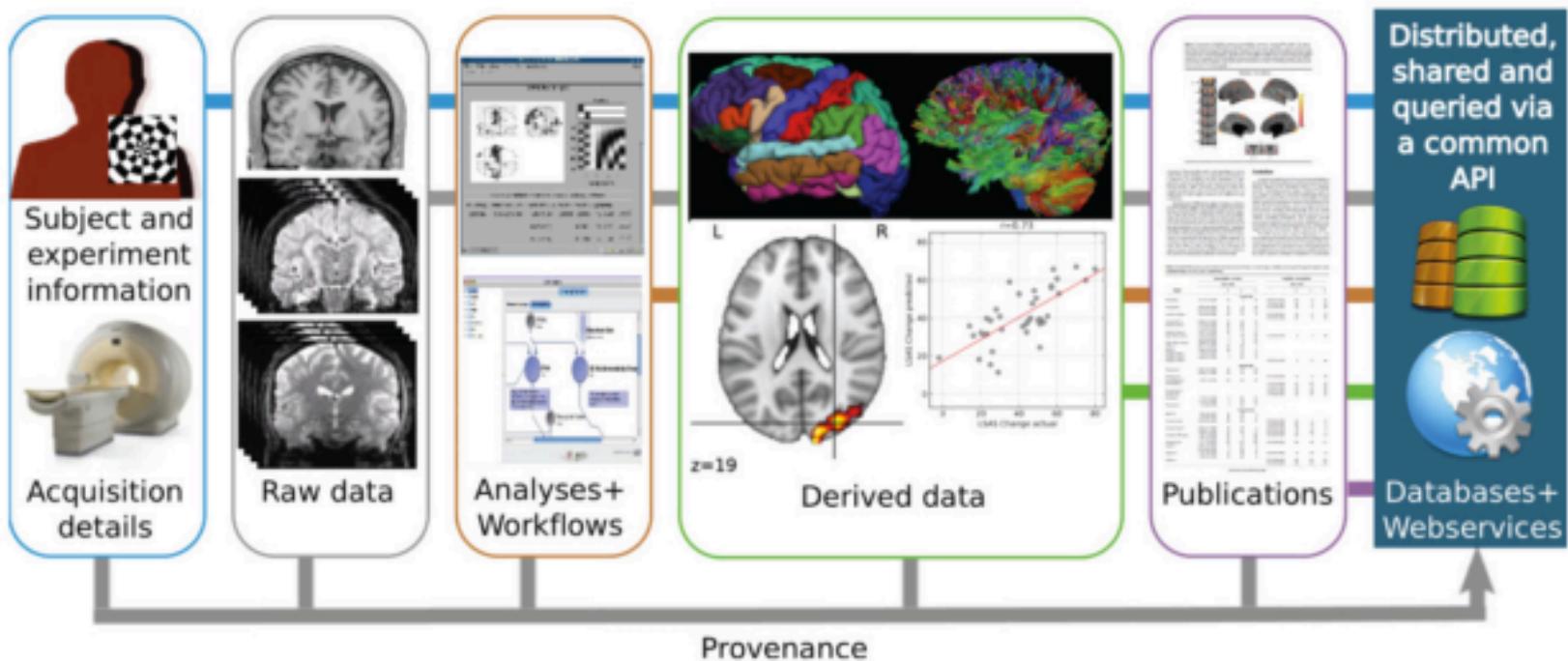
- NIDASH Task force
 - “Standards for Data Sharing aims to develop **generic standards and tools** to facilitate the **recording, sharing, and reporting of neuroscience metadata**, in order to improve practices for the **archiving and sharing of neuroscience data**.”
- BIRN Derived Data Working Group

From XCEDE to NIDM

- XML-Based Clinical Experiment Data Exchange Schema (XCEDE): www.xcede.org
 - Describes subject, study, activation
 - Limited provenance encoding
 - Initiative of the BIRN
- XCEDE-DM
- NeuroImaging Data Model (NIDM):
www.nidm.nidash.org

NIDM: Neuroimaging Data Model

Stages of Electronic Data Capture

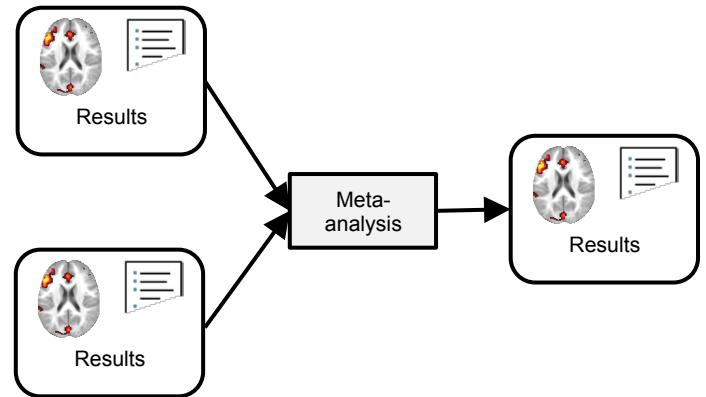


| Electronic Data Capture (EDC) workflow for data sharing in neuroimaging research.

Source: Poline et al, *Frontiers in Neuroinformatics* (2012).

NIDM: Neuroimaging Data Model

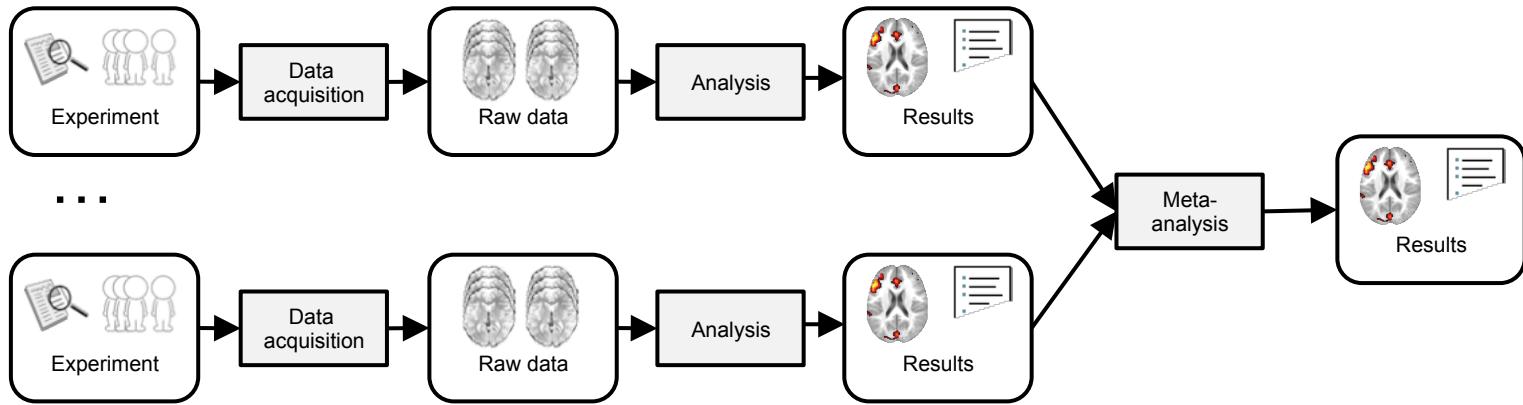
- Based on PROV-DM
- First applications
 - Description of the dataset-experiment hierarchy
 - Freesurfer volumes
 - DICOM terms



CONTEXT

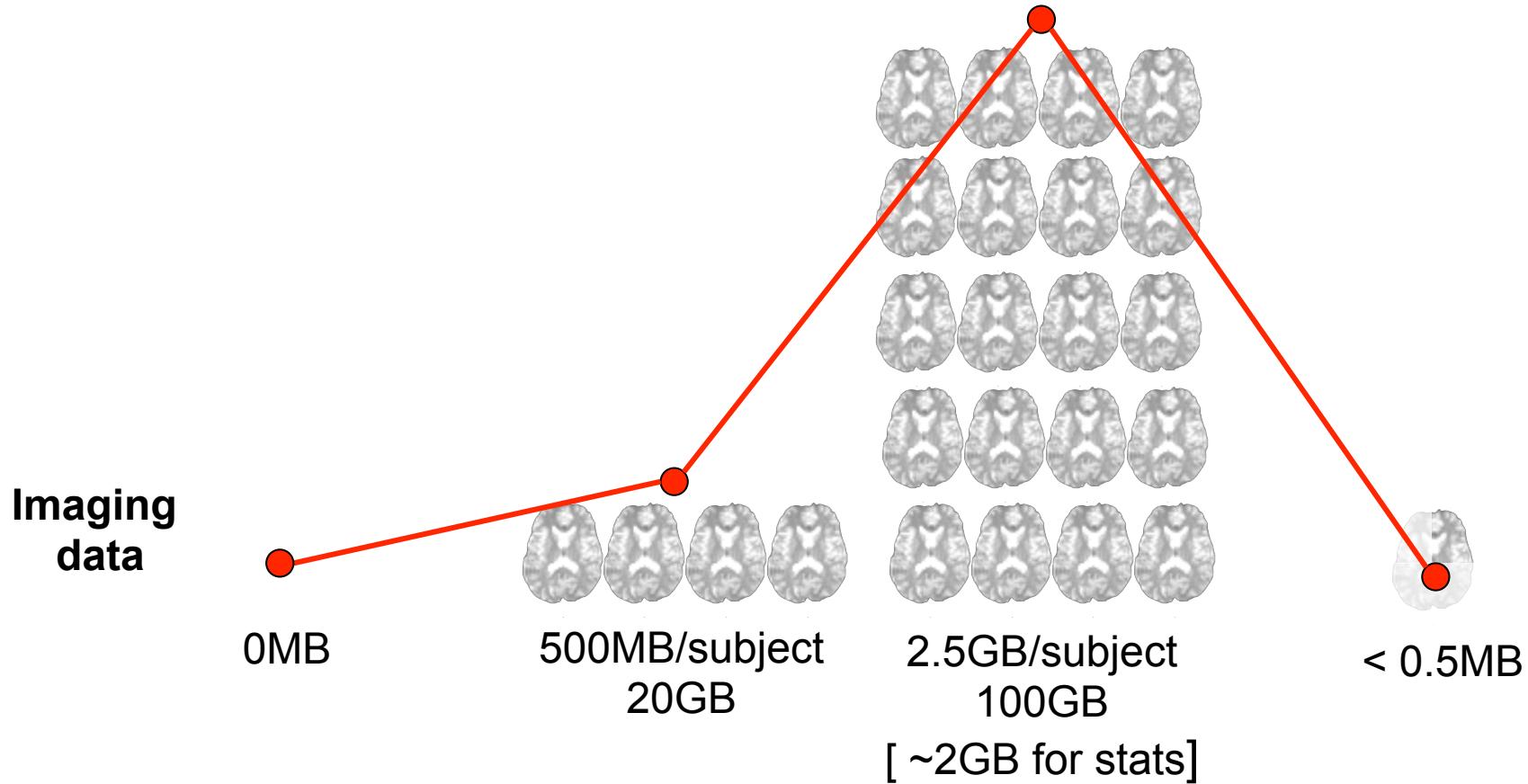
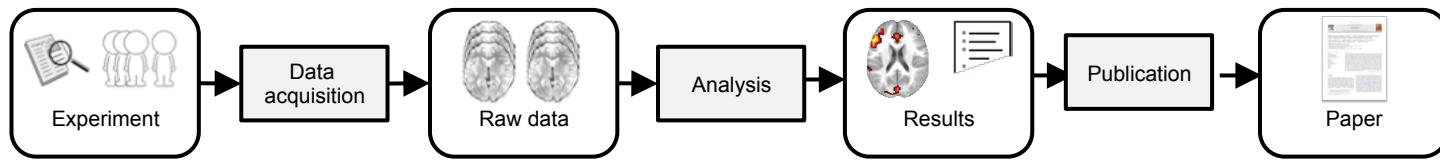
Meta-analysis use case

Why meta-analyses?

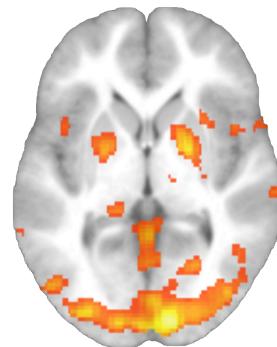
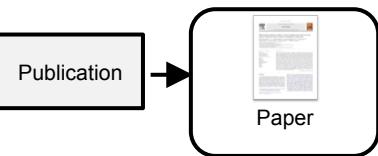


- Increase statistical power
- Combine information across studies

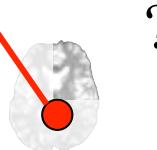
Data analysis in neuroimaging



Data analysis in neuroimaging



Detection images
(qualitative)



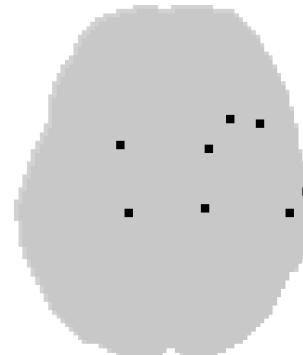
?

< 0.5MB

Table 2
Task comparisons (>) and conjunctions (C). Peak locations, cluster extent-Z-score ($p < 0.001$ unc.; $k = 10$).

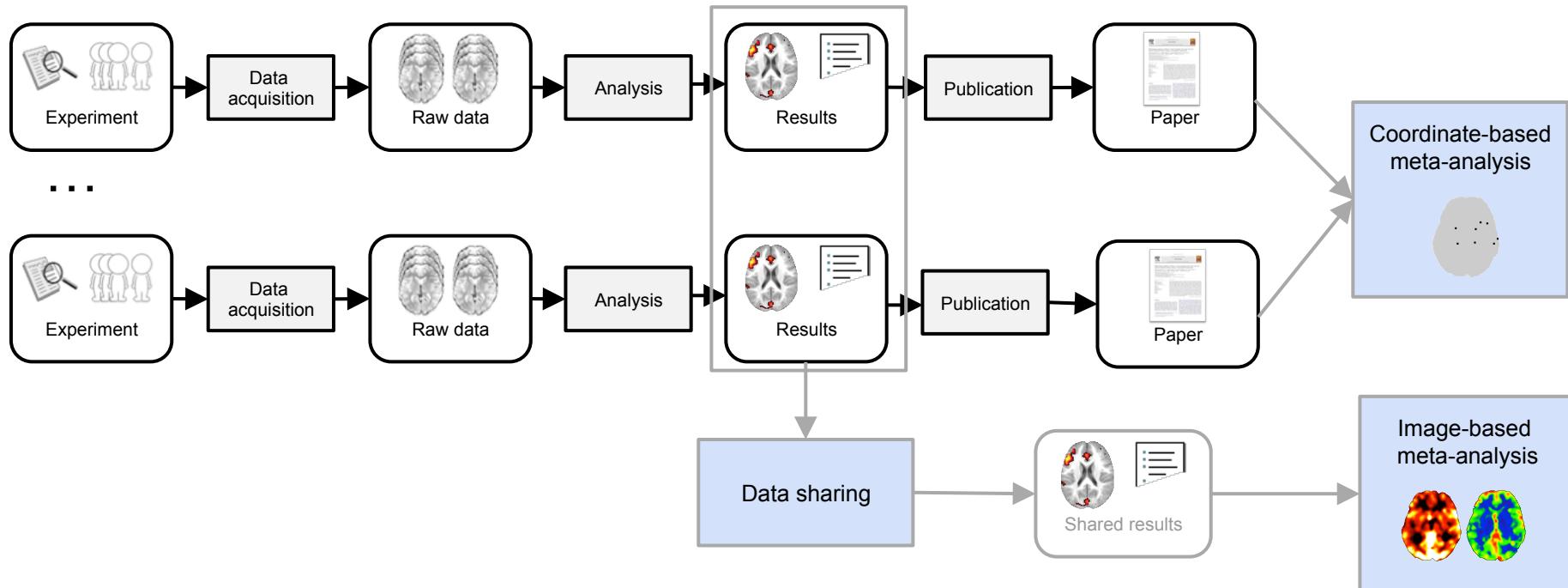
	Auditory language tasks			Visual language tasks	
	Categ>Def	Def>Categ	Categ C Def	Ph-s>Ph-d	Ph-
<i>Left Hemisphere</i>					
Inf frontal-Oper	--	--	348–4.10 ⁽⁴⁾	--	82 ^a
Precentral	18–3.38 ⁽⁵⁾	--	348–5.09	--	82 ^a
Mid frontal	33–3.66	--	--	--	--
SMA	--	--	1433–5.48	--	35 ^c
Cingulate	--	--	1433–5.08 ⁽³⁾	--	--
Med sup frontal	174–4.69	--	--	--	--
Rol operculum	--	--	--	36 – 4.31	--
Insula	--	--	396–4.87 ⁽⁸⁾	--	58–
Sup temporal	--	--	351–3.81 ⁽¹⁾	--	91–
Mid temporal	--	1658–4.67 ⁽³⁾	351–5.61 ⁽²⁾	--	10–
Inf parietal	--	1658–5.18 ⁽⁶⁾	--	--	--
Sup parietal	--	--	--	--	97 ^c
Postcentral	--	--	--	--	97 ^c
Sup occipital	--	--	--	--	--
Mid occipital	--	--	--	146–4.43	14 ^c
Inf occipital	--	--	--	--	14 ^c
Fusiform	--	--	--	397–5.44	14 ^c

Table of local maxima
(quantitative)



Peaks
(quantitative)

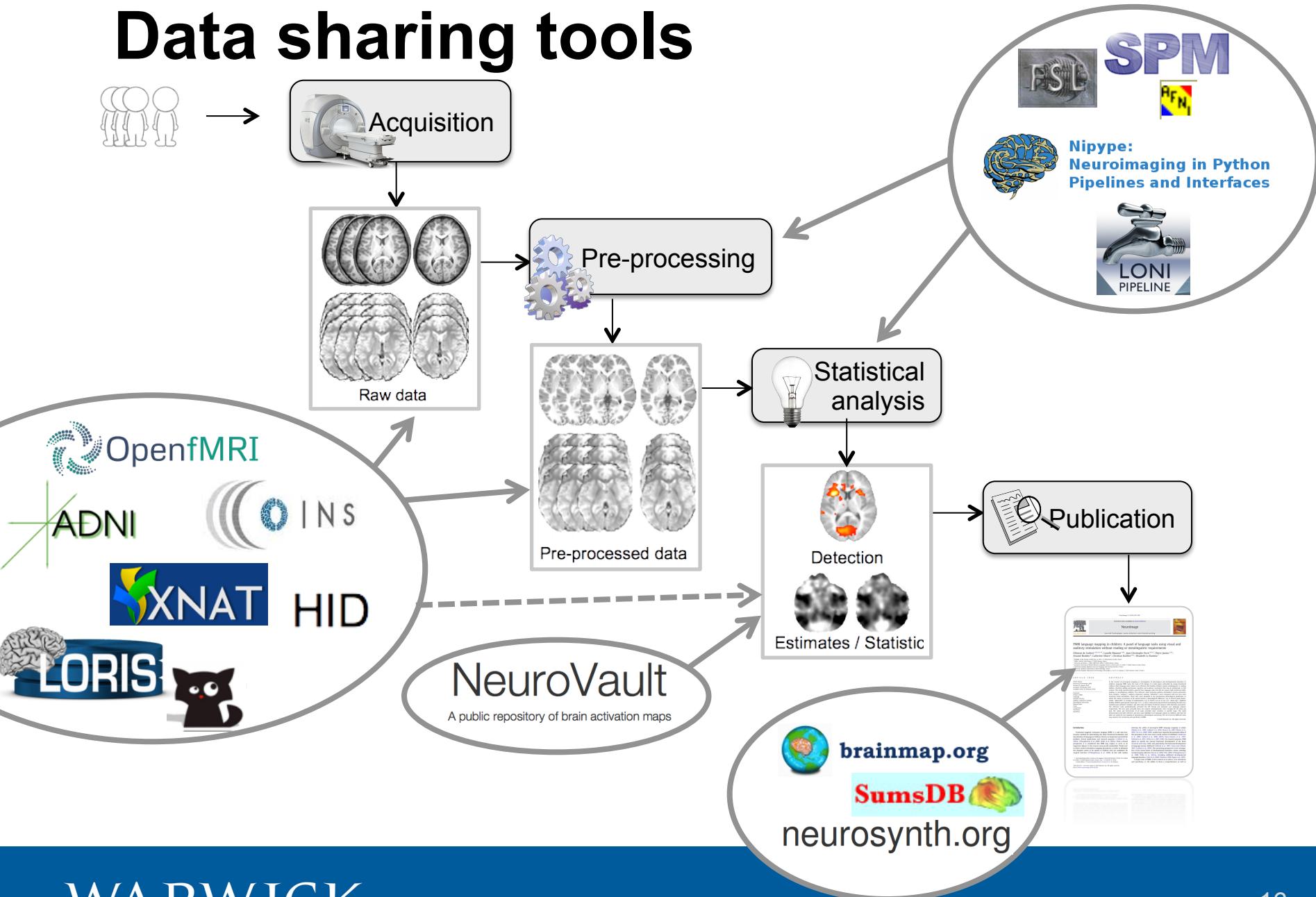
Coordinate- or Image-Based meta-analysis?



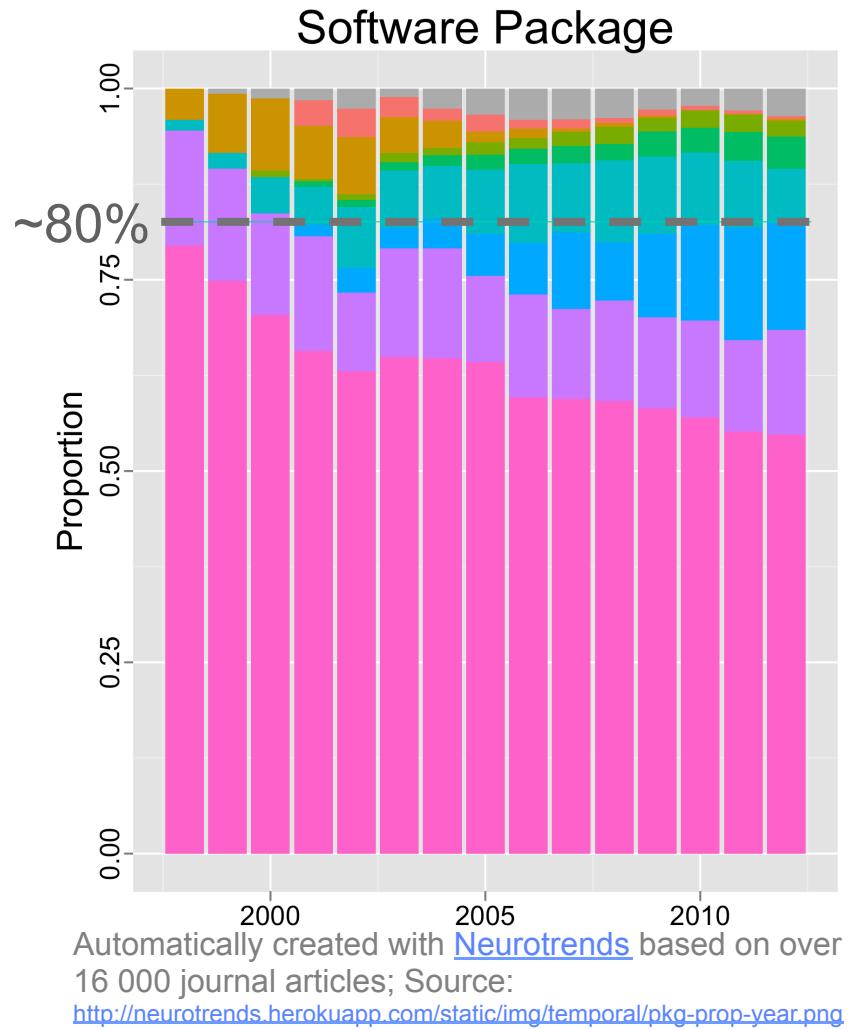
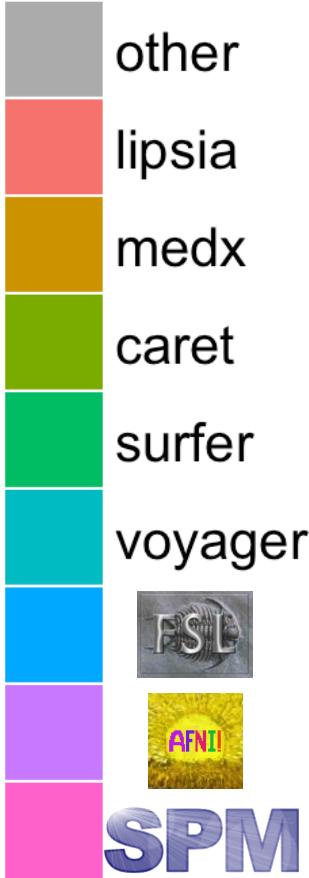
CONTEXT

Data sharing environment

Data sharing tools

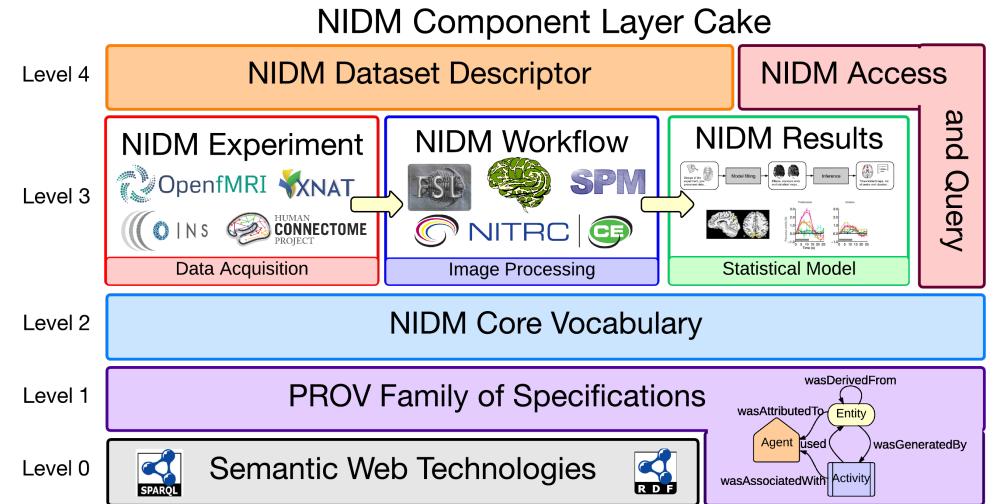


Three major software packages

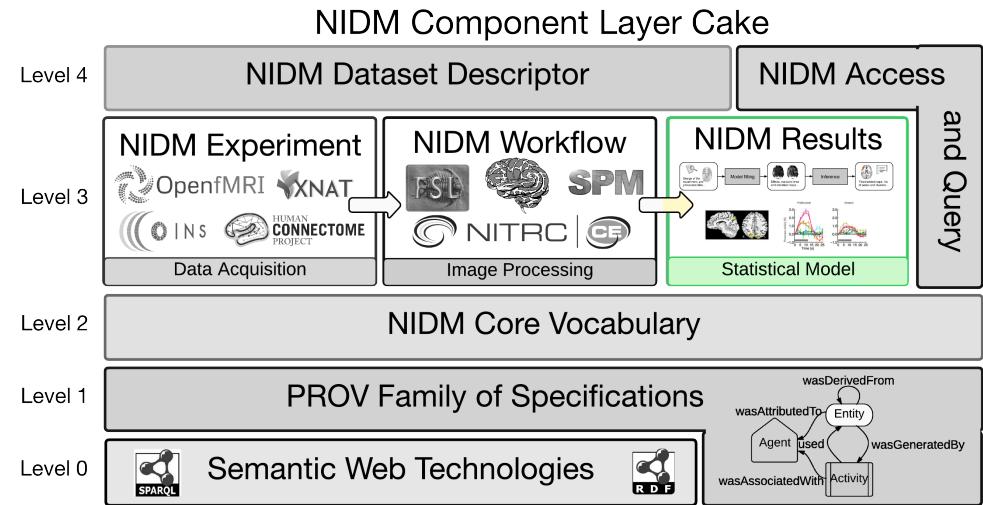


Summary of the problem

- Use-case: Support meta-analysis
- Machine-readable format describing neuroimaging results
- Easiness for the end-user
- Integrate with existing neuroimaging software packages (SPM, FSL, AFNI,...)
- Extend previous work: NIDM



NIDM FOR META-ANALYSIS

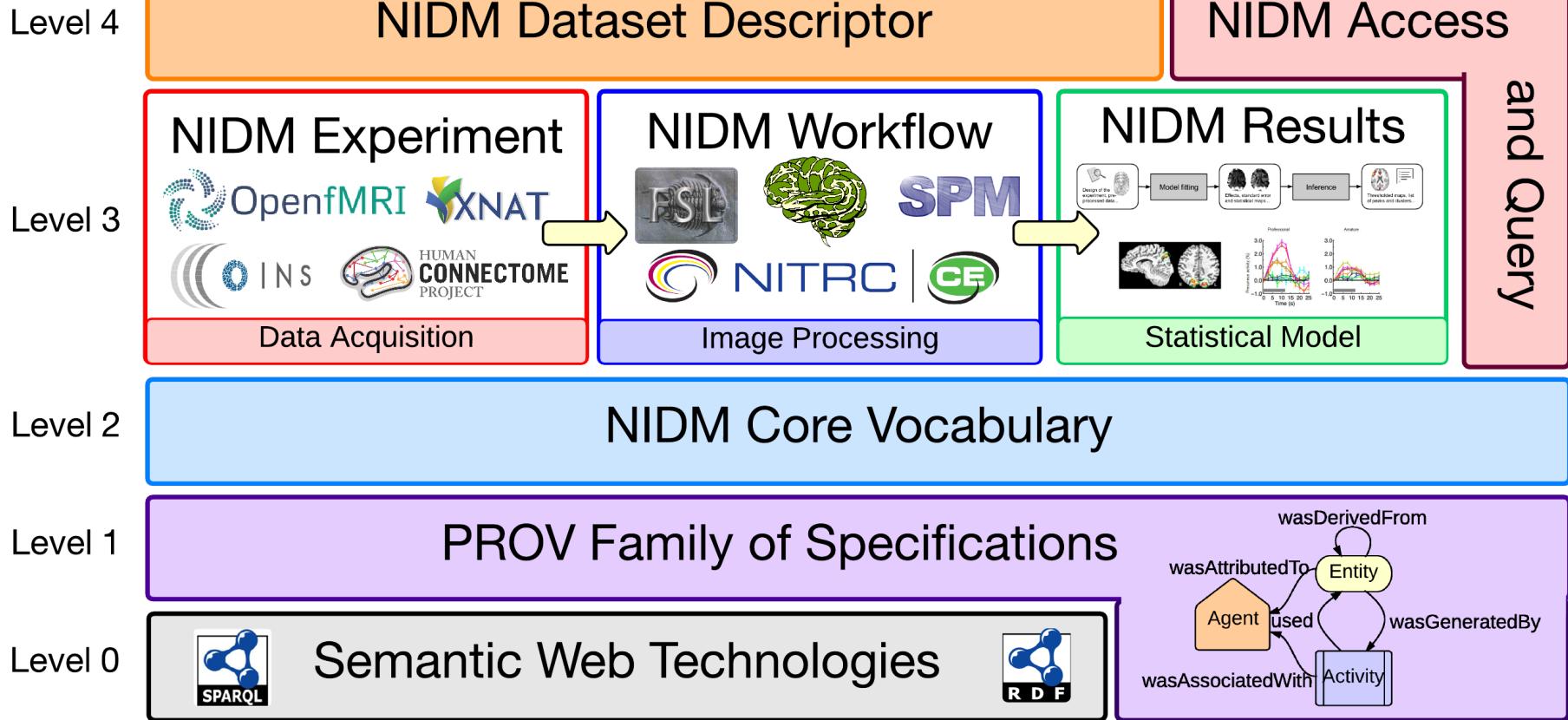


NIDM FOR META-ANALYSIS

NIDM-Results

Neuroimaging Data Model

NIDM Component Layer Cake



NIDM-Results

NIDM Component Layer Cake

Level 4

NIDM Dataset Descriptor

NIDM Access

NIDM Experiment



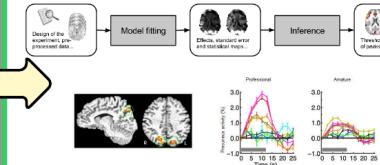
Data Acquisition

NIDM Workflow



Image Processing

NIDM Results



Statistical Model

and Query

Level 3

Level 2

NIDM Core Vocabulary

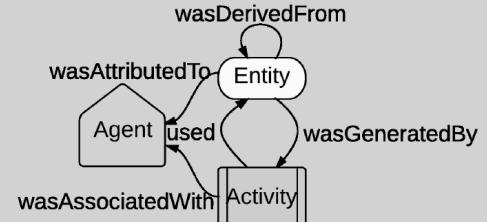
Level 1

PROV Family of Specifications

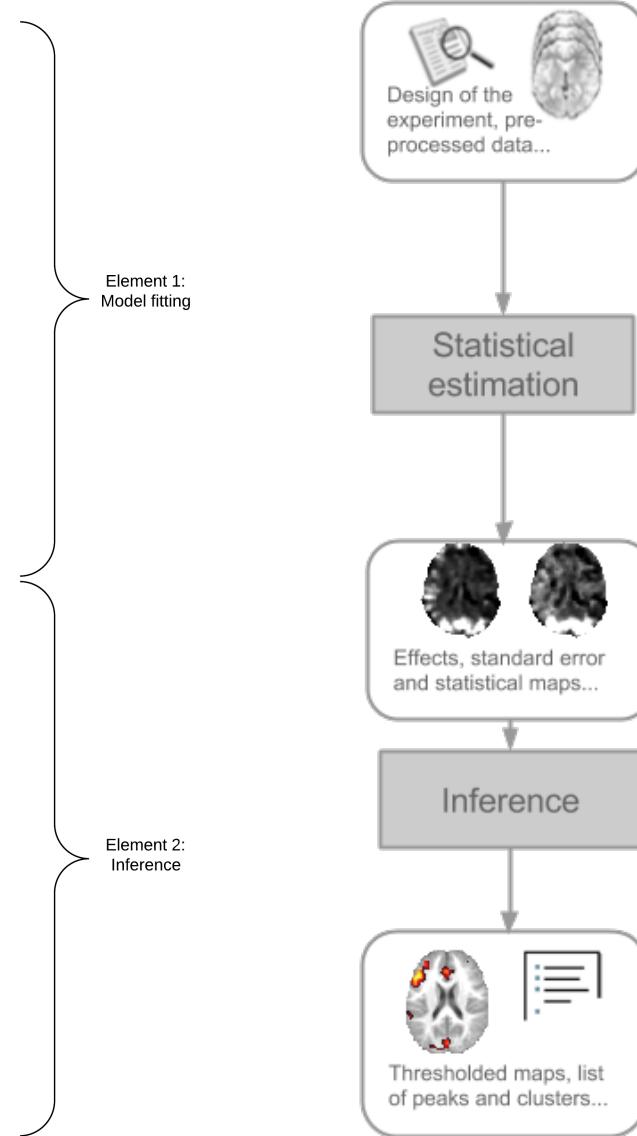
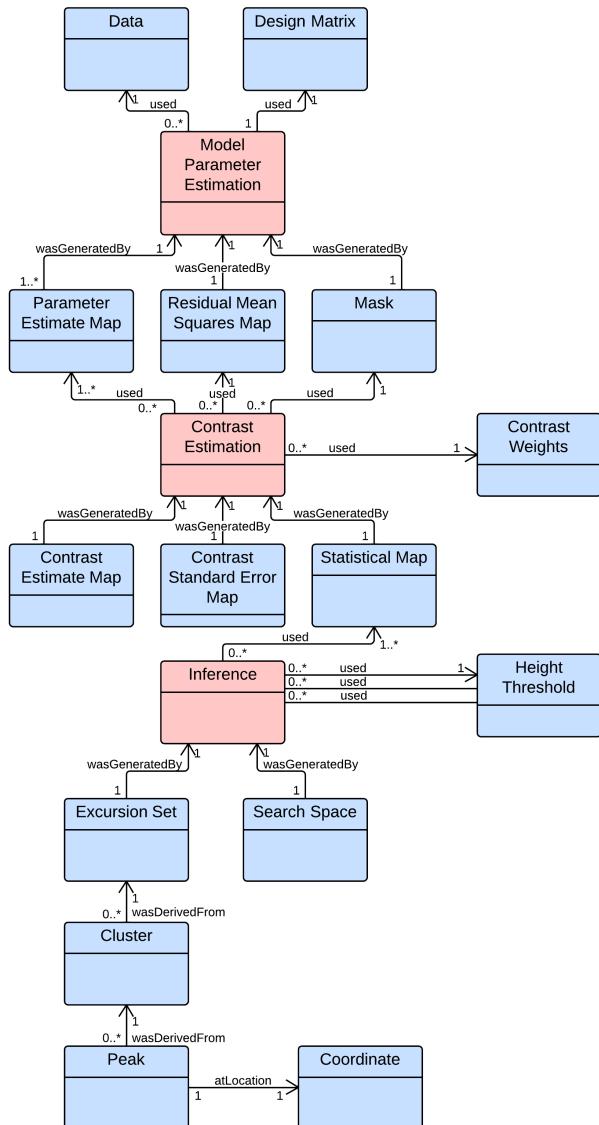
Level 0



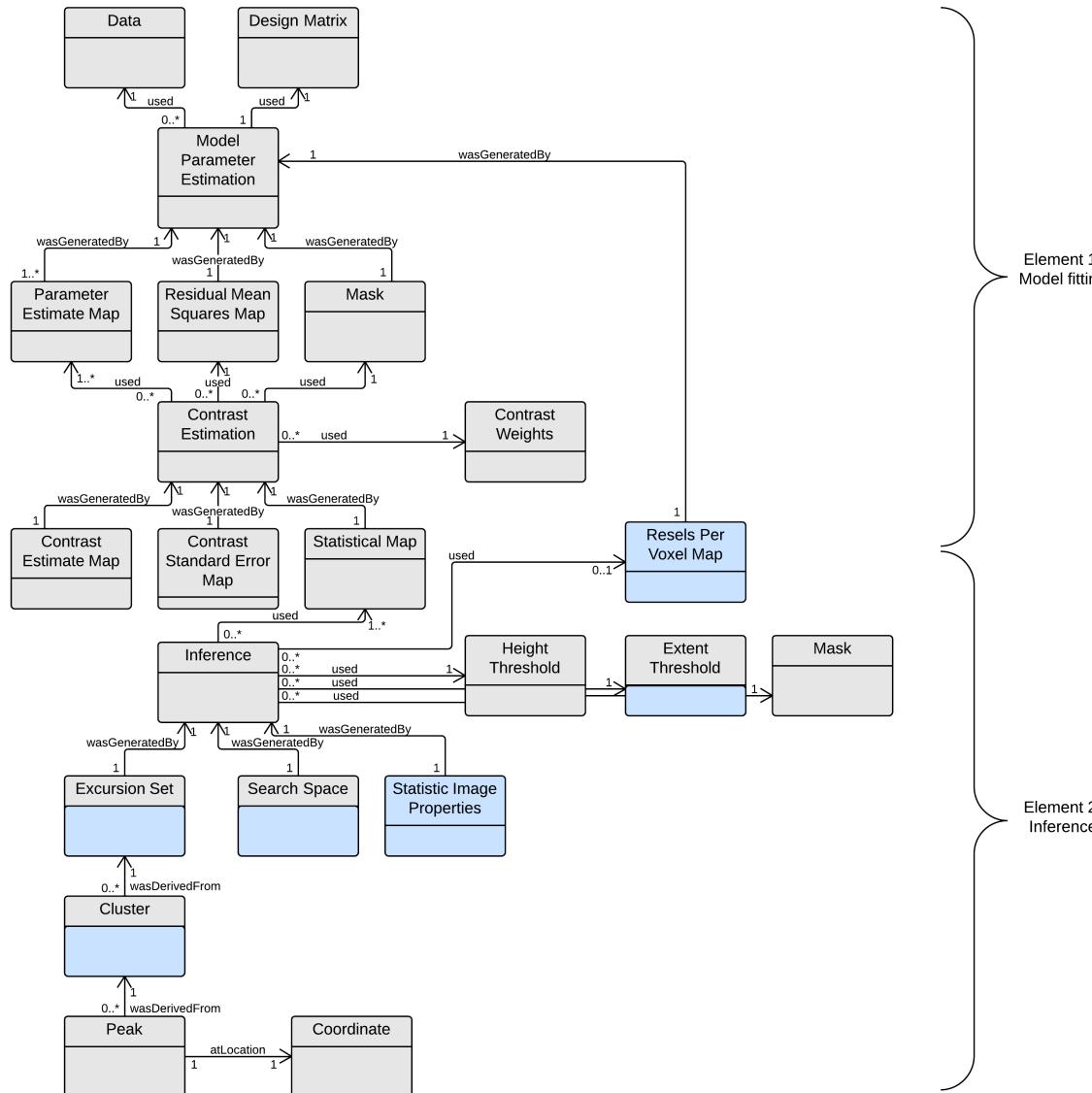
Semantic Web Technologies



NIDM-Results



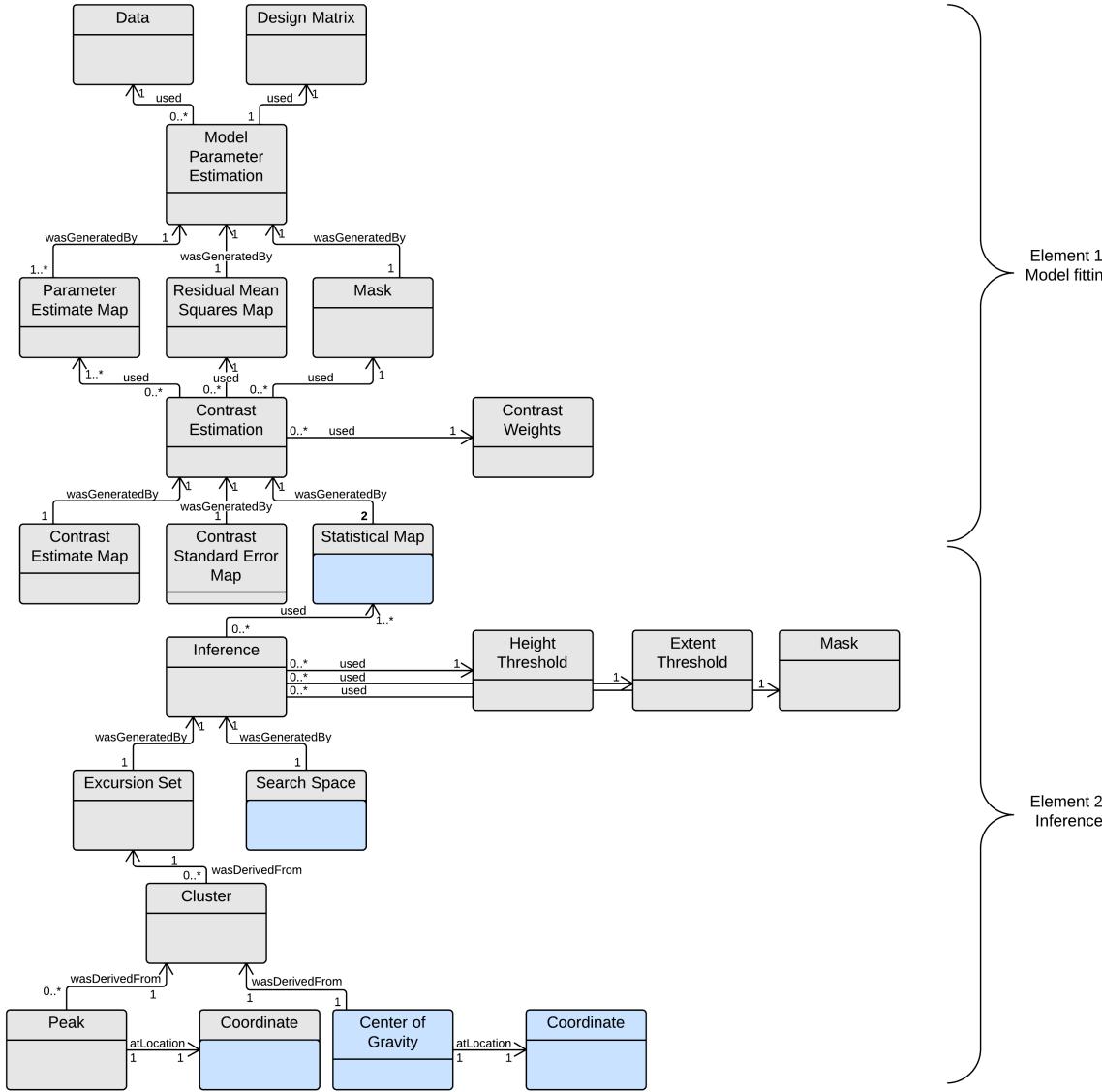
NIDM-Results: SPM-specific



Element 1:
Model fitting

Element 2:
Inference

NIDM-Results: FSL-specific

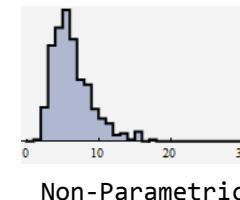
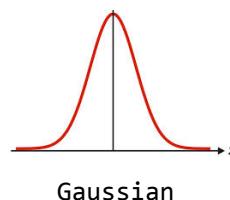


Element 1:
Model fitting

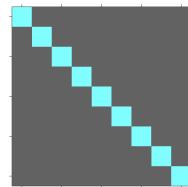
Element 2:
Inference

Standardization across software

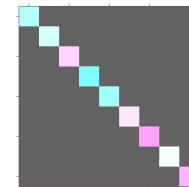
- Model of the error
 - Prob. distribution:
 - Variance:
 - Dependence:



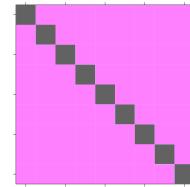
...



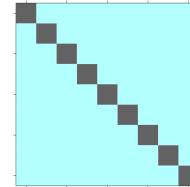
homogeneous



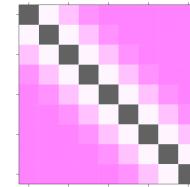
heterogeneous



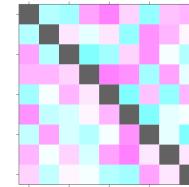
Independent
noise



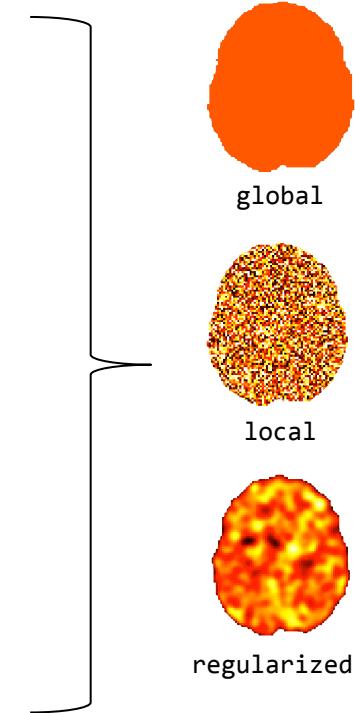
Compound
Symmetry



Serially
correlated



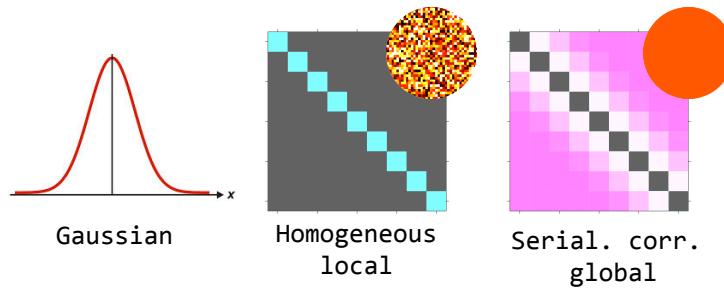
Arbitrarily
correlated



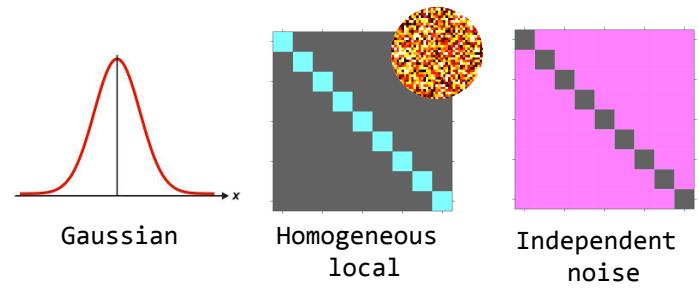
Error models : SPM, FSL and AFNI

SPM

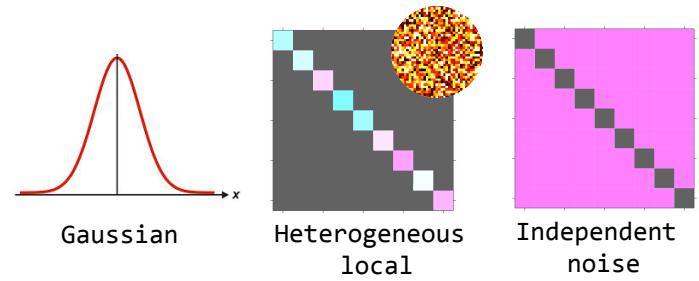
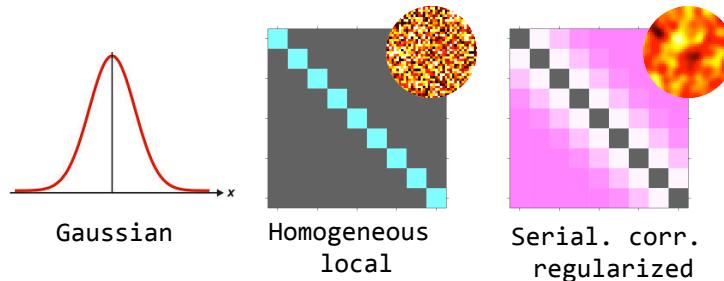
1st level



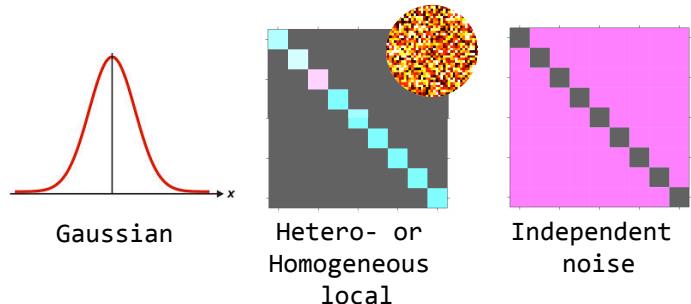
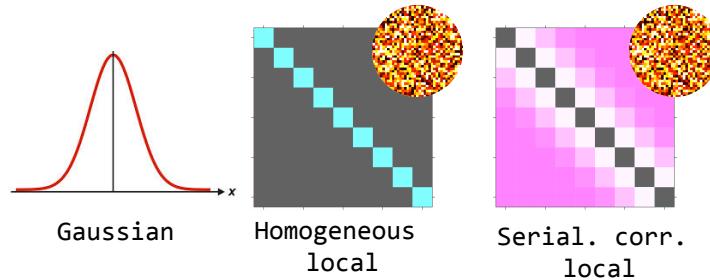
2nd level



FSL



AFNI



Error models: non-parametric

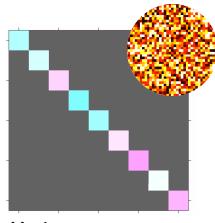
2nd level: Sign-flipping



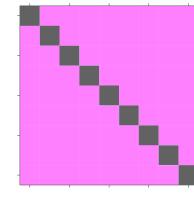
Randomise



NonParametric
Symmetric

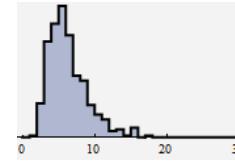


Heterogeneous
local

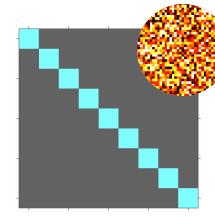


Independent
noise

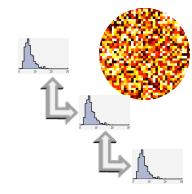
2nd level: Label permutation



NonParametric



Homogeneous
local



Exchangeable
noise local

Terms

- “Flat” ontology
- Terms re-use:
 - Interaction with STATO (statistical terms)
 - Dublin Core (file formats)
 - But also: NCIT, OBI...
- Work-in-progress
 - <http://tinyurl.com/nidm-results/terms>
- Aim: include the terms in Neurolex.



Queries

- For each contrast get name, contrast file, statistic file and type of statistic used.

```
prefix prov: <http://www.w3.org/ns/prov#>
```

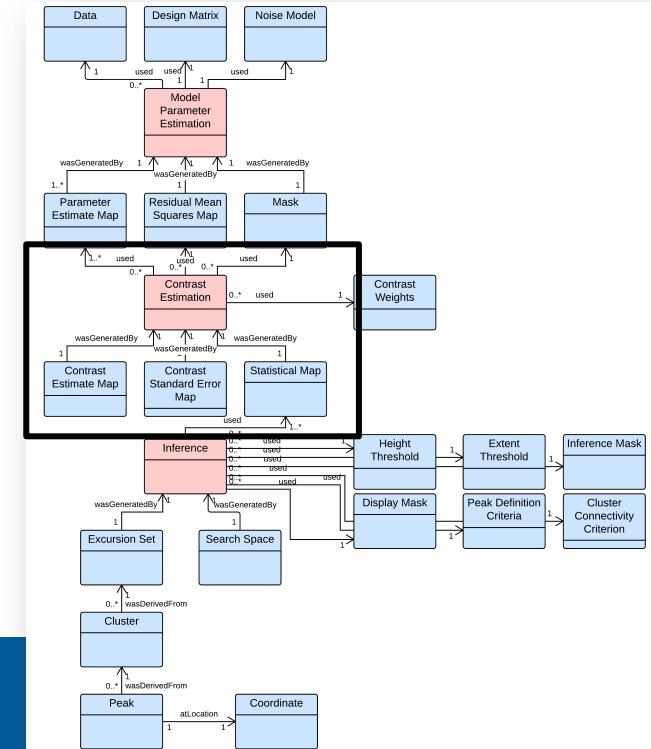
```
prefix nidm: <http://www.incf.org/ns/nidash/nidm#>
```

```
SELECT ?contrastName ?contrastFile ?statType ?statFile
```

```
WHERE {
```

```
?cid a nidm:ContrastMap ;  
      nidm:contrastName ?contrastName ;  
      prov:atLocation ?contrastFile .  
  
?cea a nidm:ContrastEstimation .  
  
?cid prov:wasGeneratedBy ?cea .  
  
?sid a nidm:StatisticMap ;  
      nidm:statisticType ?statType ;  
      prov:atLocation ?statFile .
```

```
}
```



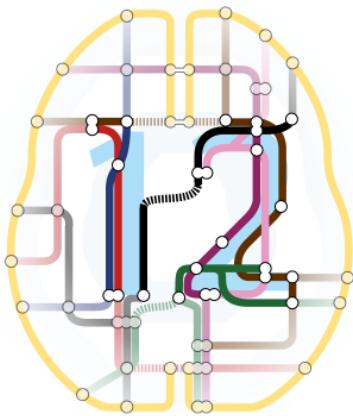
More queries: <http://tinyurl.com/nidm-results/query>

NIDM FOR META-ANALYSIS

Implementation

Implementation

- NIDM export
 - SPM12 (natively)
 - Scripts for FSL:
https://github.com/incf-nidash/nidm-results_fsl
 - First contact with AFNI developers



NIDM FOR META-ANALYSIS

Future directions

Next steps and future plans

- Extend NIDM-Results implementation:
 - AFNI
 - SnPM, Randomise
- Refine the terms and definitions.



Next steps and future plans

- NIDM import for Neurovault

NeuroVault (beta) Add new collection See all collections FAQ Give feedback Log in

NeuroVault

A public repository of unthresholded brain activation maps

What is it?
A place where researchers can publicly store and share unthresholded statistical maps 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!

Latest collections of images

Name	Number of images
Altered functional connectivity in posttraumatic stress disorder with versus without comorbid major depressive disorder: a resting state fMRI study	4
Structural and functional MRI study of the brain, cognition and mood in long-term adequately treated Hashimoto's thyroiditis	2
please affects frontoparietal and cerebellar hubs in close correlation with clinical symptoms—a resting-	6

NeuroVault (beta) Add new collection See all collections FAQ Give feedback cmaumet ▾

Add new collection

A collection is a set of images grouped together for some sensible reason. Most commonly, a collection contains all of the images from a single study. Please provide information about this collection. Only the starred fields* are mandatory, but please try to provide as much information as you can.

Essentials Subjects Design Acquisition Registration Preprocessing 1st Level 2nd Level

Type of design Blocked, event-related, hybrid, or other

No. of imaging runs Number of imaging runs acquired

No. of experimental units Number of blocks, trials or experimental units per imaging run

Length of runs Length of each imaging run in seconds

Length of blocks For blocked designs, length of blocks in seconds

Length of trials Length of individual trials in seconds

Optimization? Unknown Was the design optimized for efficiency

Optimization method What method was used for optimization?

Save

NIDM-Results and NIDM-Workflow

- NIDM-Results: effort on standardization across software
 - A small number of generic activities
 - A few software-specific entities
- NIDM-Workflow: a detailed view of all software-specific processes.

CONCLUSION

Conclusion

- NIDM-Results: standardized reporting of neuroimaging results
 - Use-case: Meta-analysis
 - Terms: <http://tinyurl.com/nidm-results/terms/>
 - Specification: <http://nidm.nidash.org>
 - Implementation in SPM12 & FSL
- Next steps
 - Refine the terms, AFNI and SnPM/Randomise models
 - Integration with Neurovault
 - Build apps

Resources

- Github: <https://github.com/incf-nidash>
- Specifications: <http://nidm.nidash.org>

2. Overview

This section introduces neuroimaging results concepts with informal explanations and illustrative examples (e.g. see [SPM results](#) structures, forming the essence of the results, from software-specific structures catering for more specific uses of results by different studies respectively presented in Section 2.1 and Section 2.2).

2.1 Domain covered by NIDM-Results

NIDM-Results is concerned with the modelling of model fitting and inference in the context of massively univariate analyses. Analyses involving other modalities (such as PET) and sequences (e.g. anatomical MRI through VBM) can also be modelled. The domain is represented in .



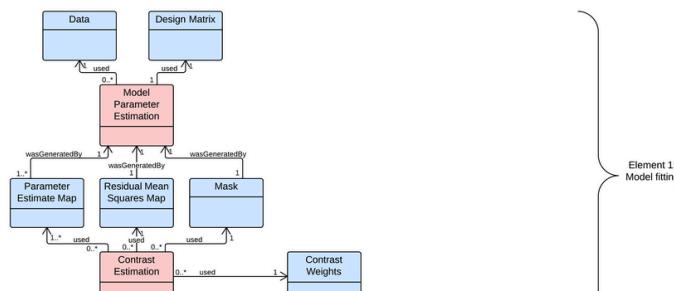
Fig. 2 Domain overview

2.2 NIDM-Results Core Structures

The concepts found in the core of NIDM-Results are introduced in the rest of this section.

2.2.1 Overview

The core NIDM-Results structures are presented in . The color coding corresponds to the prov:type (blue: prov:entity, red: prov:Activity, "Model fitting" and "Inference", the structures and relations belonging to each element are presented in details in and .



NIDM-Results Terms curation status

Curation status: PendingFinalVetting; MetadataIncomplete; RequiresDiscussion; Uncurated; ToBeReplacedByExternalOntologyTerm

Classes

Curation Status	Term
	<code>fsl:ZStatisticMap</code> : A map whose value at each location is a Z-statistic value.
	<code>nidm:ContrastMap</code> : A map whose value at each location is statistical contrast estimate.

Acknowledgements

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

NIDM working group

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INCF NIDASH - Other members

David Kennedy, Cameron Craddock, Stephan Gerhard, Yaroslav Halchenko, Michael Hanke, Christian Haselgrove, Arno Klein, Daniel Marcus, Franck Michel, Simon Milton, Russell Poldrack, Rich Stoner.

This work is supported by the

wellcome trust

Q & A

NIDM Resources

- Github: <https://github.com/incf-nidash>
- Specifications: <http://nidm.nidash.org>