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# Tools and standards to make neuroimaging derived data reusable

Camille Maumet

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Submitted on 2 Oct 2018

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# Tools and standards to make neuroimaging derived data reusable

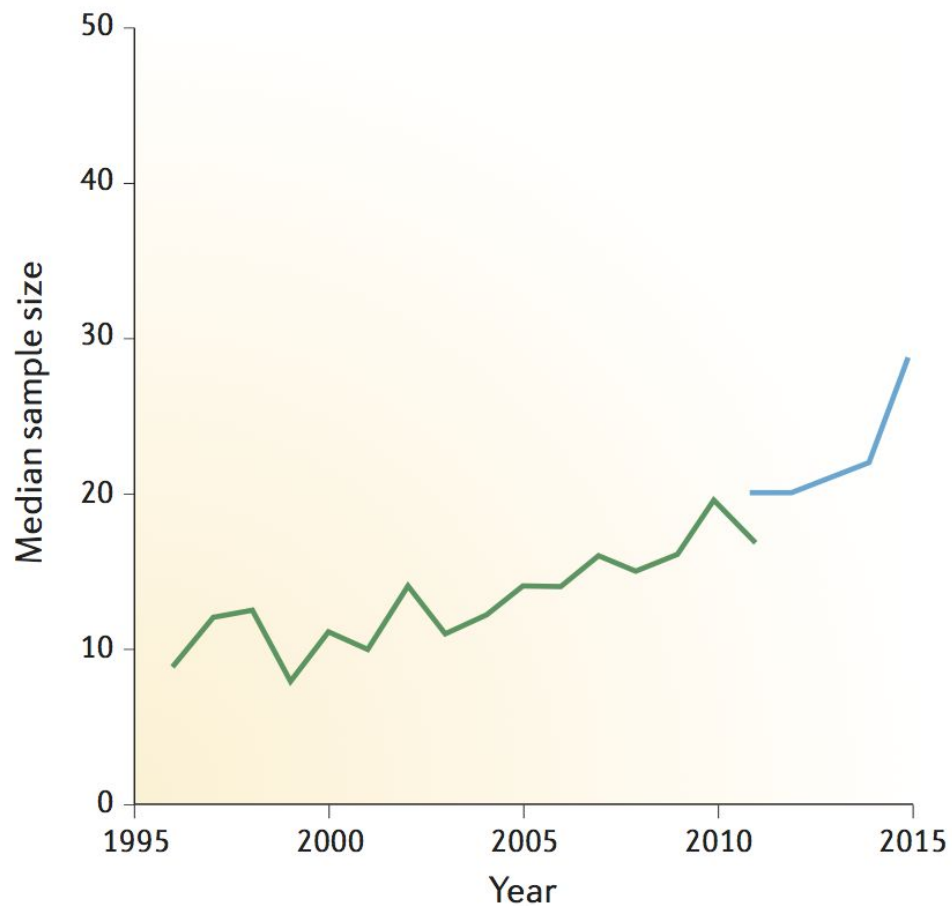
**Camille Maumet**



Univ Rennes, Inria, CNRS, Inserm, IRISA UMR 6074, VisAGeS ERL U-1228

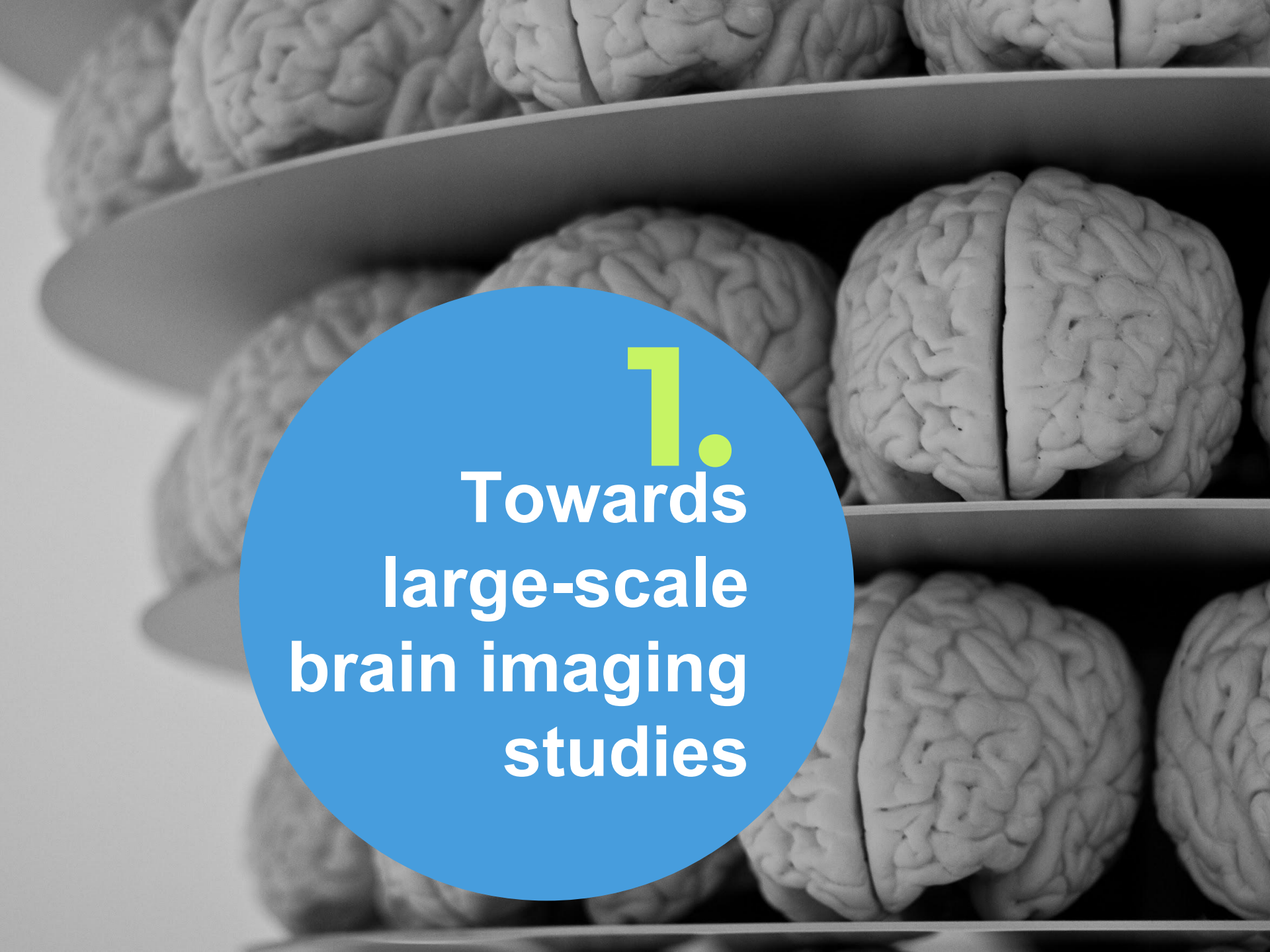


# Sample sizes in neuroimaging



2015: 30 subjects / study

Poldrack et. al (2017)



**1.**  
**Towards  
large-scale  
brain imaging  
studies**

# More and more shared data available

## Single study

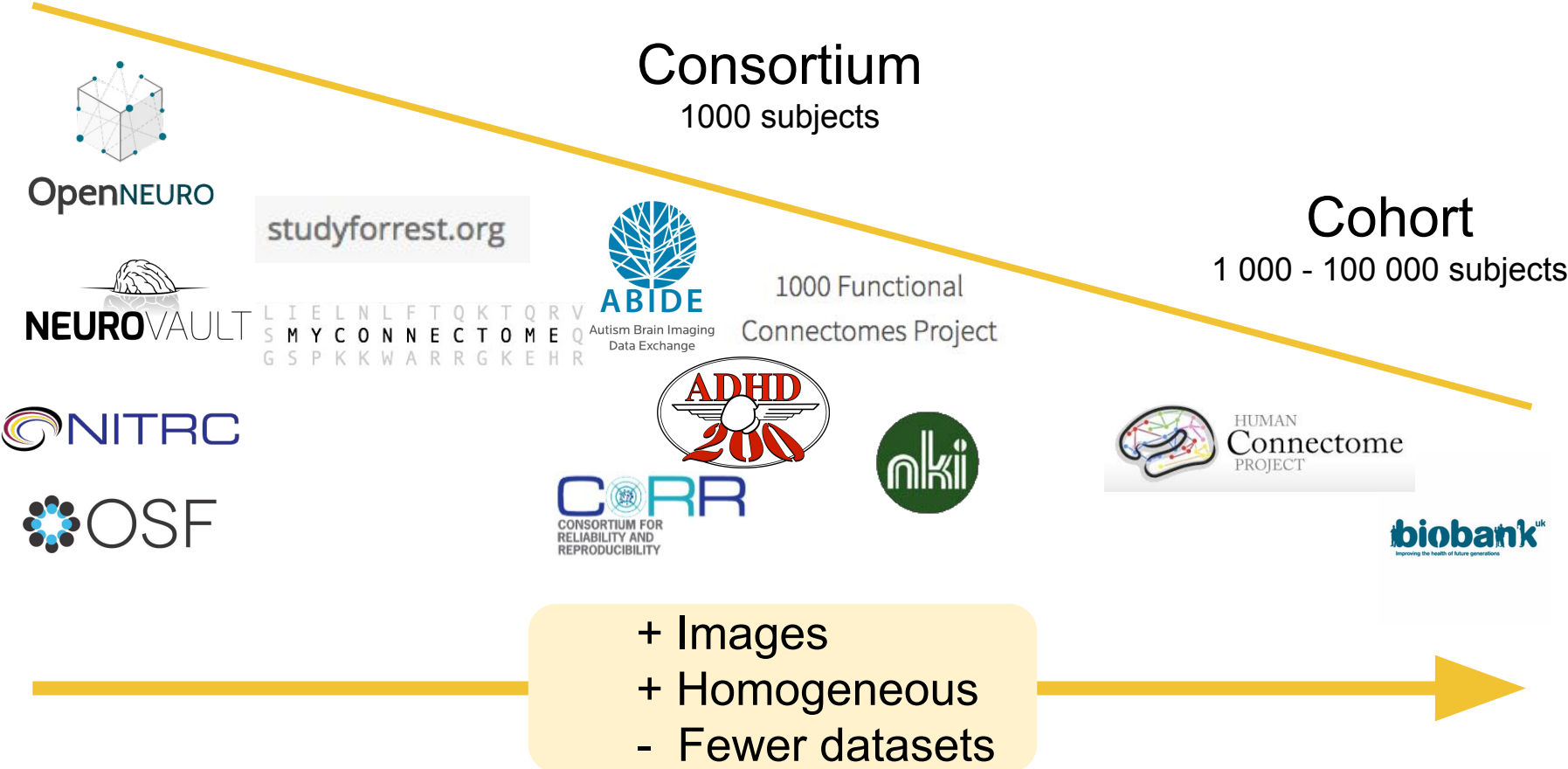
30 subjects

## Consortium

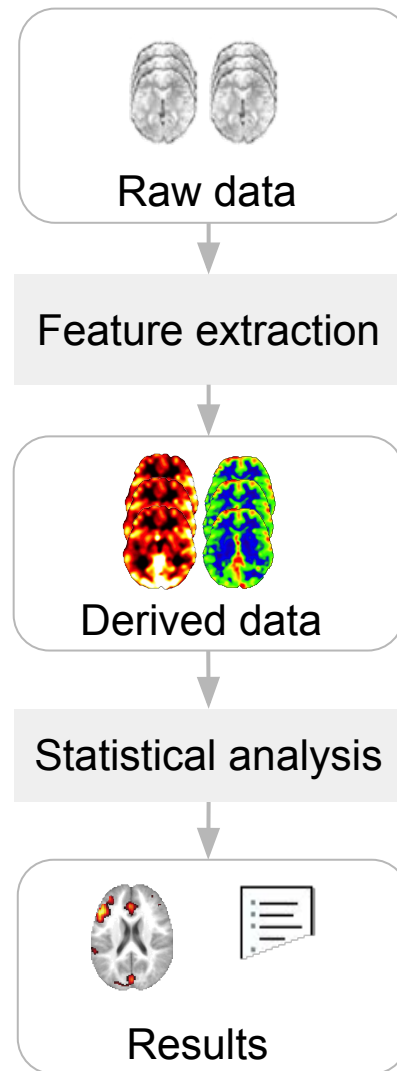
1000 subjects

## Cohort

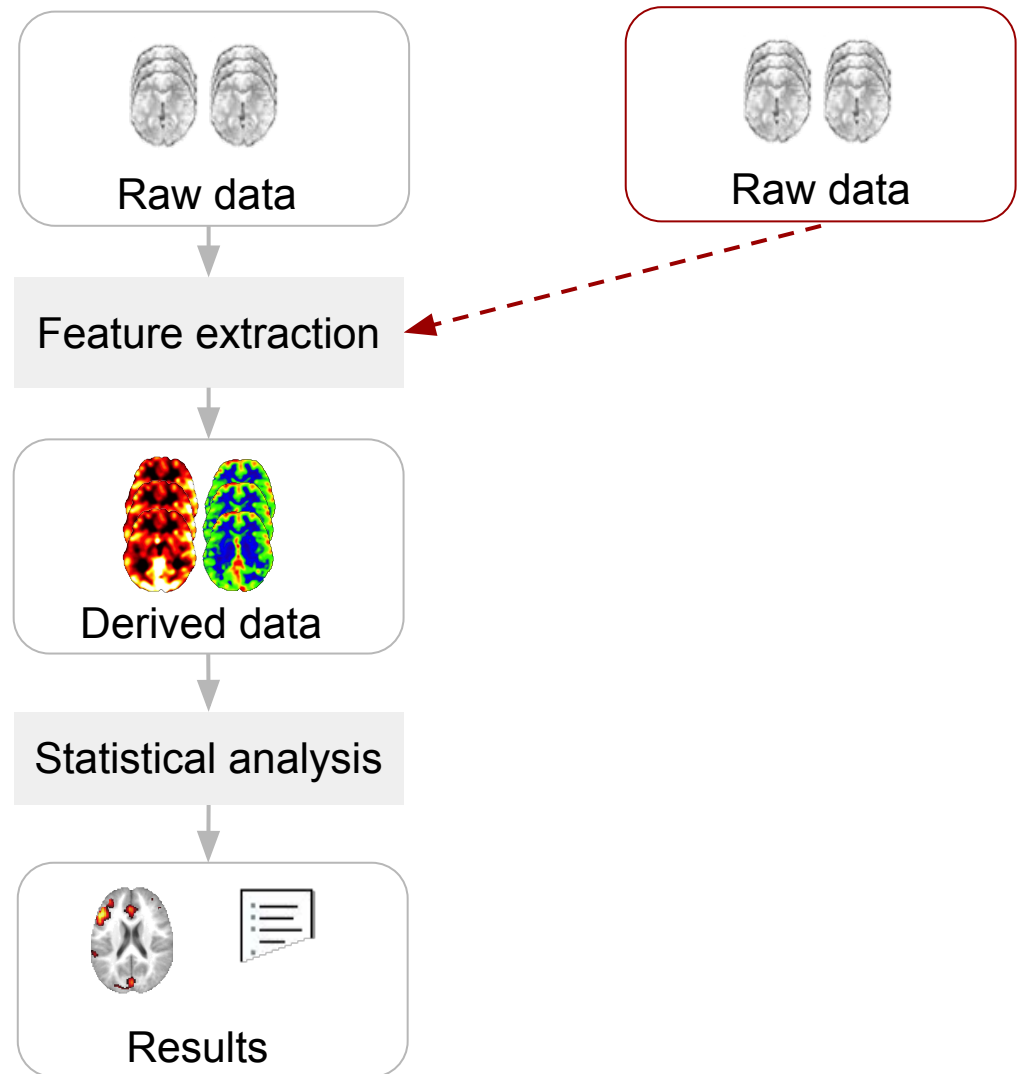
1 000 - 100 000 subjects



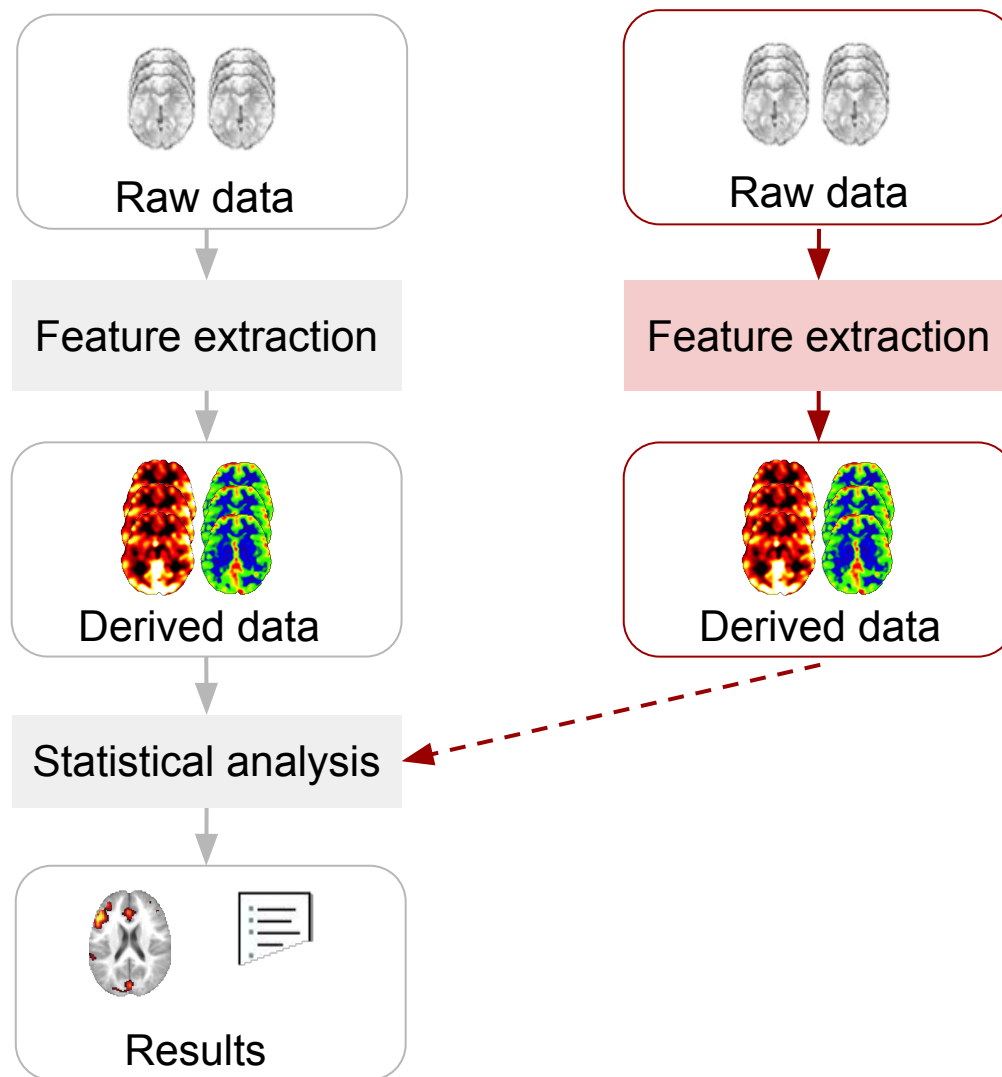
# New challenges when working with open data



# New challenges when working with open data

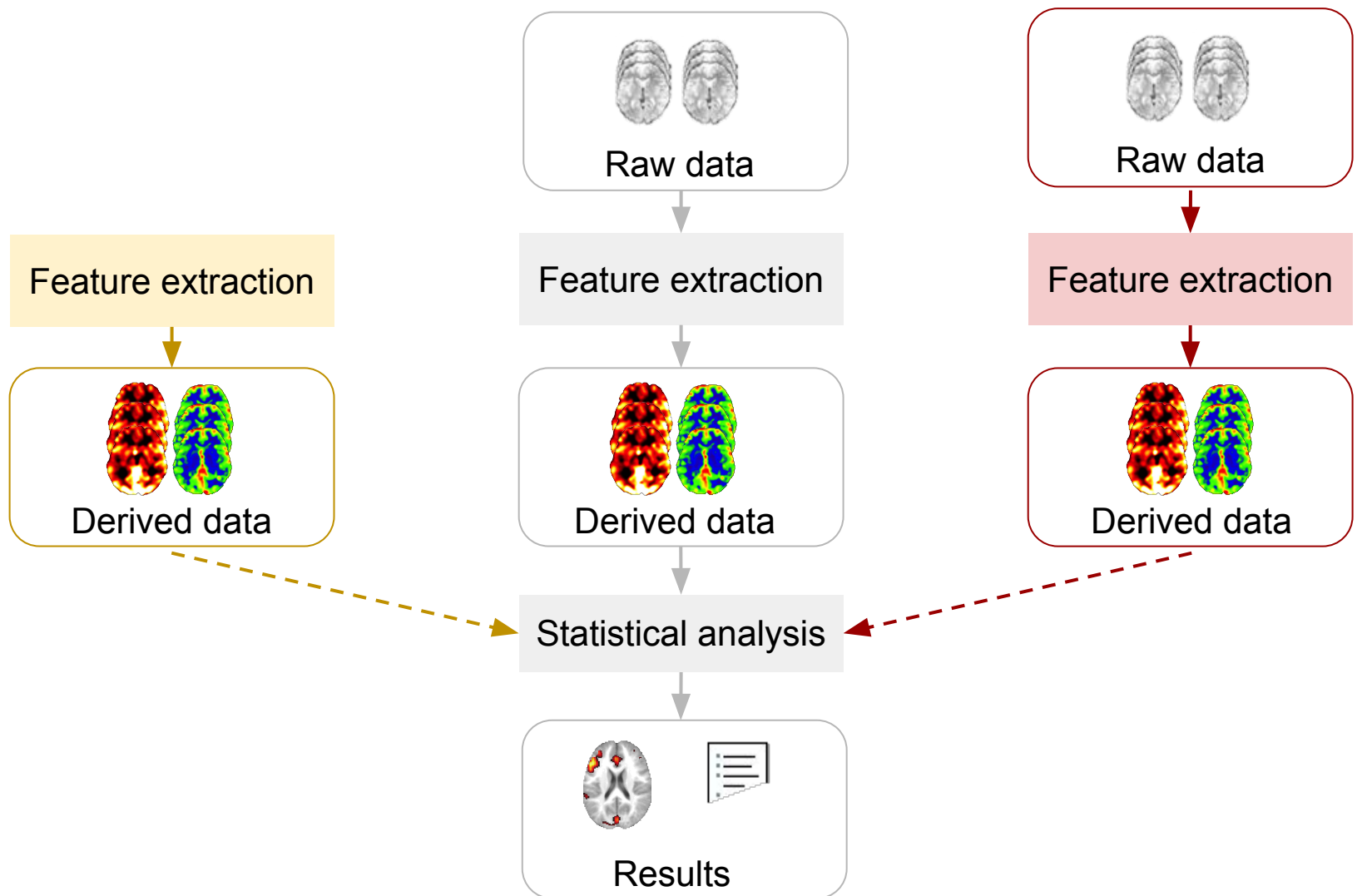


# New challenges when working with open data

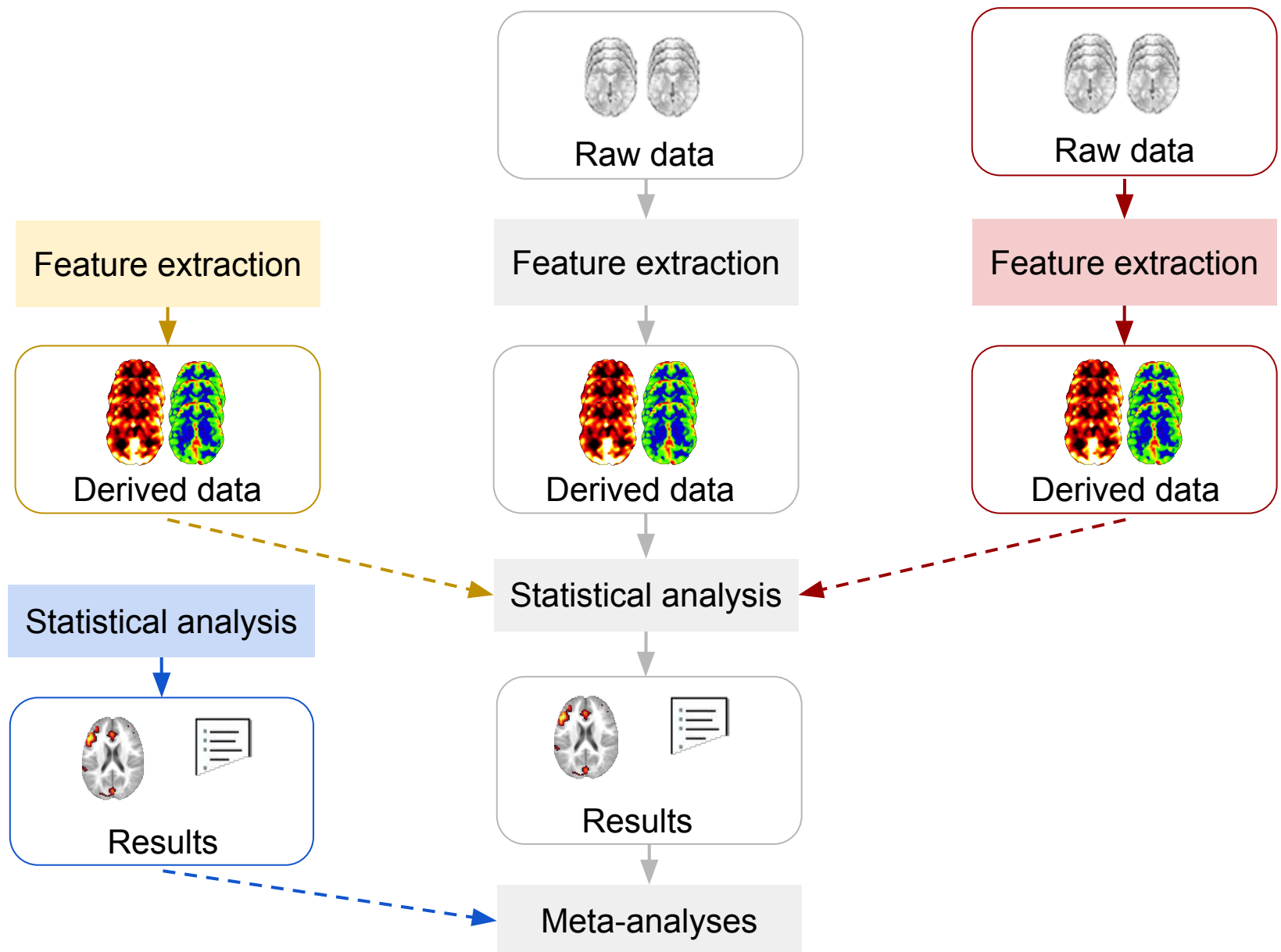




# New challenges when working with open data



# New challenges when working with open data

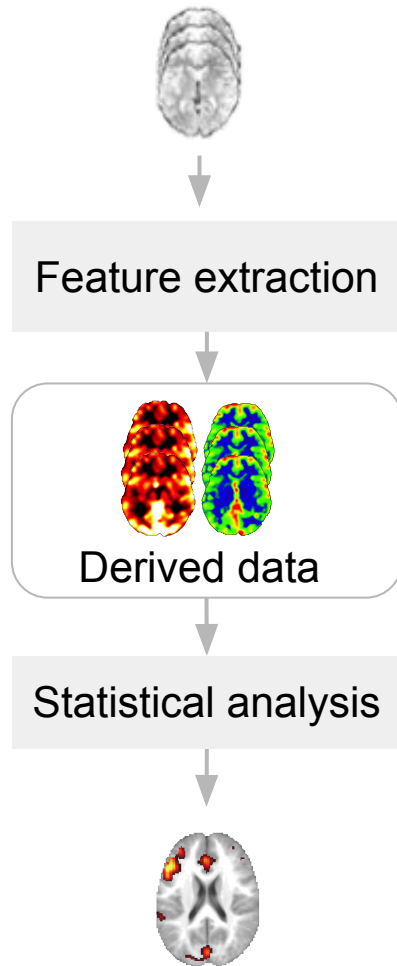


The background features six vertical columns of circles. The first column has 10 circles, the second has 4 (including a diamond at the top), the third has 4 (including a diamond at the top), the fourth has 10, the fifth has 10, and the sixth has 10. The circles vary in shades of gray and some have a cross-hatch pattern. A large blue circle is centered in the foreground.

2.

**Analytic  
variability?**

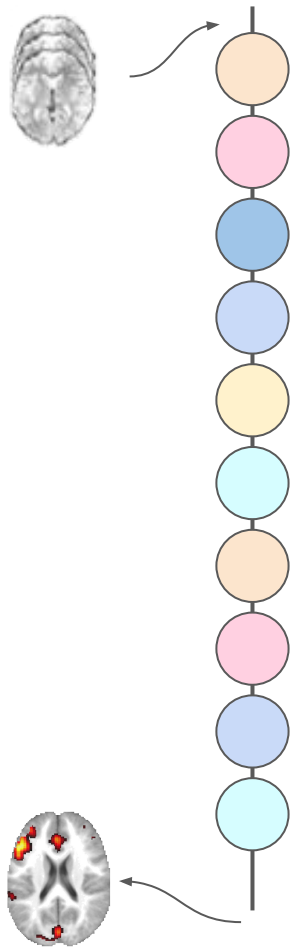
# Analytic variability



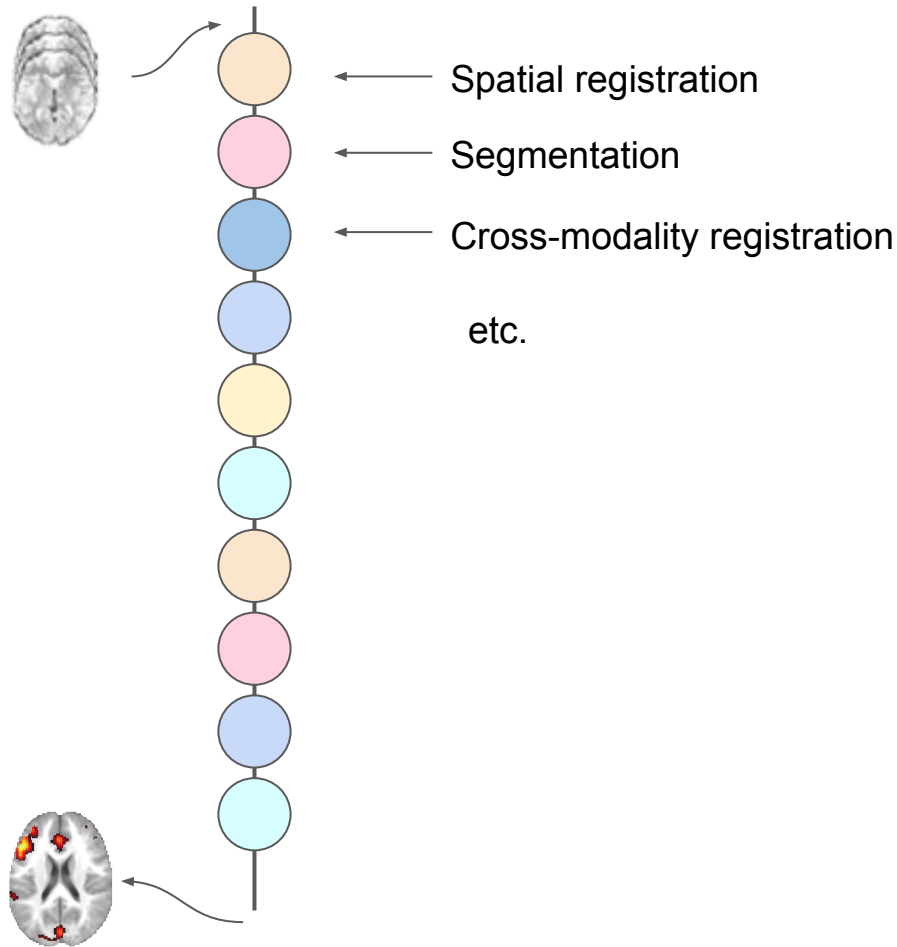
“Different **acceptable** analysis methods”

Carp et al. (2012)

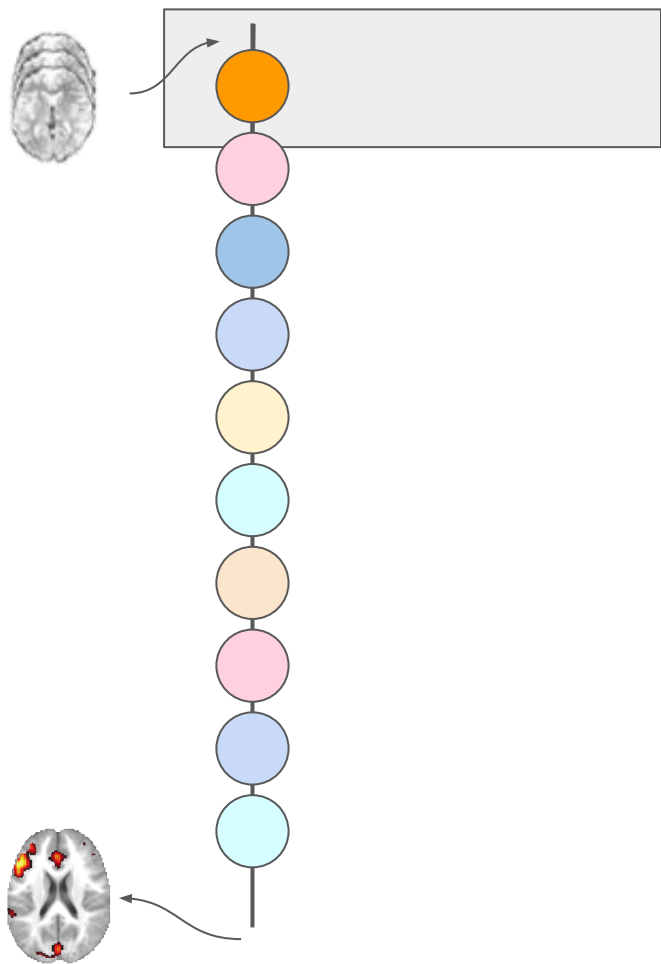
# Analytic variability



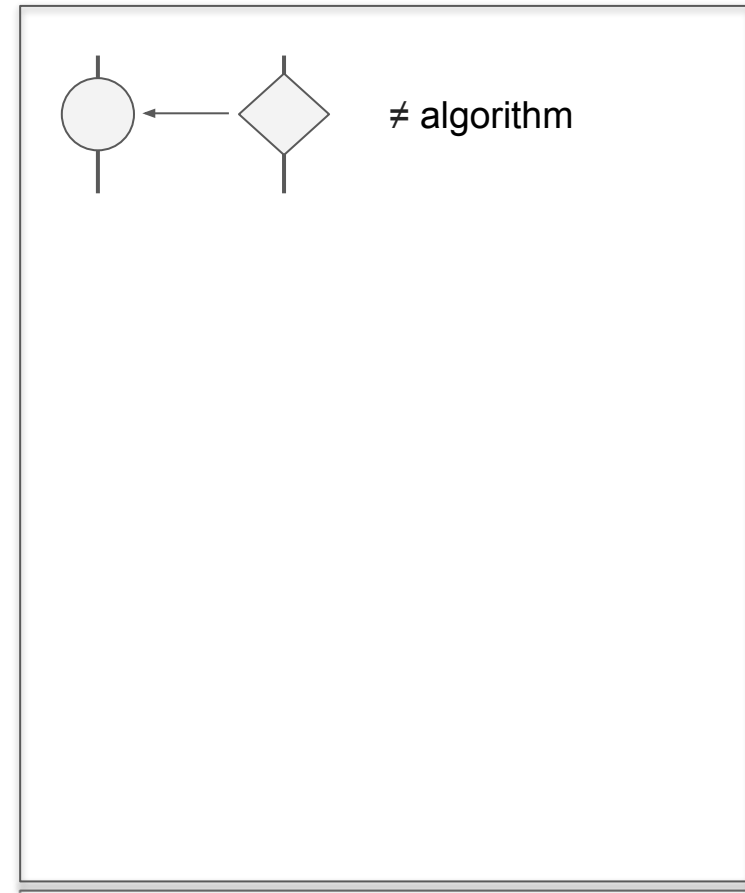
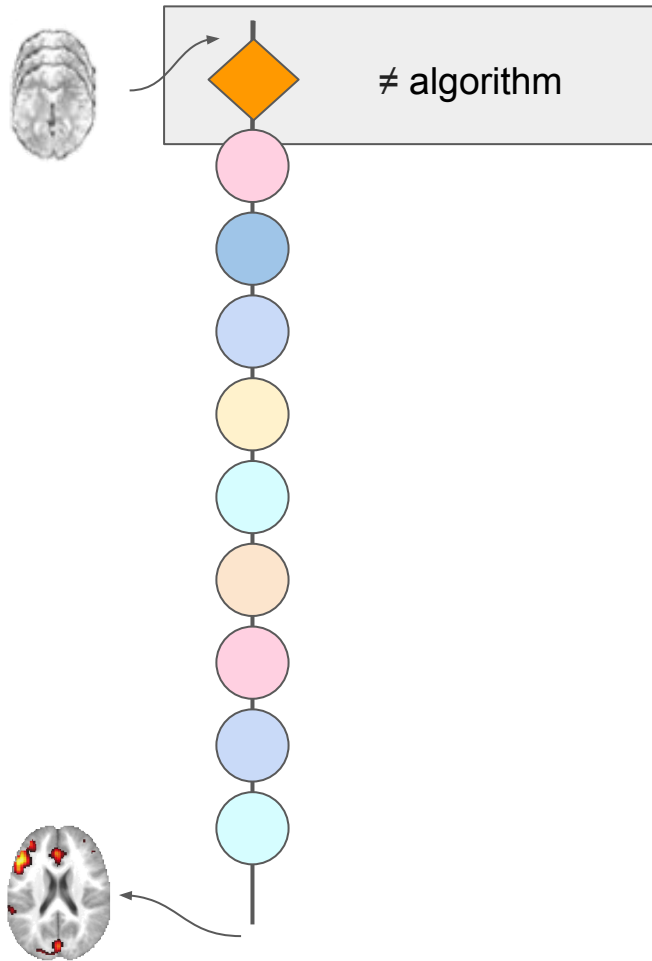
# Analytic variability



# Analytic variability

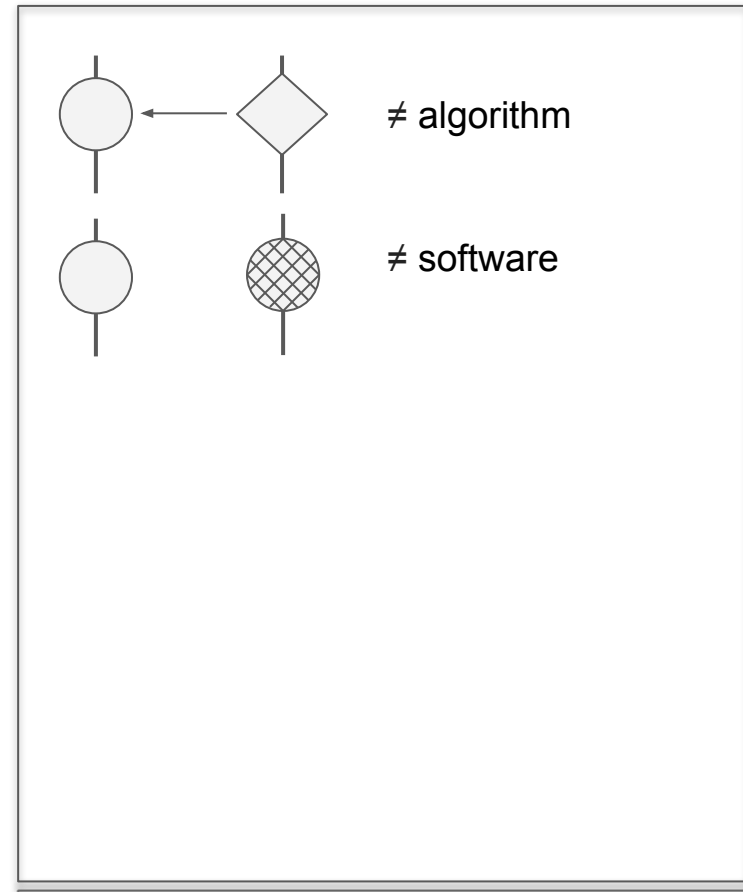
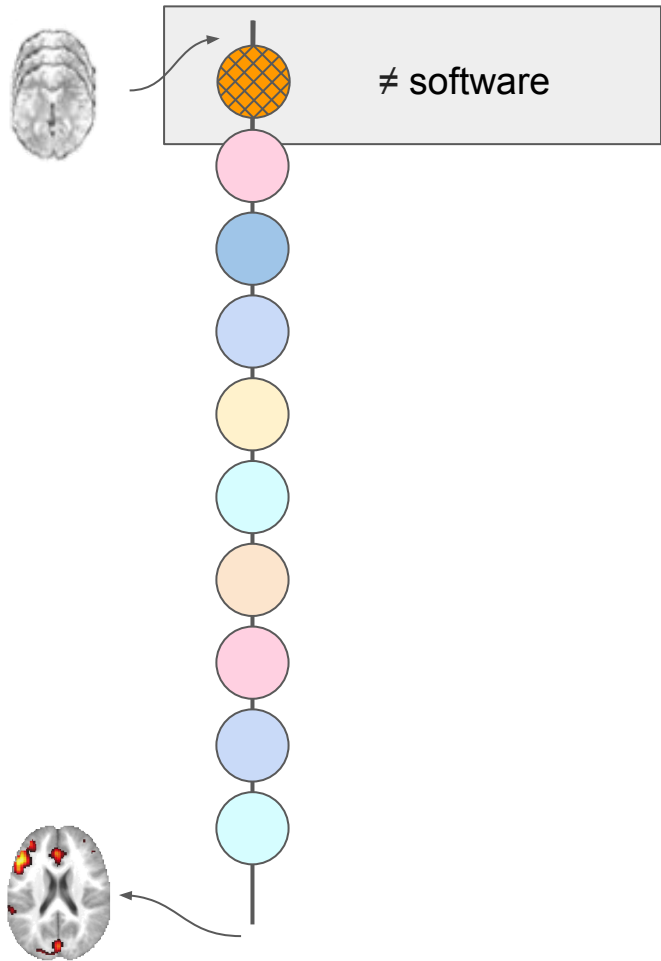


# Analytic variability

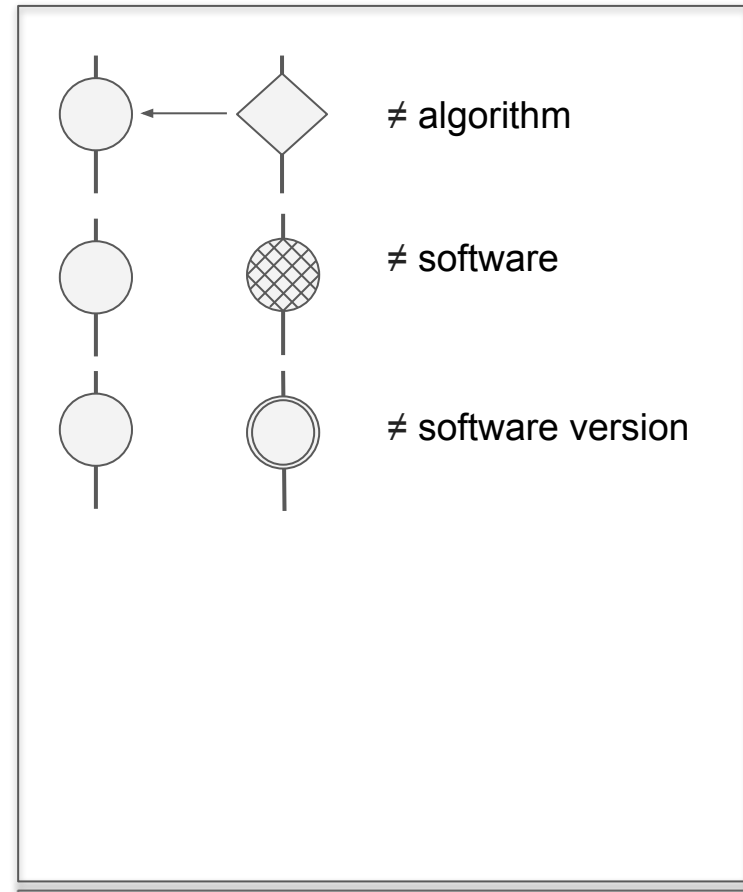
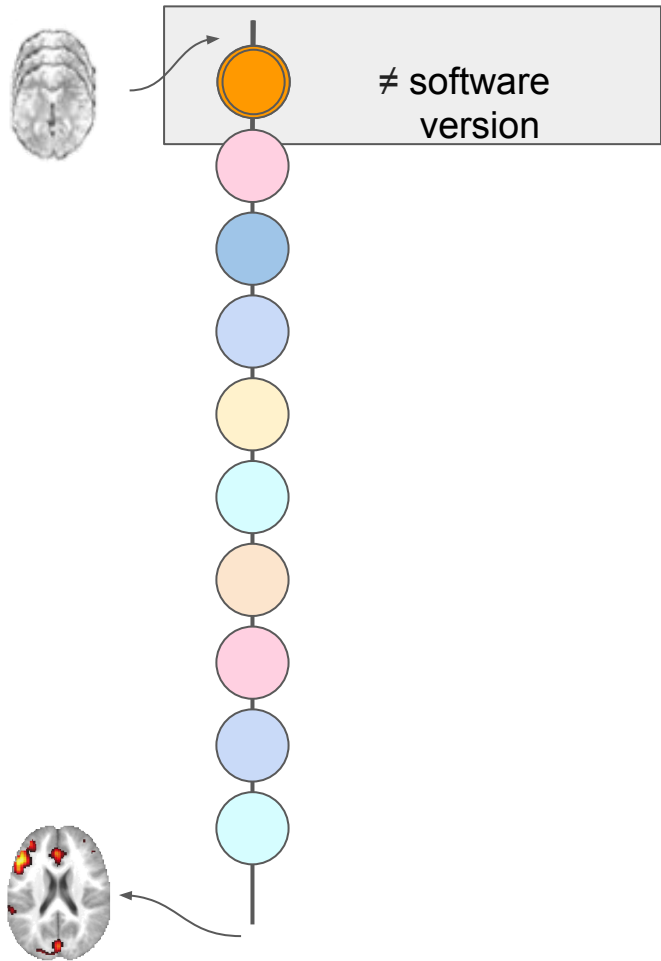




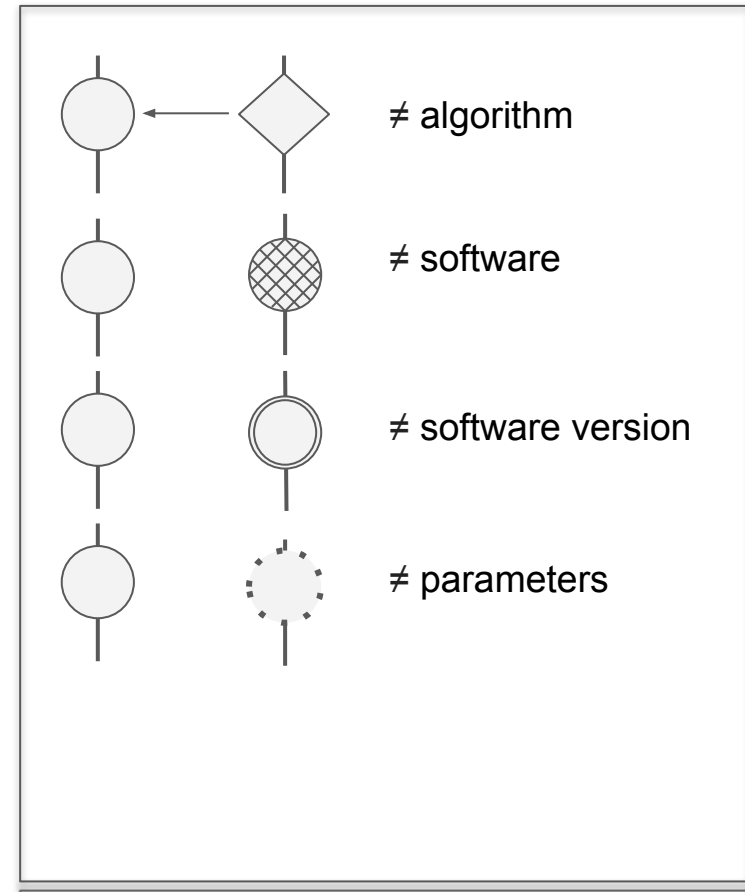
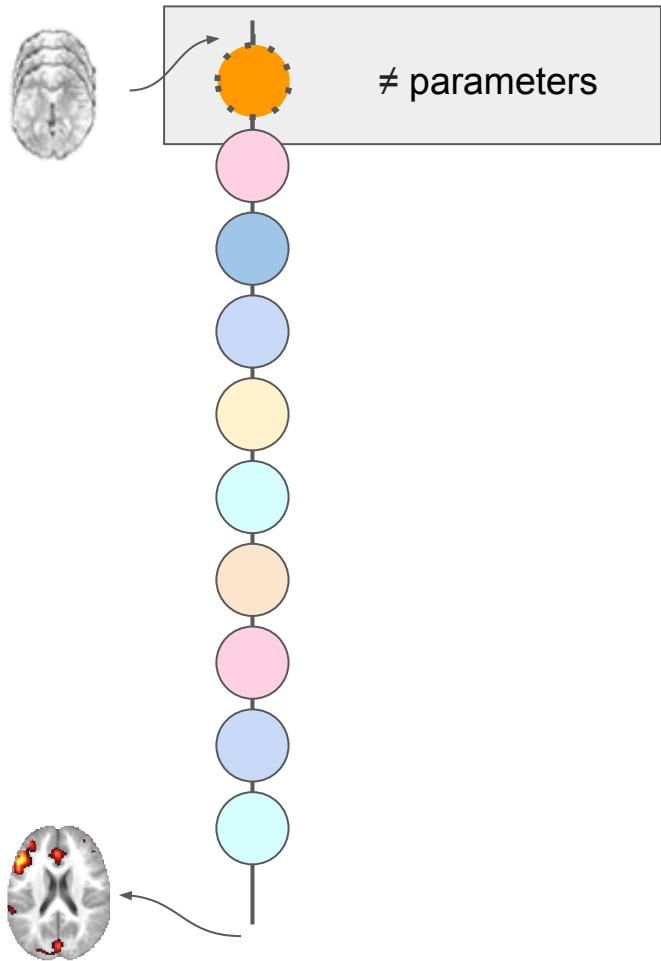
# Analytic variability



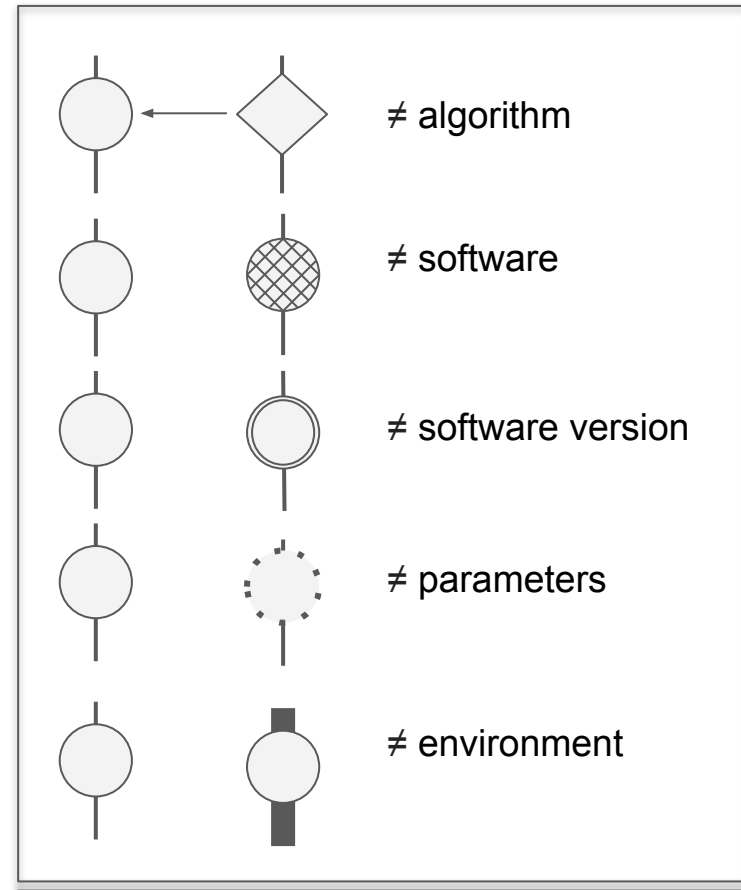
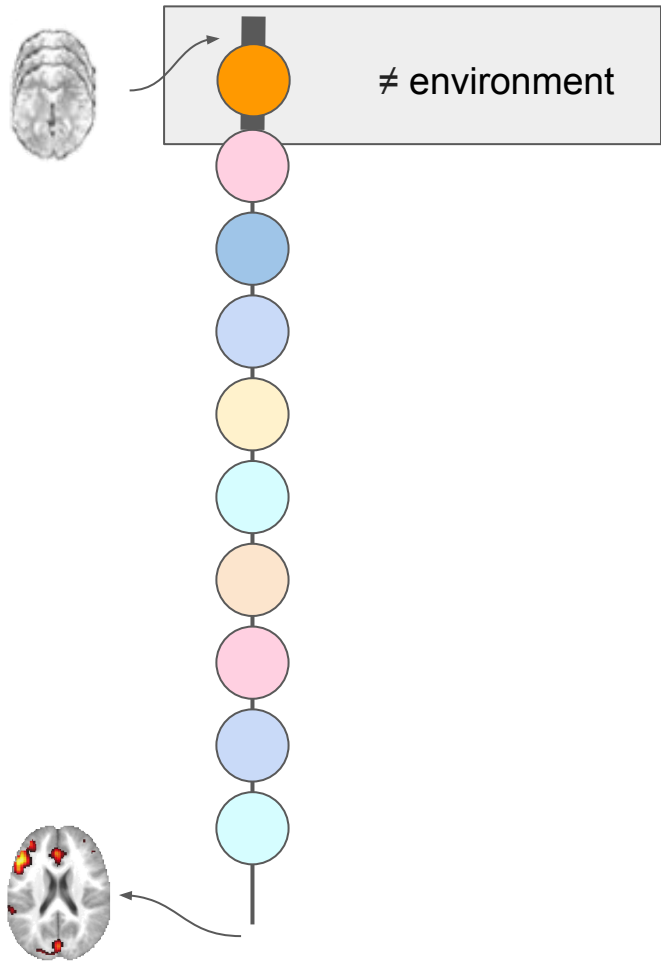
# Analytic variability



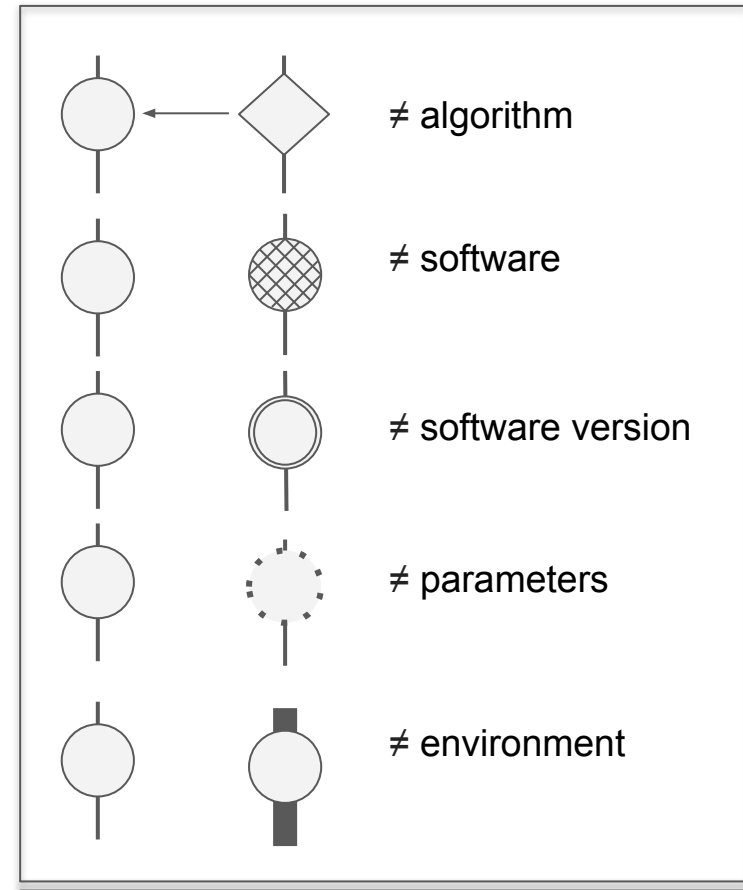
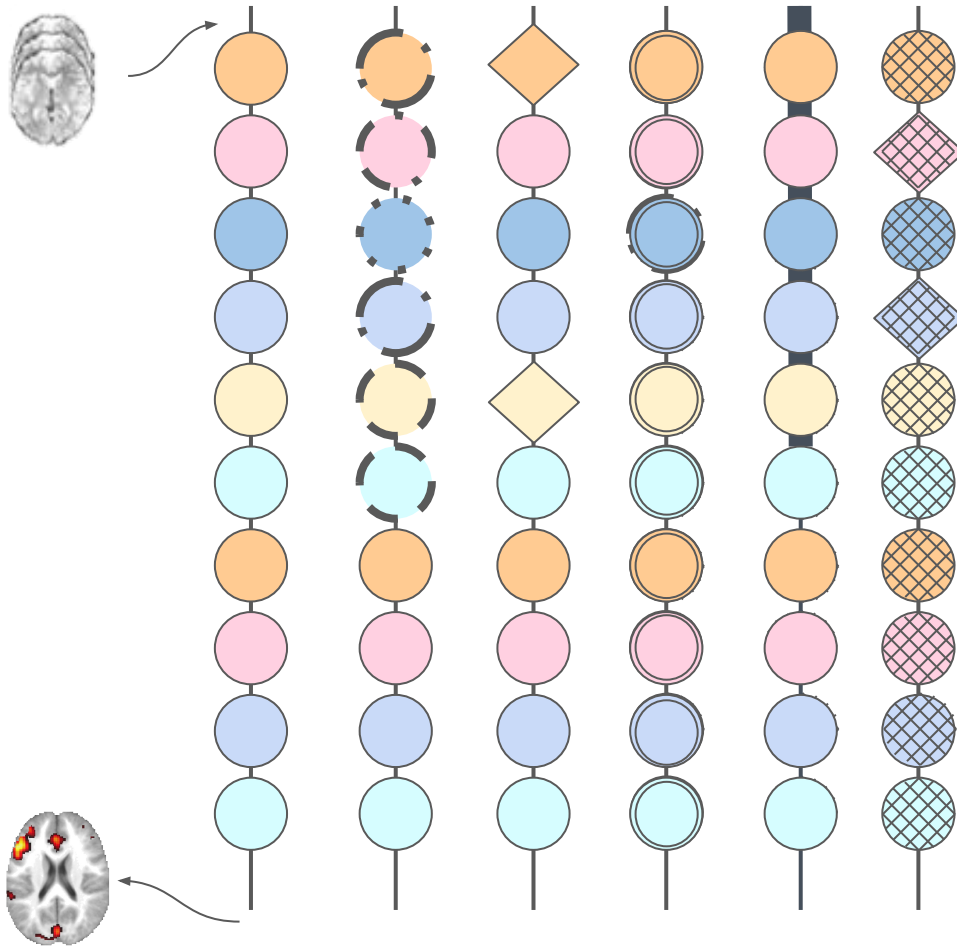
# Analytic variability



# Analytic variability



# Analytic variability





# Question?

**How does analytic variability impact  
neuroimaging results?**

## Background

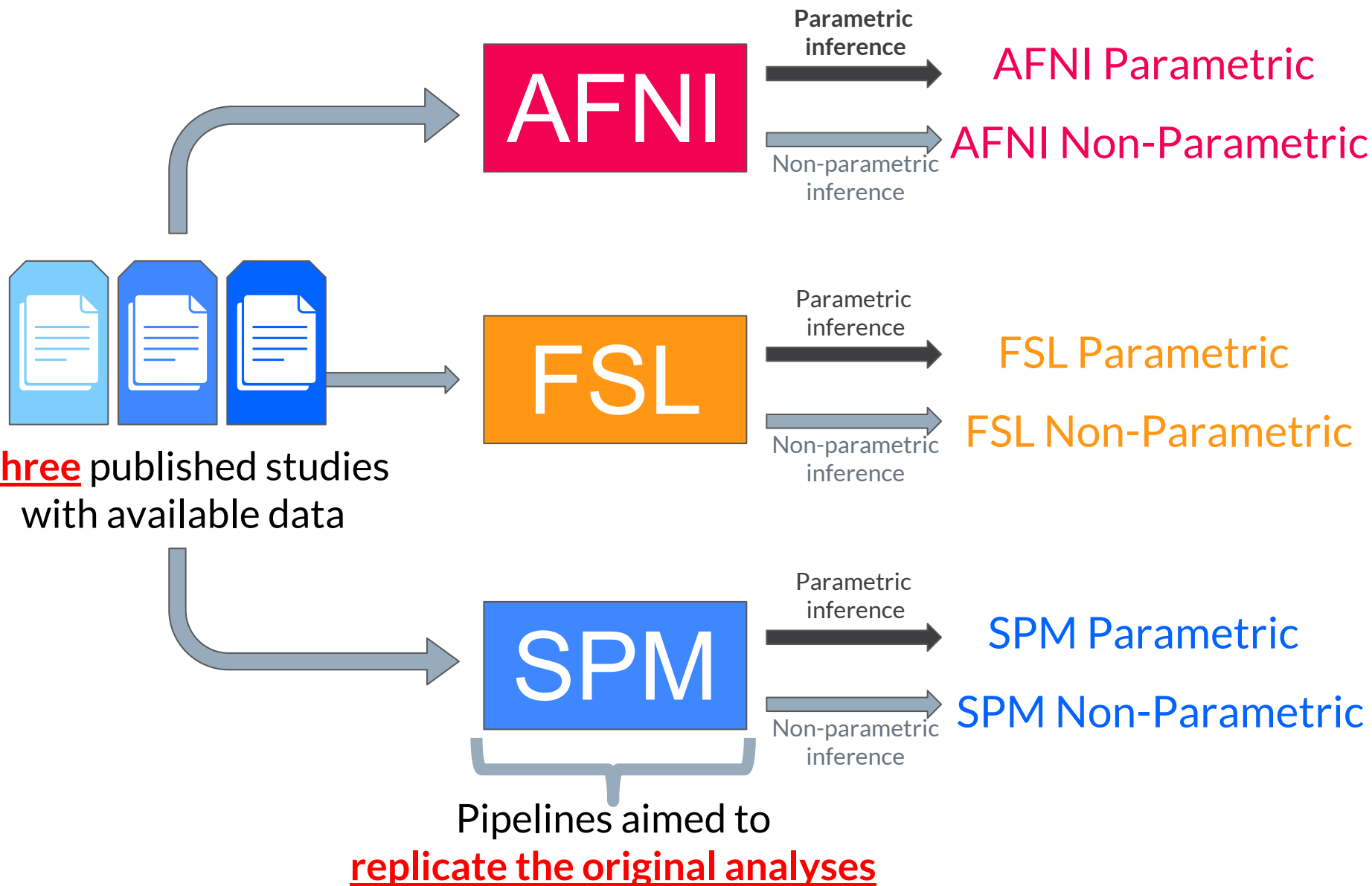
- ▷ **Choice of Analysis Pipeline (functional MRI)**  
*Carp (2012)*
- ▷ **Choice of Analysis Software Version**  
*Groenenschild et al (2012)*
- ▷ **Choice of operating system**  
*Glatard et al (2015)*
- ▷ **Choice of analysis software package**  
*Pauli et al (2016)*  
*Bowring et al (2018) (preprint)*

# Background

- ▷ **Choice of Analysis Pipeline (functional MRI)**  
*Carp (2012)*
- ▷ **Choice of Analysis Software Version**  
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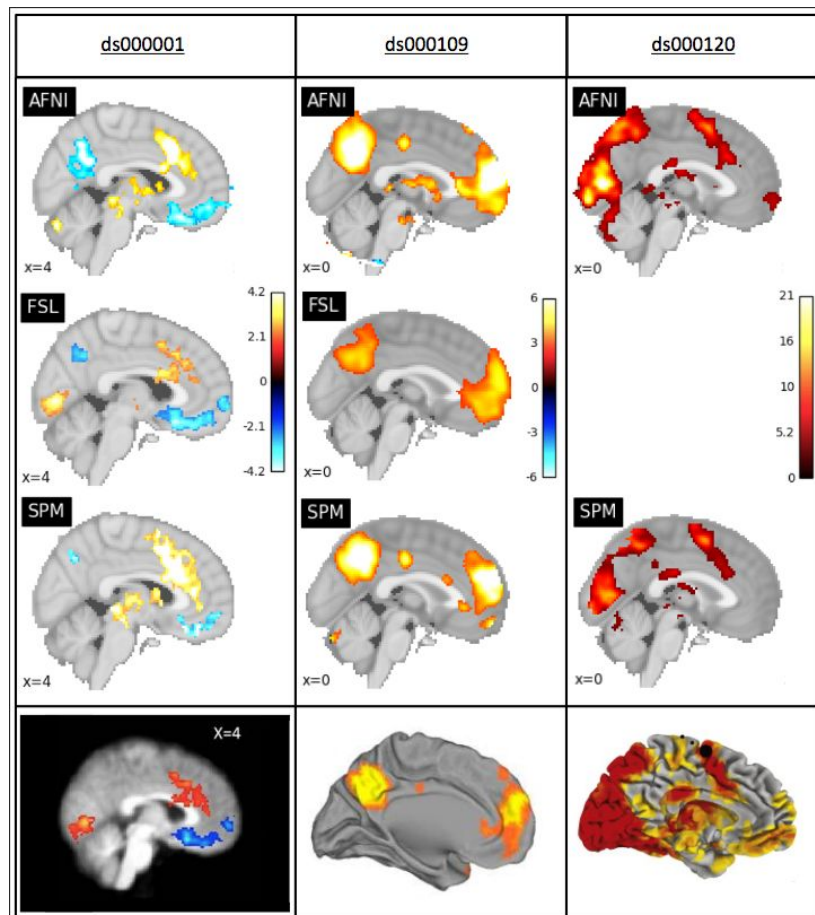
Joint work with Alexander Bowring and Thomas Nichols





# Impact of Analysis Software on Task fMRI Results

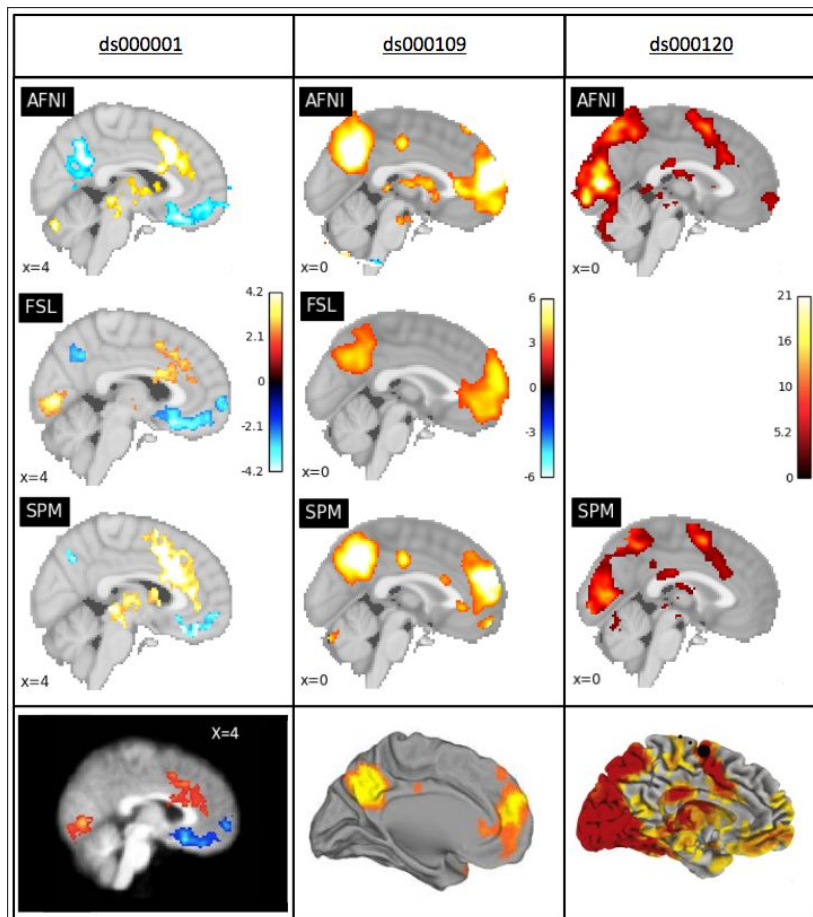
## Reproducing the main figure



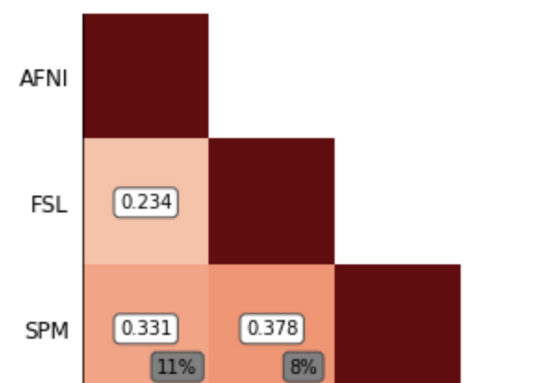
Bowring et al (2018) (preprint)

# Impact of Analysis Software on Task fMRI Results

## Reproducing the main figure

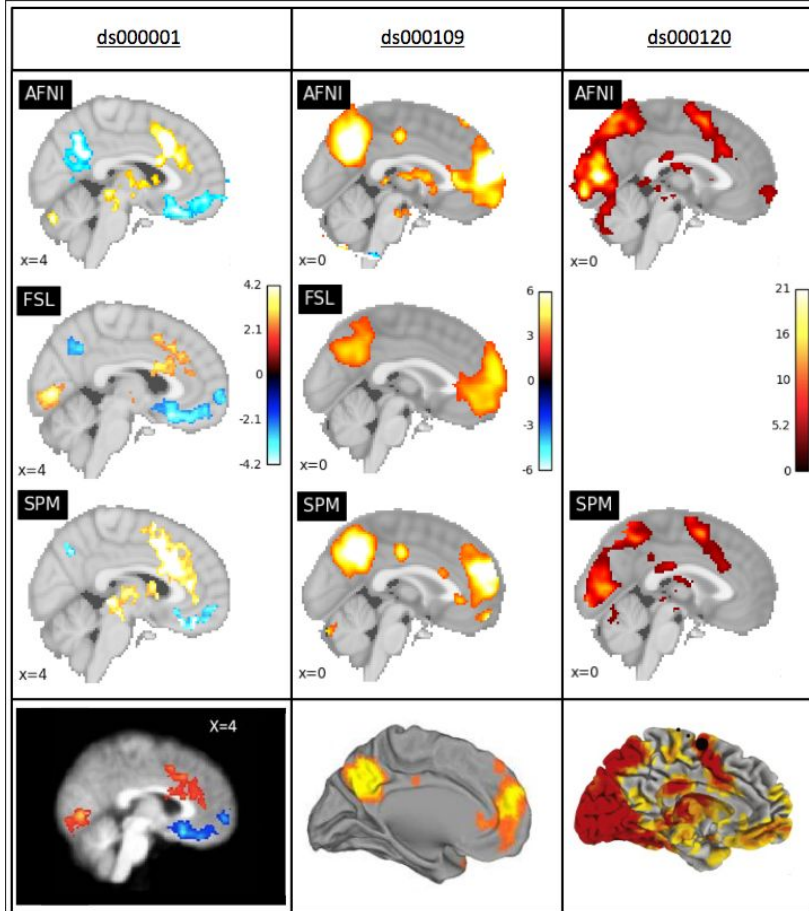


## Dice coefficients

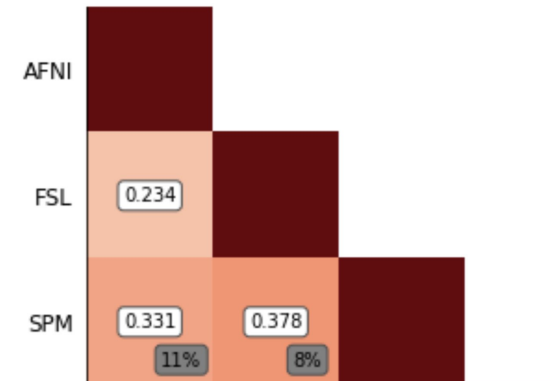


# Impact of Analysis Software on Task fMRI Results

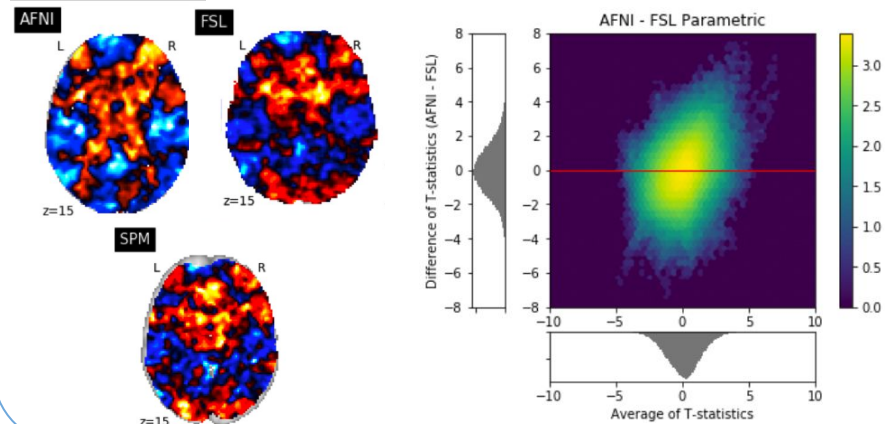
## Reproducing the main figure



## Dice coefficients



## Unthresholded statistics

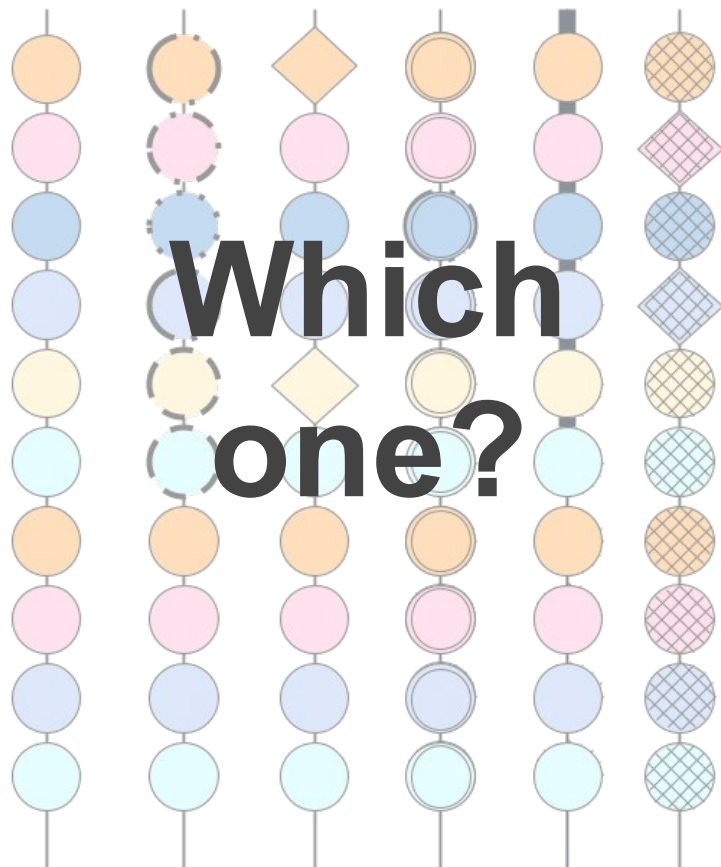




**3.**

**Transparency**

# Disclosing analytical details



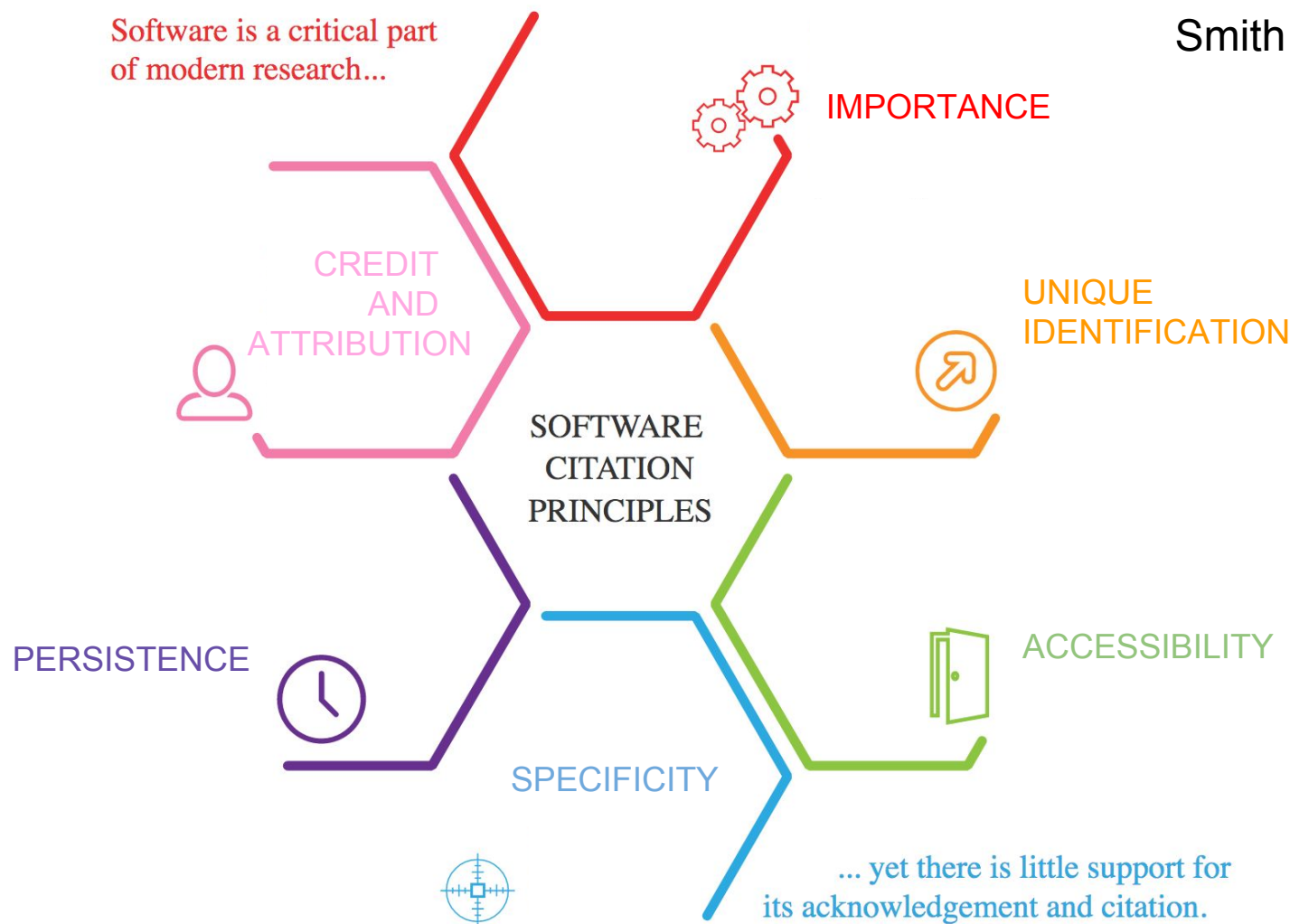
Details about the analysis pipeline are in the code.

In manuscripts, it is best practice to:

- Cite custom code
- Cite libraries and tools

# How to cite software? The software citation principles

Smith et al (2016)



# Citing custom code

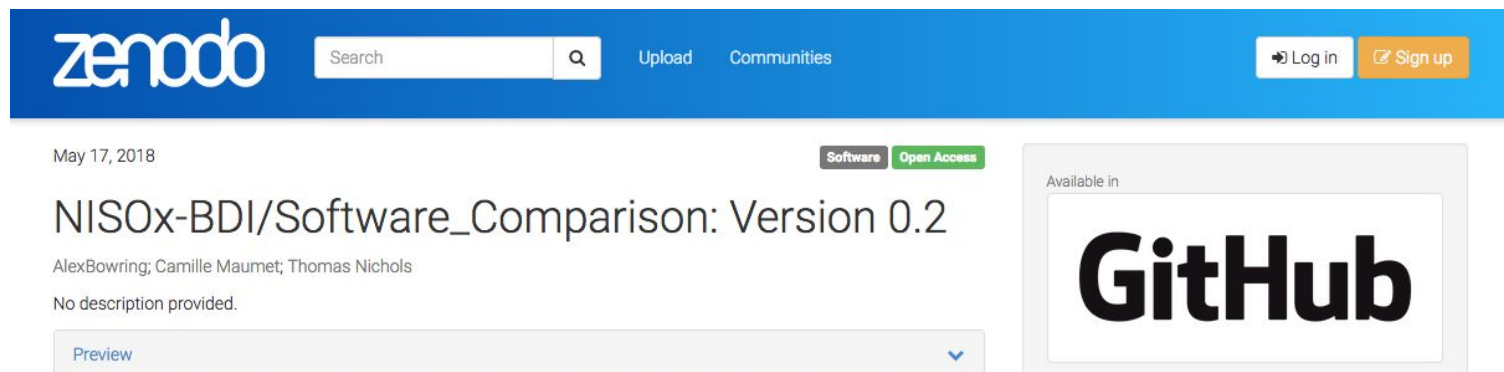
## 3. Results

Bowring et al (2018)

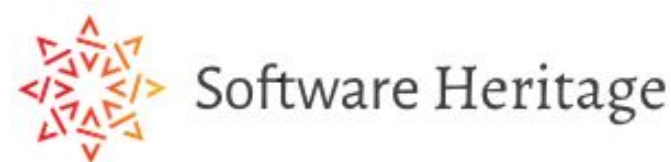
[...] All analysis scripts, results reports, and notebooks for each of study are available through Zenodo (Nielsen and Smith, 2014) at <https://zenodo.org/record/1203654> (Alexander Bowring et al., 2018).

Persistence

Accessibility



The screenshot shows the Zenodo website interface. At the top is a blue navigation bar with the Zenodo logo, a search bar, and links for 'Upload' and 'Communities'. On the right side of the bar are 'Log in' and 'Sign up' buttons. Below the navigation bar, the record details are displayed: the date 'May 17, 2018', the title 'NISOx-BDI/Software\_Comparison: Version 0.2', and the authors 'AlexBowring; Camille Maumet; Thomas Nichols'. There are 'Software' and 'Open Access' tags. A note states 'No description provided.' Below this is a 'Preview' button with a dropdown arrow. To the right, a box indicates the record is 'Available in' GitHub, with the GitHub logo prominently displayed.





# Let others cite your code

The screenshot shows the Zenodo interface for a software repository. The main title is "NISOx-BDI/Software\_Comparison: Version 0.2" by AlexBowring, Camille Maumet, and Thomas Nichols. The page includes a file tree, a file table, and a versions list. Annotations highlight key features: "Attribution" points to the author names, "Unique identifier" points to the DOI, and "Specificity" points to the version list.

**zenodo** Search [ ] Upload Communities Log in Sign up

May 17, 2018 **Software** **Open Access**

## NISOx-BDI/Software\_Comparison: Version 0.2

AlexBowring; Camille Maumet; Thomas Nichols

No description provided.

**Attribution**

Preview

Software\_Comparison-0.2.0.zip

- Software\_Comparison-0.2.0
  - .gitignore 482 Bytes
  - README.md 7.4 kB
  - ds001
    - AFNI
      - LEVEL2
        - euler\_chars.csv 941 Bytes
        - permutation\_test
          - euler\_chars.csv 933 Bytes
      - SCRIPTS
        - level2.sh 7.7 kB
        - permutation\_test.sh 4.8 kB
        - sub-01\_level1.sh 4.3 kB
        - sub-02\_level1.sh 4.3 kB
        - sub-03\_level1.sh 4.3 kB
        - sub-04\_level1.sh 4.3 kB
        - sub-05\_level1.sh 4.3 kB
        - sub-06\_level1.sh 4.3 kB



### Publication date:

May 17, 2018

### DOI:

DOI 10.5281/zenodo.1248809

**Unique identifier**

### Related identifiers:

Supplement to:  
[https://github.com/NISOx-BDI/Software\\_Comparison/tree/v0.1](https://github.com/NISOx-BDI/Software_Comparison/tree/v0.1)

### License (for files):

[Other \(Open\)](#)

**Specificity**

### Versions

Version 0.2 10.5281/zenodo.1248809 May 17, 2018

Version v0.1 10.5281/zenodo.1203655 Mar 19, 2018

**Cite all versions?** You can cite all versions by using the DOI 10.5281/zenodo.1203654. This DOI represents all versions, and will always resolve to the latest one. [Read more.](#)

### Share



# Citing libraries and tools

## **2.2 Data Analyses**

Bowring et al (2018)

All data analyses were conducted using AFNI 17.0.18 (RRID:SCR\_005927, (Cox, 1996)), FSL 5.0.10 (RRID:SCR\_002823, (Jenkinson et al., 2012)), and SPM12 v6906 (RRID:SCR\_007037, (Penny et al., 2011)).

# Citing libraries and tools

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Specificity



# Citing libraries and tools

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Specificity

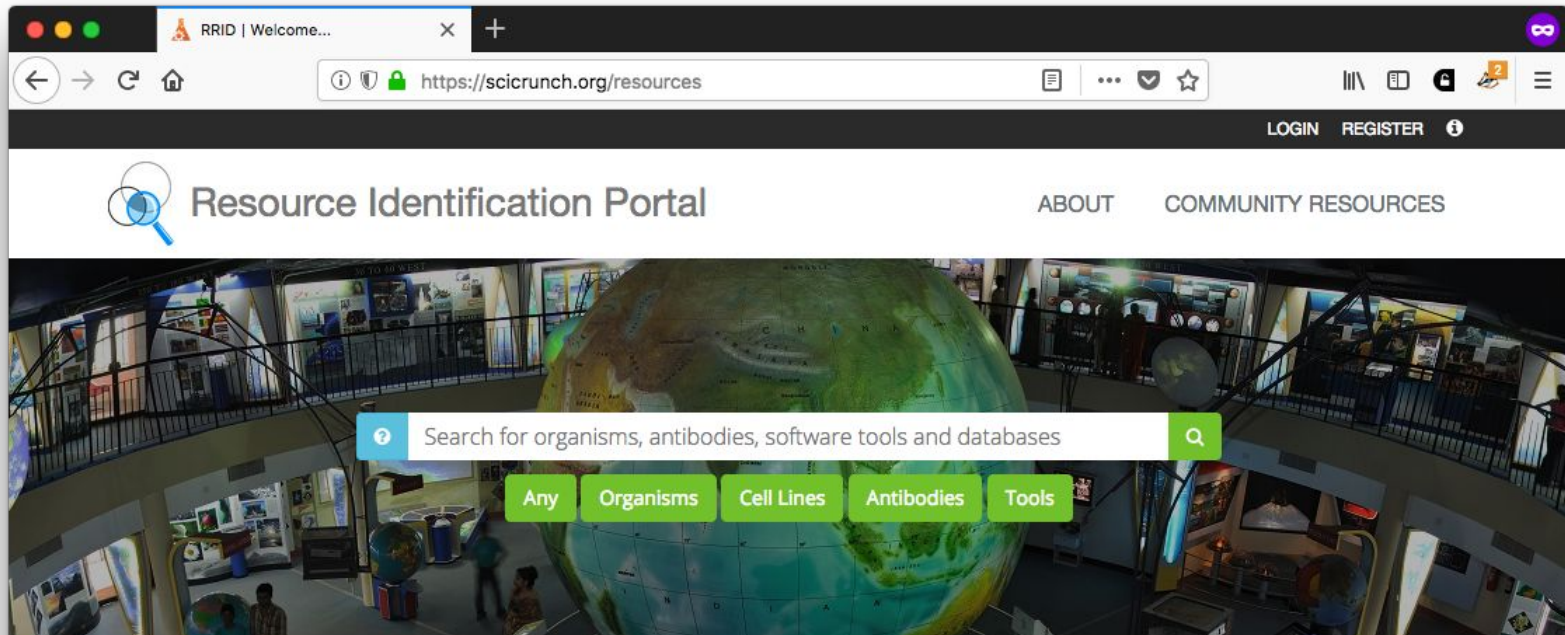
Unique identifier

# Citing libraries and tools

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Bowring et al (2018)

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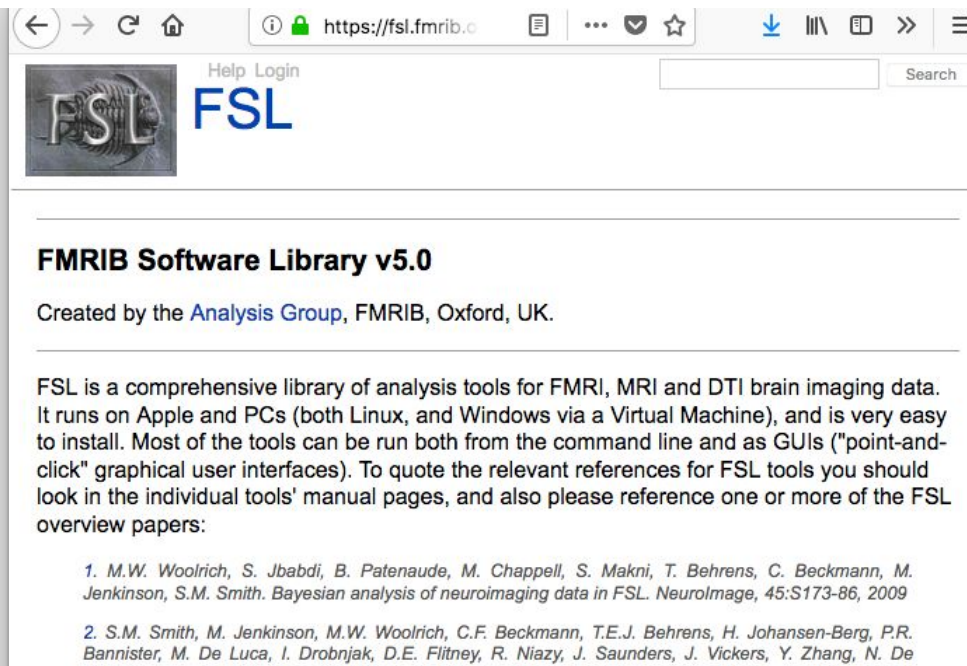


# Citing libraries and tools

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The screenshot shows the FSL website homepage. The browser address bar displays "https://fsl.fmrib.ox.ac.uk/fsl/fslwiki". The page features the FSL logo, a search bar, and the title "FMRIB Software Library v5.0". Below the title, it states "Created by the Analysis Group, FMRIB, Oxford, UK." The main content describes FSL as a comprehensive library of analysis tools for FMRI, MRI, and DTI brain imaging data, and lists two references.

Help Login

**FSL**

**FMRIB Software Library v5.0**

Created by the [Analysis Group](#), FMRIB, Oxford, UK.

FSL is a comprehensive library of analysis tools for FMRI, MRI and DTI brain imaging data. It runs on Apple and PCs (both Linux, and Windows via a Virtual Machine), and is very easy to install. Most of the tools can be run both from the command line and as GUIs ("point-and-click" graphical user interfaces). To quote the relevant references for FSL tools you should look in the individual tools' manual pages, and also please reference one or more of the FSL overview papers:

1. M.W. Woolrich, S. Jbabdi, B. Patenaude, M. Chappell, S. Makni, T. Behrens, C. Beckmann, M. Jenkinson, S.M. Smith. Bayesian analysis of neuroimaging data in FSL. *NeuroImage*, 45:S173-86, 2009
2. S.M. Smith, M. Jenkinson, M.W. Woolrich, C.F. Beckmann, T.E.J. Behrens, H. Johansen-Berg, P.R. Bannister, M. De Luca, I. Drobnjak, D.E. Flitney, R. Niazy, J. Saunders, J. Vickers, Y. Zhang, N. De

<https://fsl.fmrib.ox.ac.uk/fsl/fslwiki>

# Citing libraries and tools

## 2.2 Data Analyses

Bowring et al (2018)

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Also applies to other (non-neuroimaging) tools, repositories and libraries...

## 2.5 Scripting of analyses and figures

Bowring et al (2018)

A Python **Jupyter Notebook** (Kluyver et al., 2016) was created for each of the three studies. Each notebook harvests our results data from **Neurovault** (RRID:SCR\_003806) and applies the variety of methods discussed in the previous section using **NiBabel 2.2.0** (Brett et al., 2017), **NumPy 1.13.3** (Walt et al., 2011) and **Pandas 0.20.3** (McKinney and Others, 2010) packages. Figures were created using **Matplotlib 2.1.0** (Hunter, 2007) and **Nilearn 0.4.0** (Abraham et al., 2014).



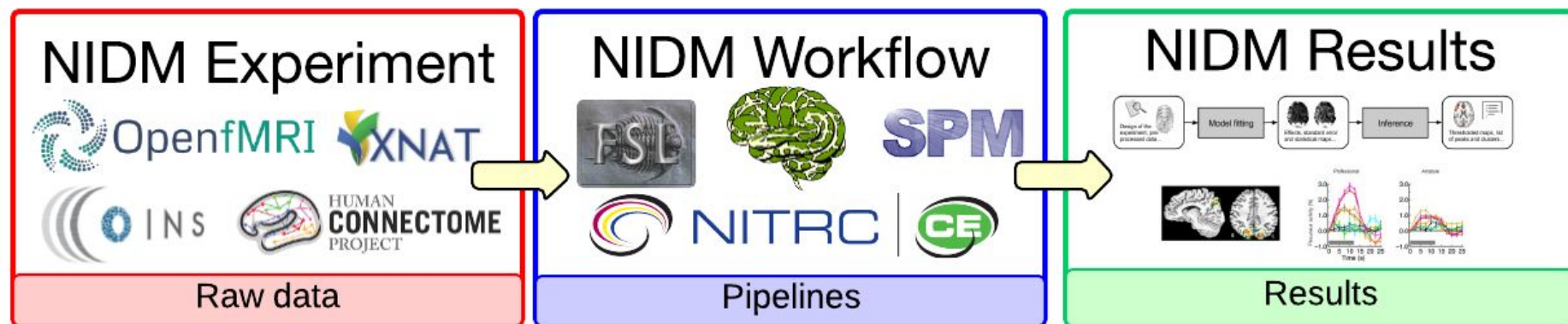
# Provenance

**“Provenance is information about entities, activities, and people involved in producing a piece of data or thing” — W3C PROV**



# Machine-readable provenance

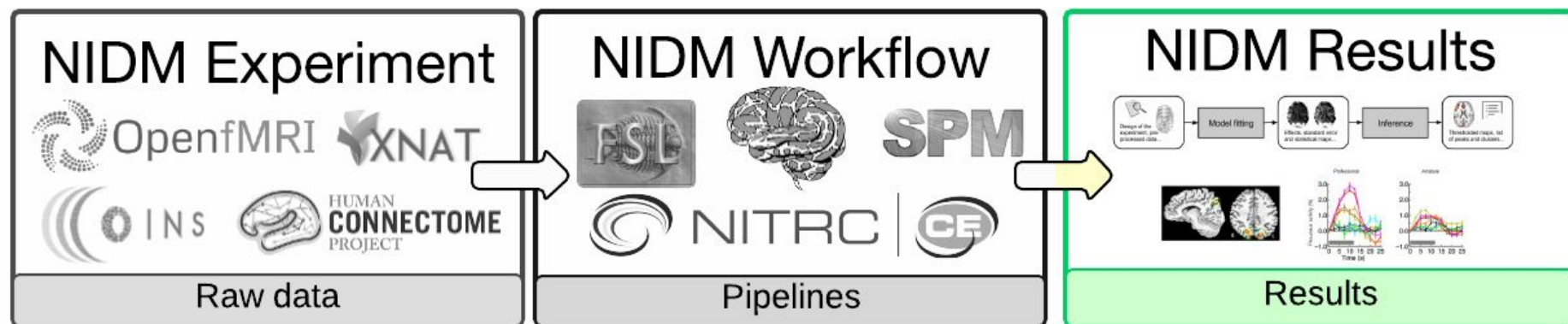
# Machine-readable provenance



## NIDM: neuroimaging data model

International collaboration with INCF SIG on Reproducibility and Best Practices in Human Brain Imaging

# Machine-readable provenance



## NIDM: neuroimaging data model

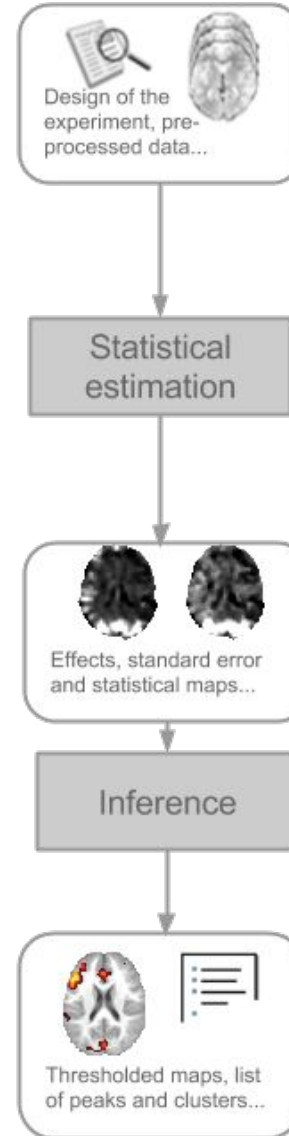
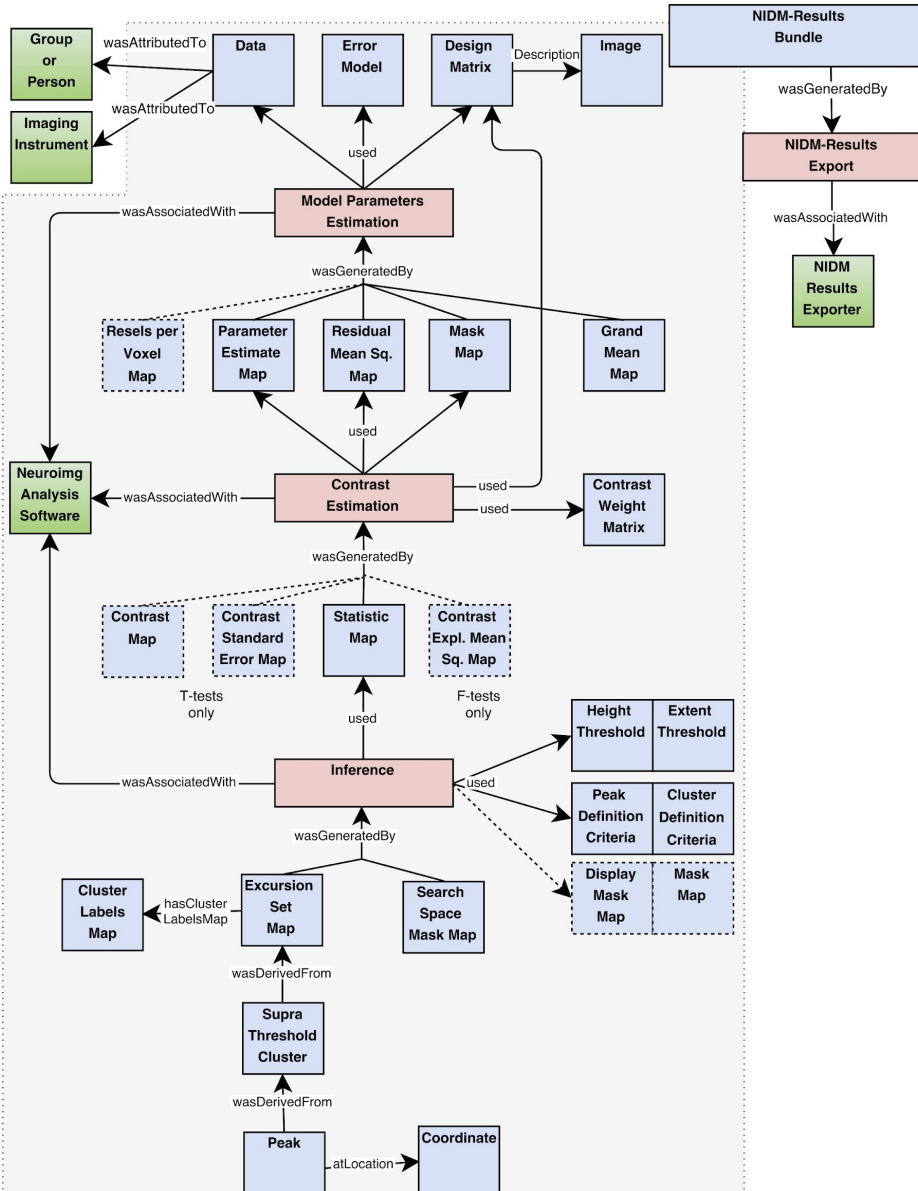
International collaboration with INCF SIG on Reproducibility and Best Practices in Human Brain Imaging.

## NIDM-Results → fMRI, VBM results

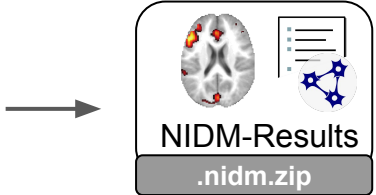
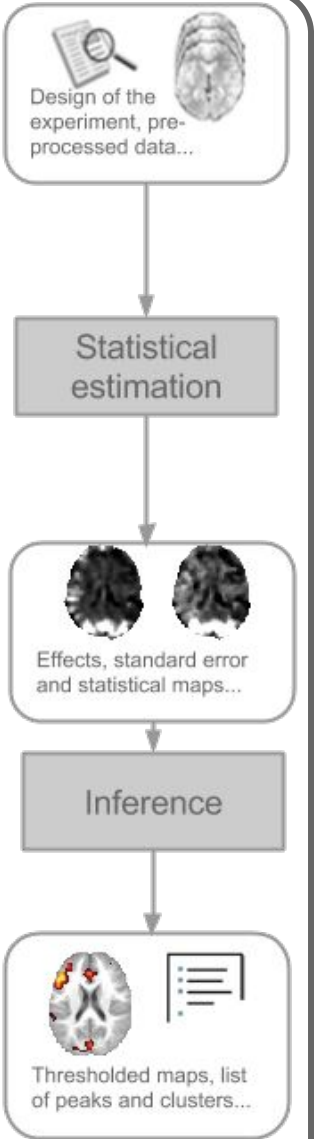
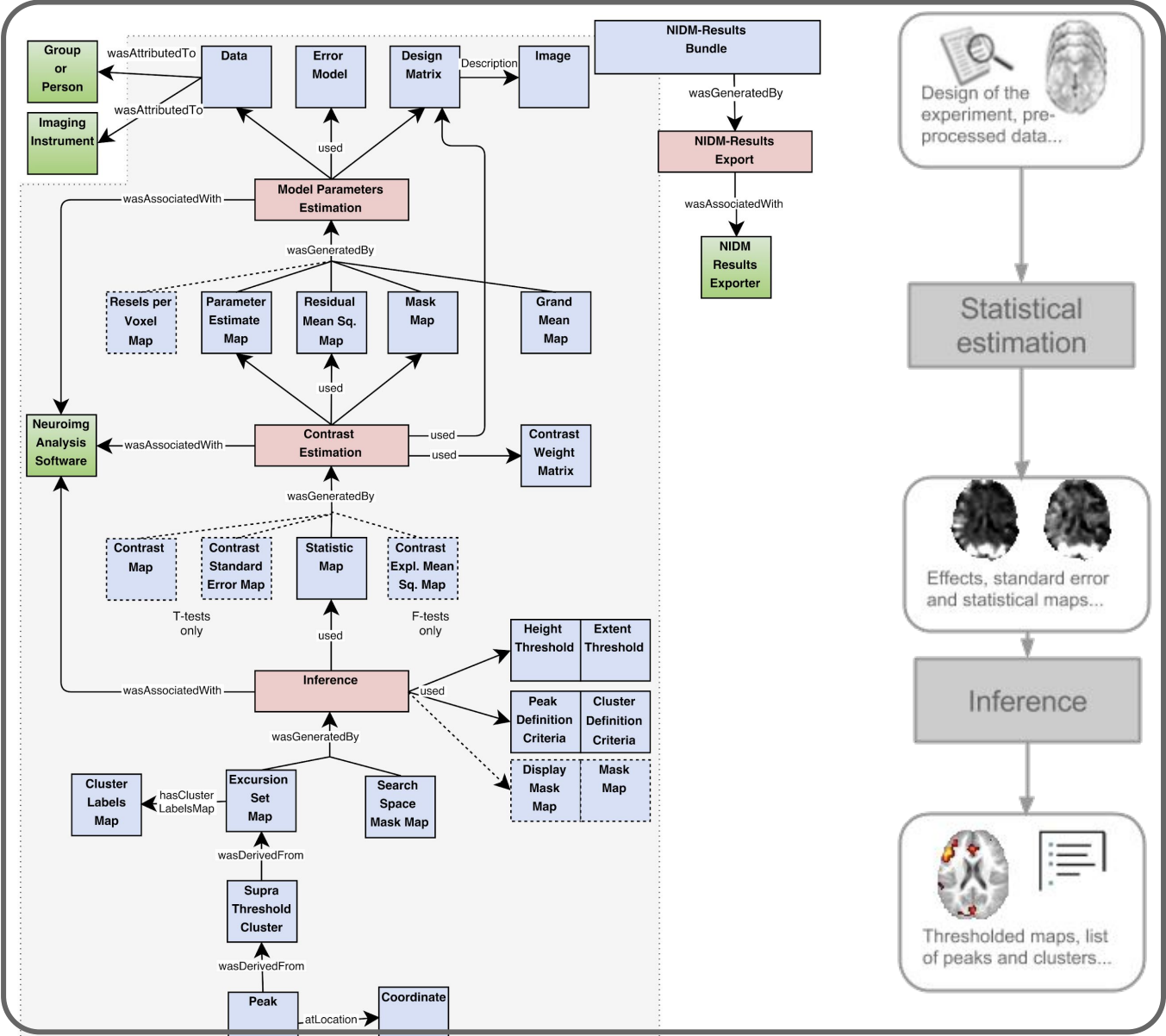
Harmonised model and provenance.

Joint work with INCF NIDASH working group - <https://github.com/incf-nidash/>

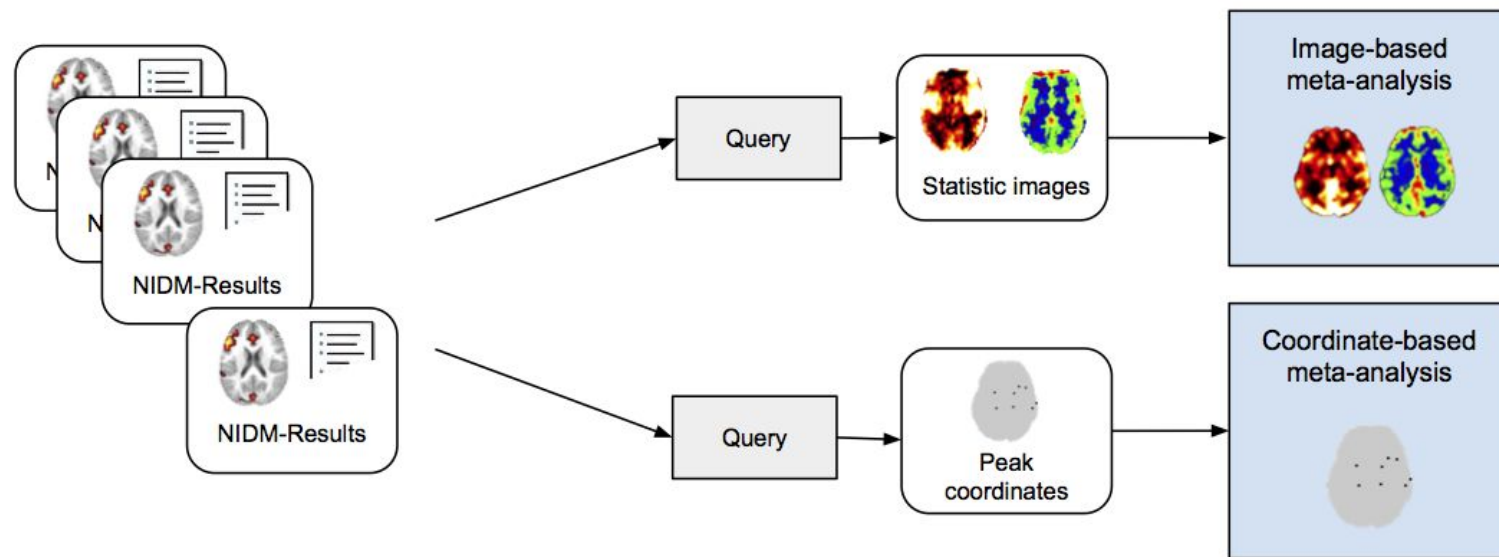
# NIDM-Results in brief



# NIDM-Results in brief



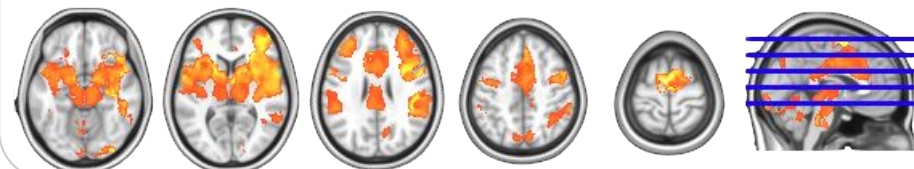
# Derived data reuse with NIDM-Results: meta-analysis



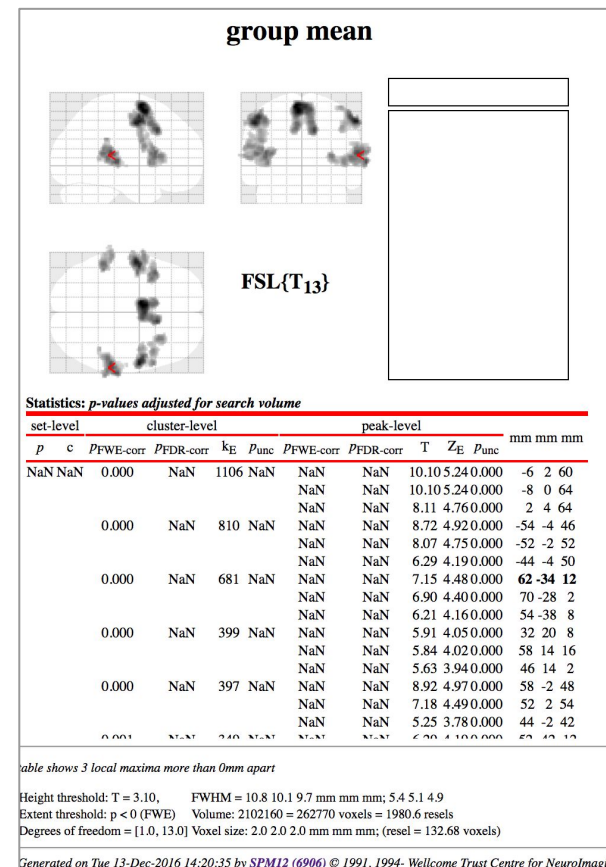
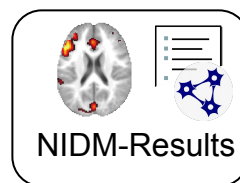
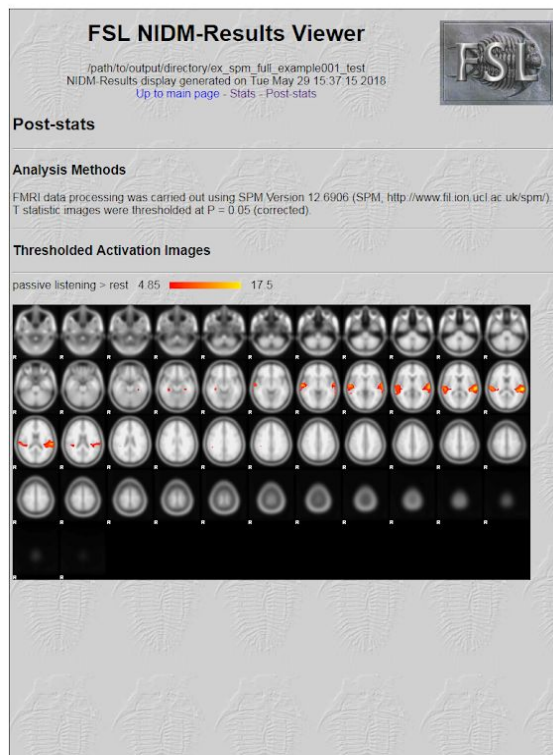
Coordinate-based meta-analysis



Image-based meta-analysis



# Derived data inspection with NIDM-Results: SPM- and FSL-like views

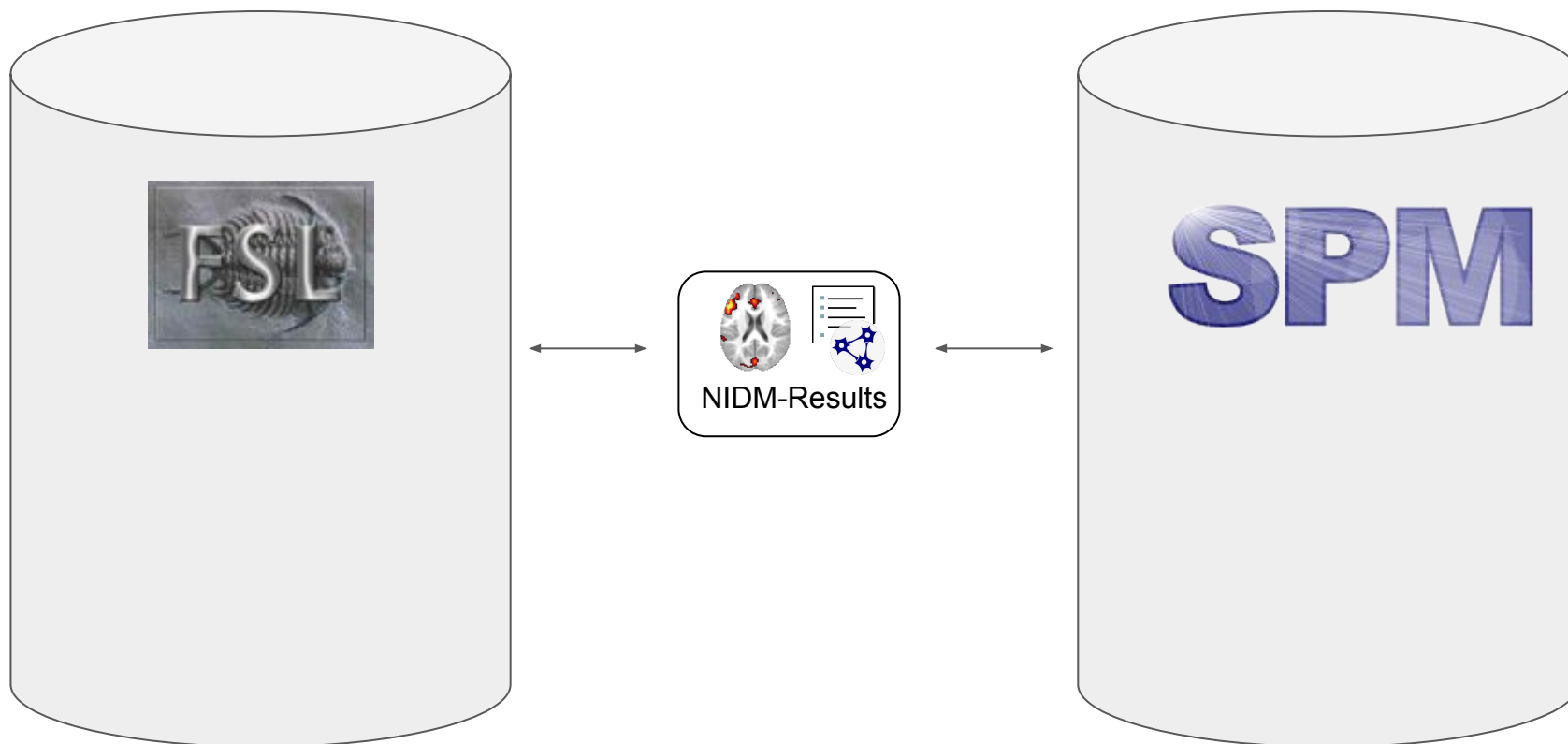


<https://github.com/incf-nidash/nidmresults-spmhtml>

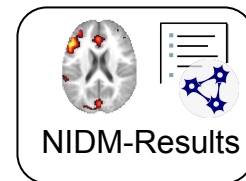
<https://github.com/incf-nidash/nidmresults-fslhtml>

Maullin-Sapey et al (2017)

# Derived data inspection with NIDM-Results: SPM- and FSL-like views

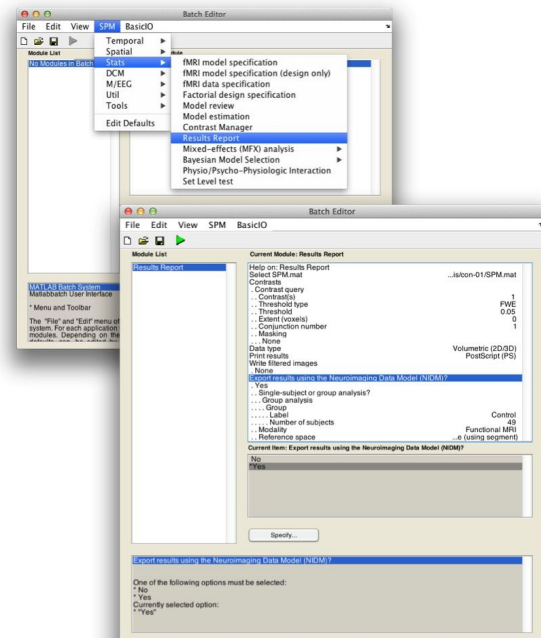






# How to use NIDM-Results for my study?

SPM



## 1. Export



```
$ nidmfsfsl fsl_ds107_group 49 -g Control
```

<https://github.com/incf-nidash/nidmresults-spm>  
<https://github.com/incf-nidash/nidmresults-fsl>

## 2. Publication on NeuroVault



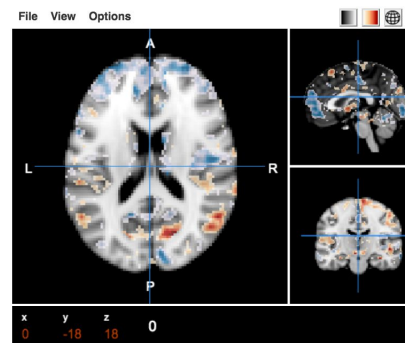
### A Correspondence between Individual Differences in the Brain's Intrinsic Functional Architecture and the Content and Form of Self-Generated Thoughts

Contributed by ChrisFilioGorgolewski

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



Images Details

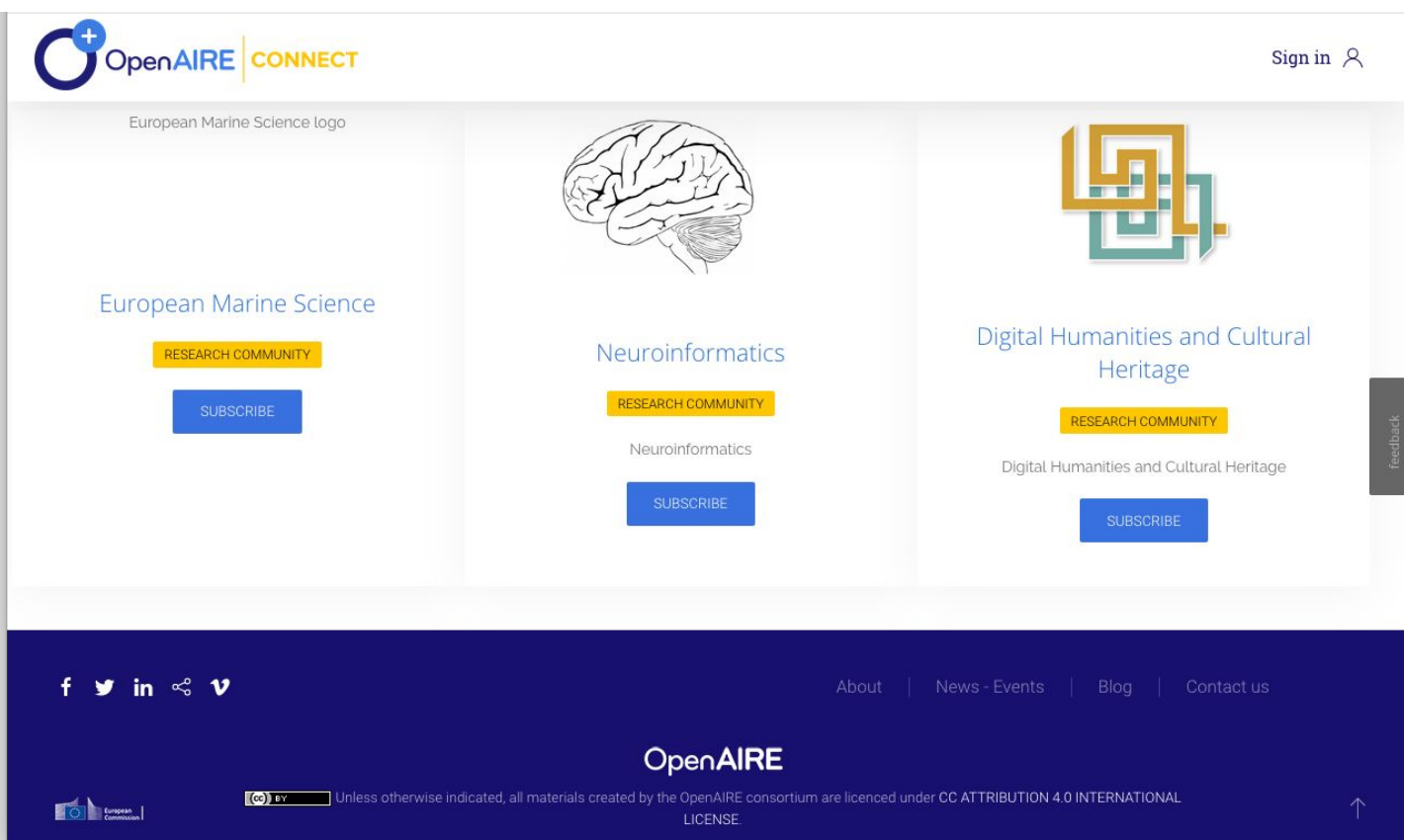
Show 7 entries Search:

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

# One step further: linking it all together!

“Gather, view and monitor all research outcomes”



# One step further: linking it all together!

“Gather, view and monitor all research outcomes”



The screenshot shows the Neuroinformatics page on the OpenAIRE CONNECT platform. At the top, there is a brain icon, the title "Neuroinformatics", and navigation links for "Search", "Monitor", "Share", and "Link". A "Sign in" link with a user icon and a blue "SUBSCRIBE" button are also present. Below the title, there are two rows of topic tags: "BRAIN MAPPING", "BRAIN IMAGING", "ELECTROENCEPHALOGRAPHY", "ARTERIAL SPIN LABELLING", "BRAIN FINGERPRINTING", "BRAIN", "NEUROIMAGING" in the first row; and "MULTIMODAL BRAIN IMAGE ANALYSIS", "FMRI", "NEUROINFORMATICS" in the second row, with a "show more" link. Below the tags, it says "Curated by: sorina.pop, camille.maumet, christian.barillot", "Created: 18-04-2018", and "Members: 4". A statistics section shows: 87 publications, 1 research data, 0 software, 10 projects, and 5 content providers. The "Recent publications" section features a paper titled "TOWARDS INTEGRATING SPATIAL LOCALIZATION IN CONVOLUTIONAL NEURAL NETWORKS FOR BRAIN IMAGE SEGMENTATION" by UNKNOWN (2018), with a snippet: "Semantic segmentation is an established while rapidly evolving field in medical imaging. In this paper we focus on the segmentation of ...". The "Recent research data" section shows "BROCCOLI: SOFTWARE FOR FAST FMRI ANALYSIS ON MANY-CORE CPUS AND GPUS" by Anders Eklund (2014) with an "OPEN" button and a "VIEW ALL" link. The "Recent software" section shows "No results found". A "feedback" button is located on the right side of the page.

# Many ways to contribute

You can...

- Make your research outputs available and citable
- Cite existing software
- Use derived data standards and tools
- Contribute to the development of new specifications and their ecosystems
- Make datasets in neuroimaging data repository discoverable

Join the NIDASH community! <https://github.com/incf-nidash/nidm-specs>

OpenAIRE-connect portal: <https://beta.ni.connect.openaire.eu/> and  
guidelines for data repository managers:

<https://www.openaire.eu/openaire-guide-for-repository-managers>

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## Photo and template credits

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Presentation template by [SlidesCarnival](#), adapted.

# Acknowledgements

## **NIDM working group**

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**Meta-analysis datasets** Tracey group at FMRIB.

Thank you! To all INCF NIDASH task force members.

# Thank you!



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**Join the NIDASH community:**

**<https://github.com/incf-nidash/nidm-specs>**