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Variability in brain imaging studies across different analysis pipelines

Camille Maumet

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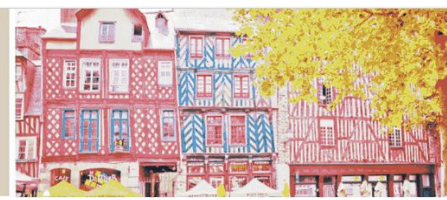


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February 4, 2025

VAMOS 2025

4 - 6 FEBRUARY
- RENNES, FRANCE

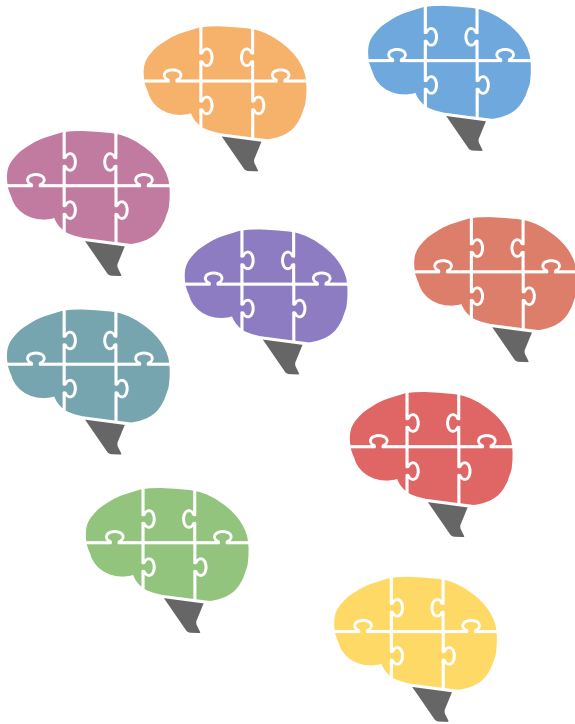


Variability in **brain imaging** studies across different **analysis pipelines**

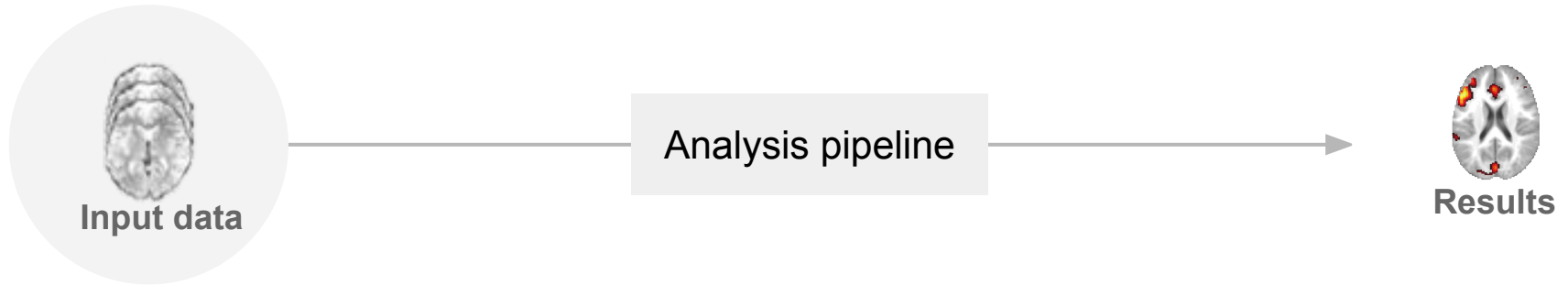
19th International Working Conference on Variability Modelling of Software-Intensive Systems (VaMoS)

Camille Maumet

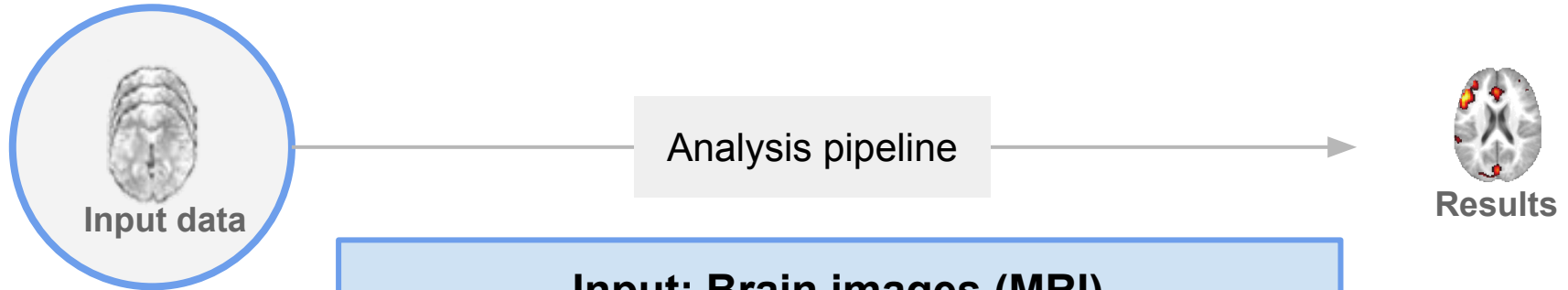
Inria, Univ Rennes, Inserm, CNRS, IRISA



A multiplicity of analysis pipelines



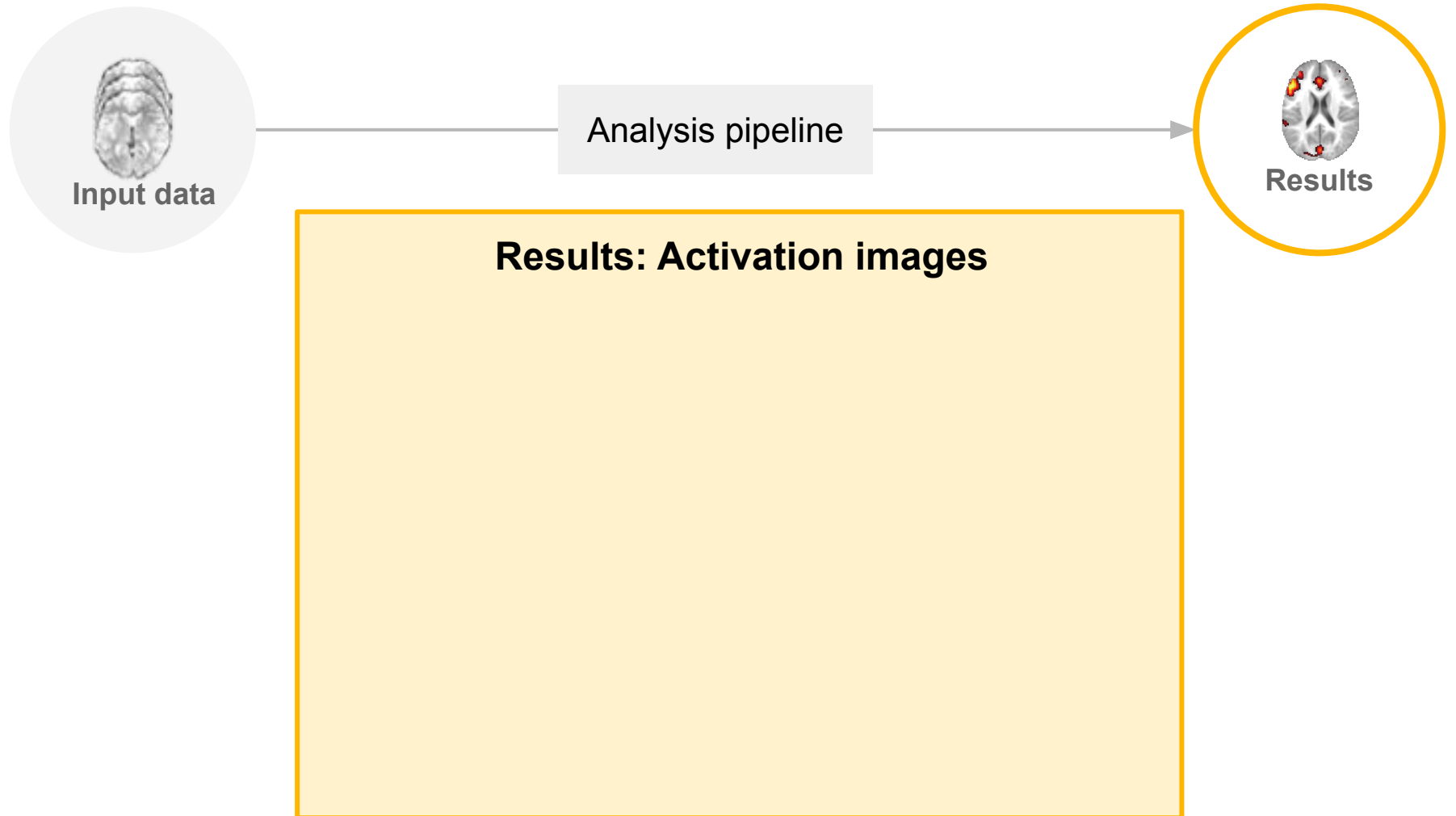
A multiplicity of analysis pipelines



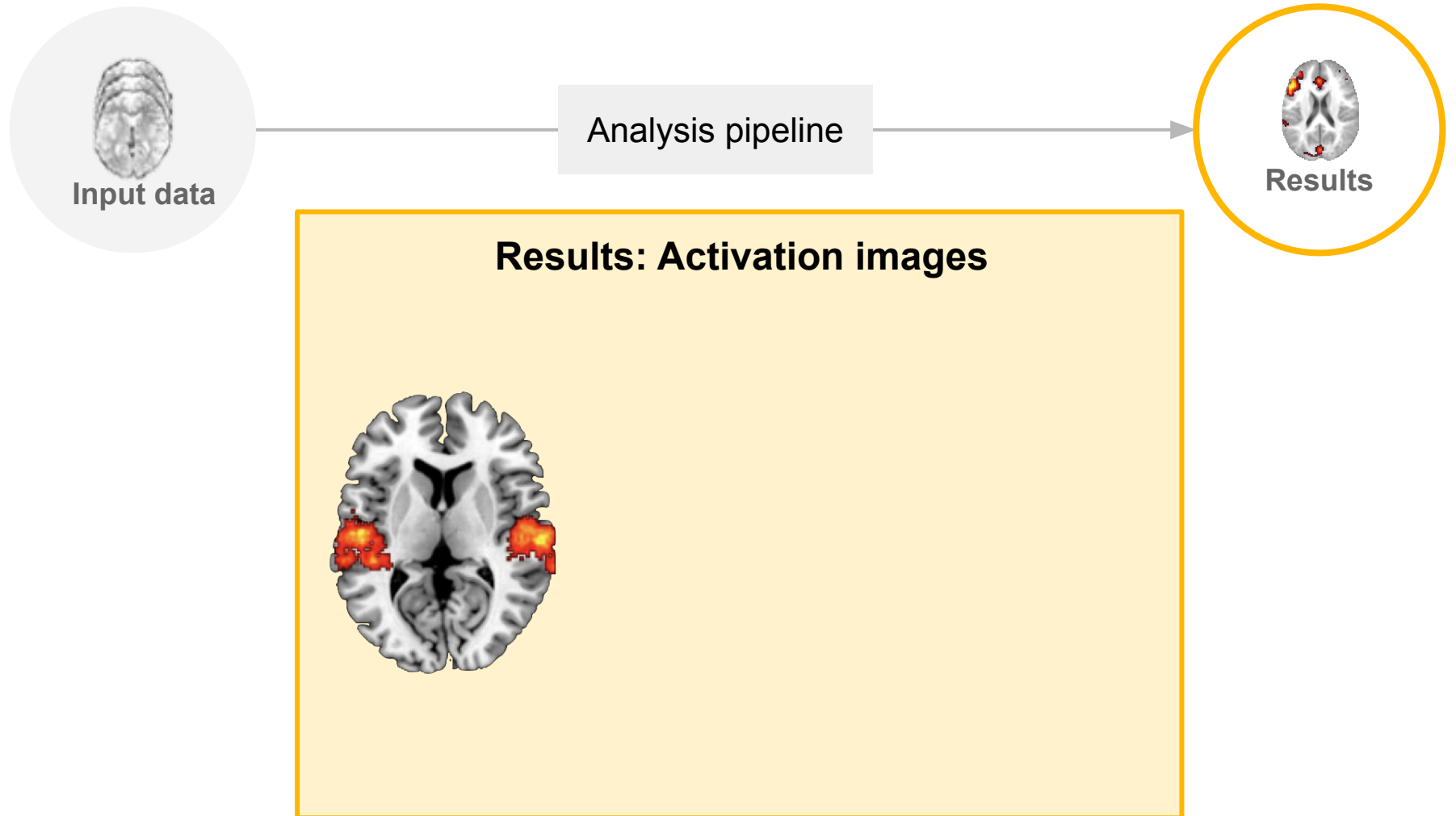
Input: Brain images (MRI)



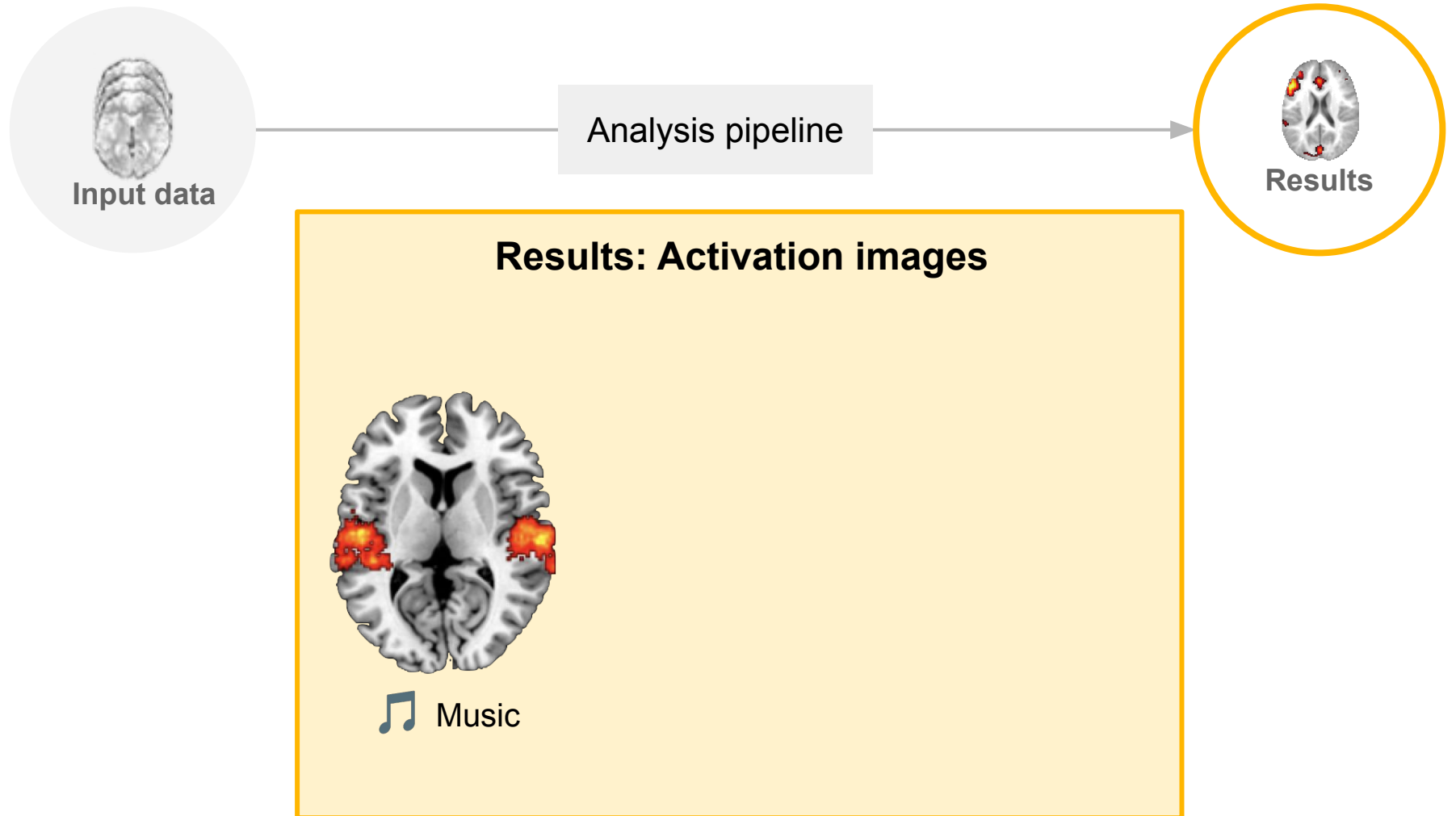
A multiplicity of analysis pipelines



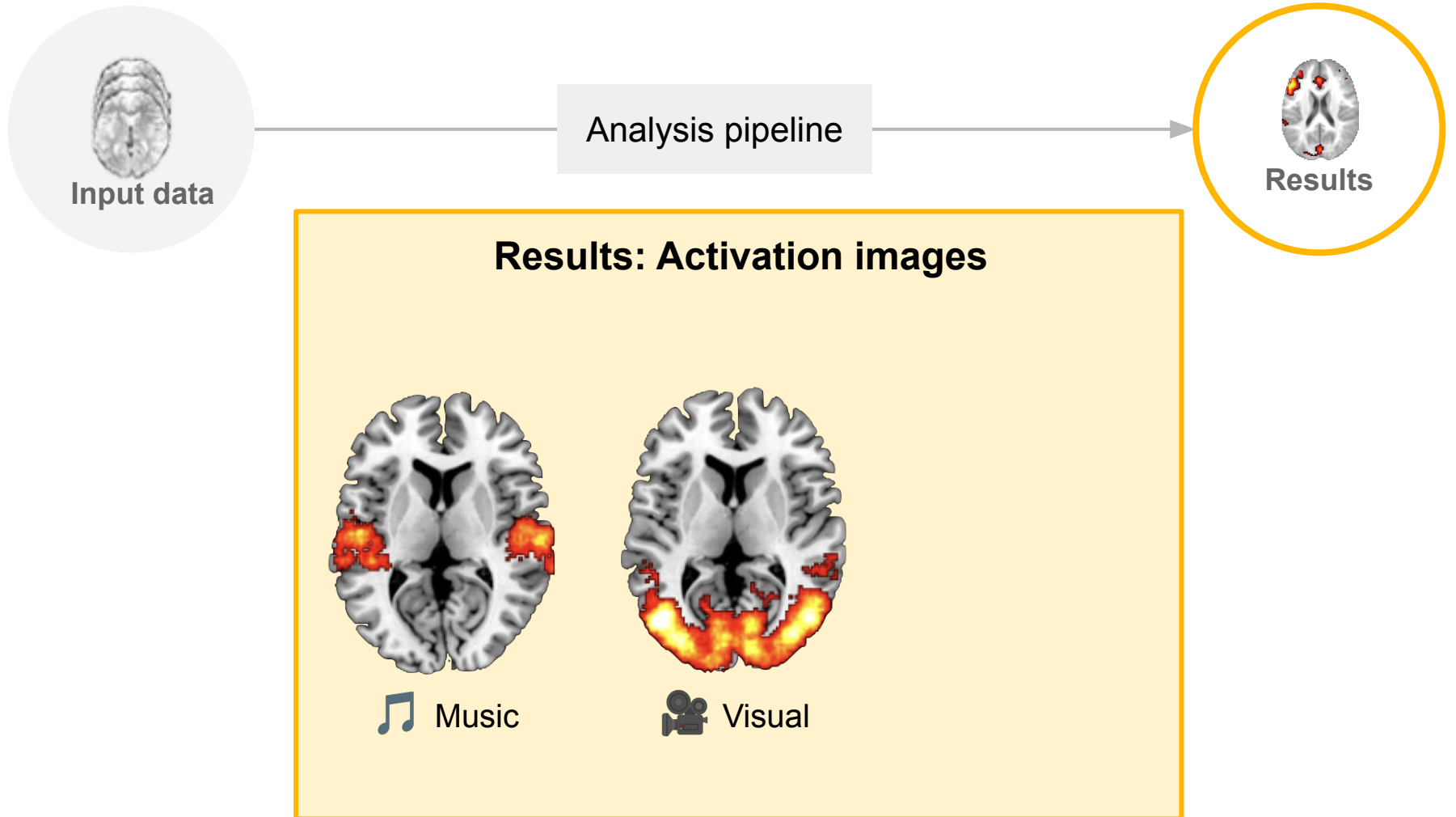
A multiplicity of analysis pipelines



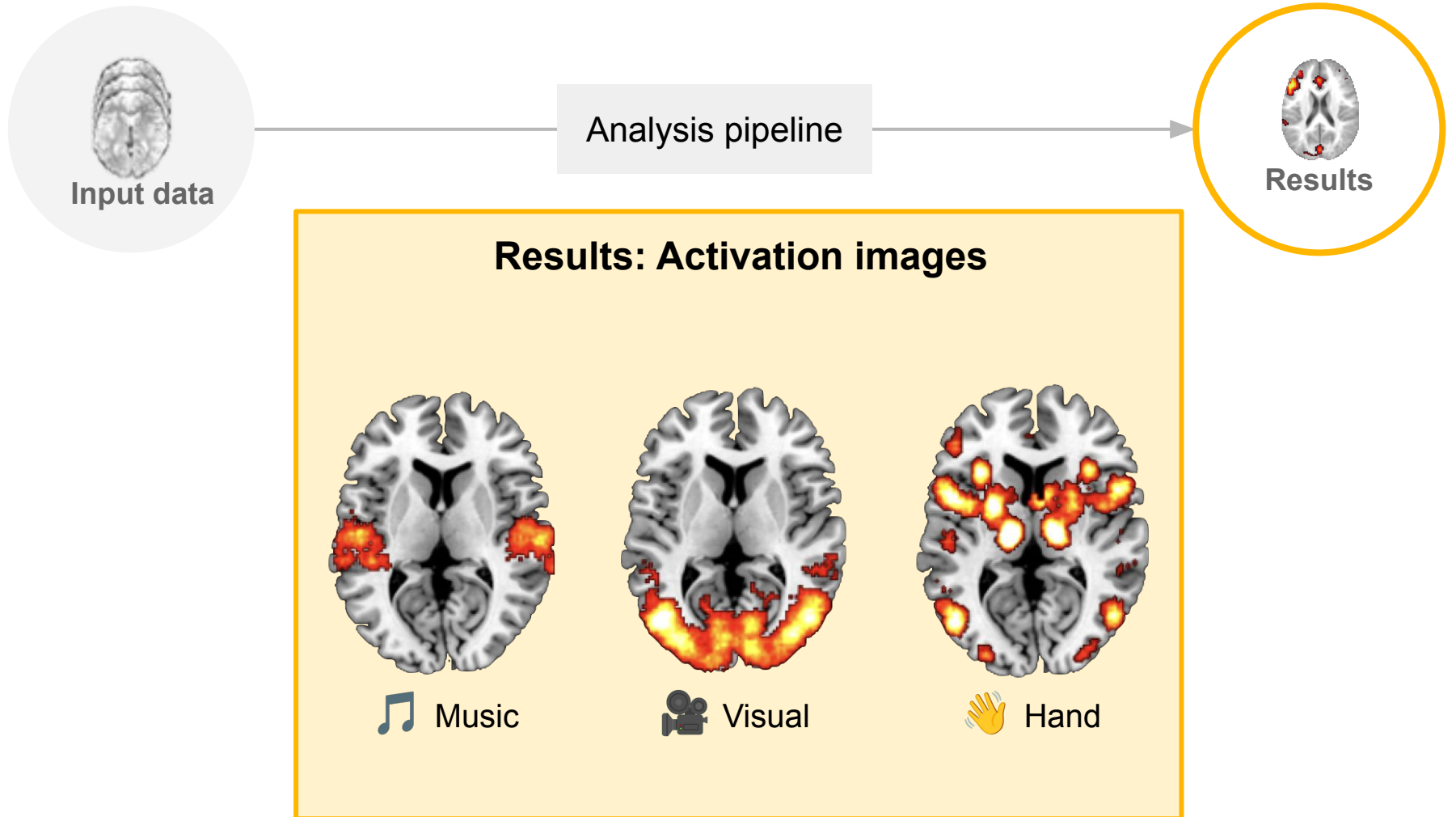
A multiplicity of analysis pipelines



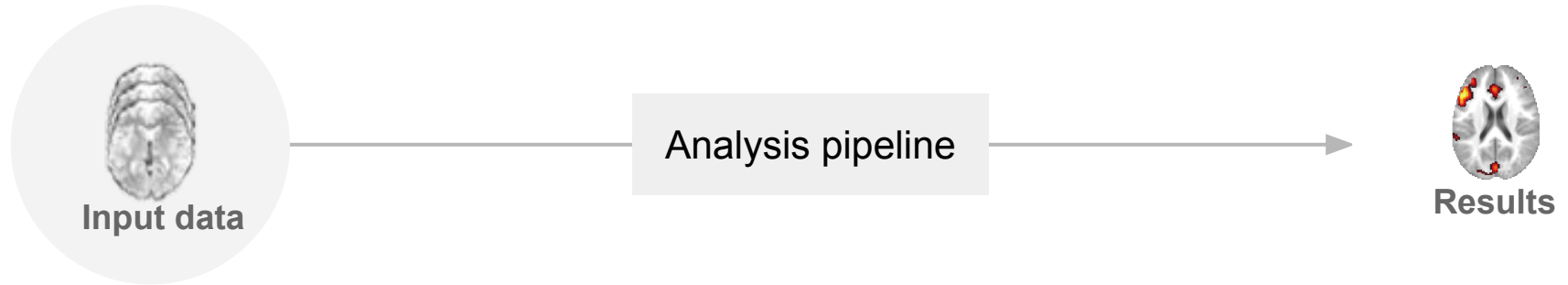
A multiplicity of analysis pipelines



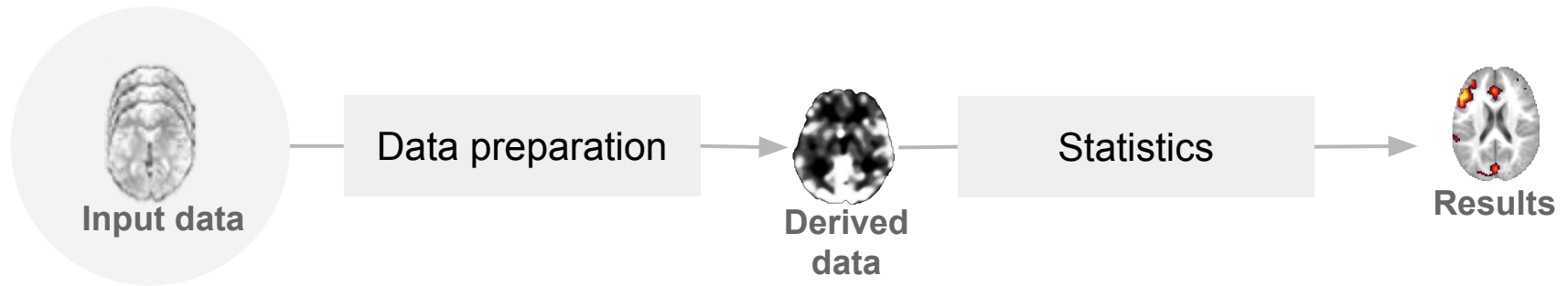
A multiplicity of analysis pipelines



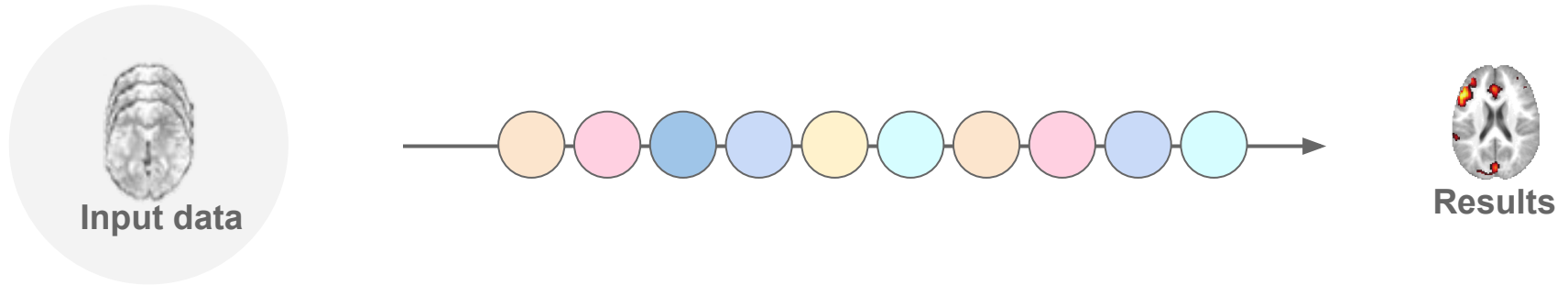
A multiplicity of analysis pipelines



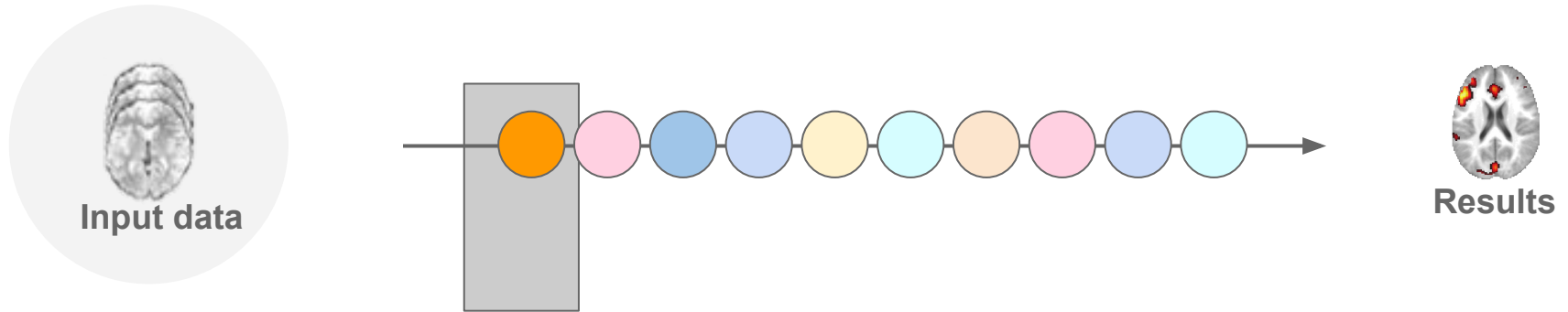
A multiplicity of analysis pipelines



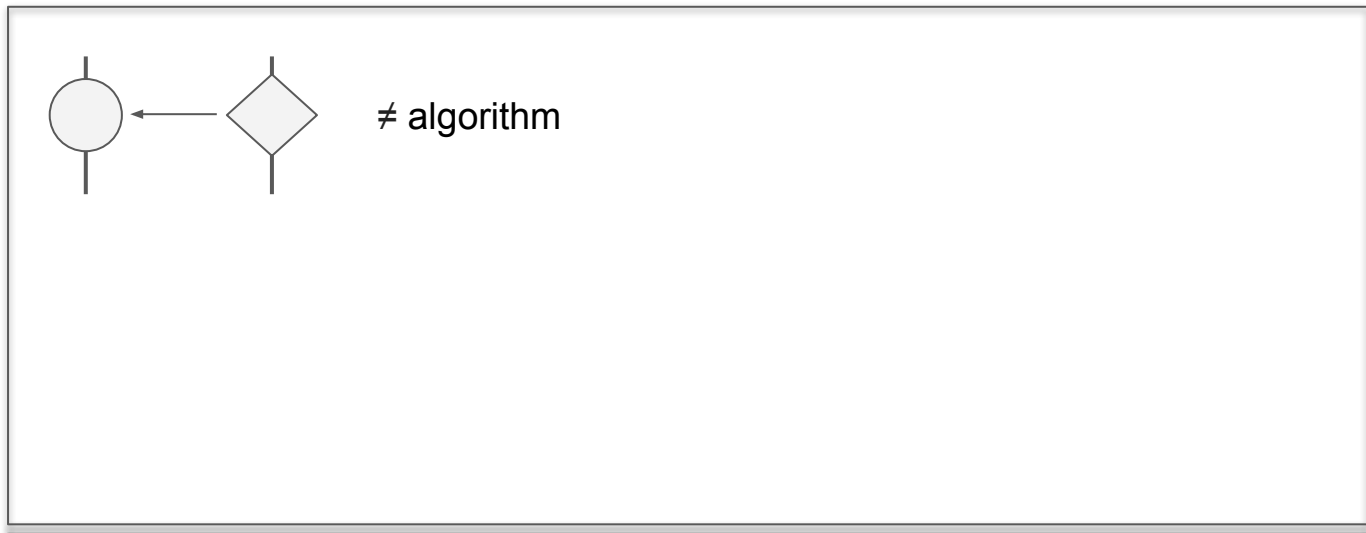
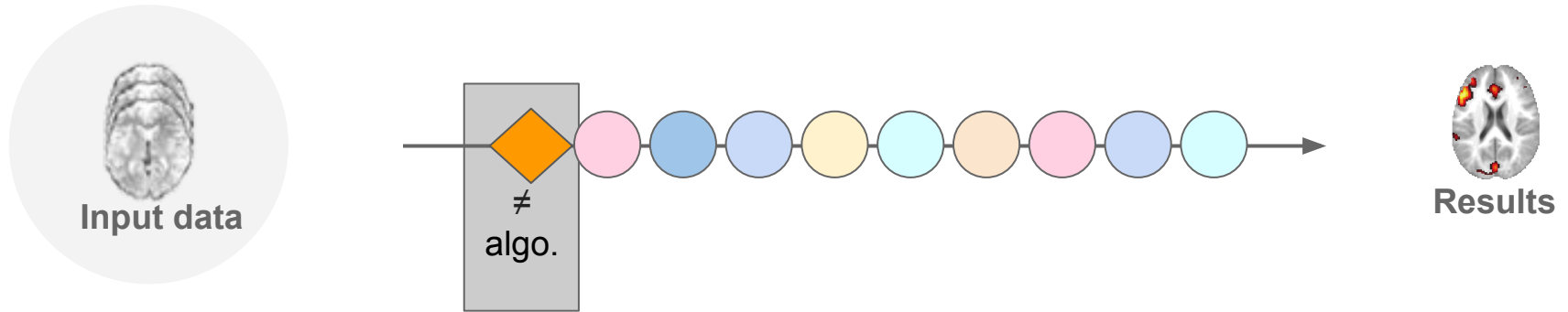
A multiplicity of analysis pipelines



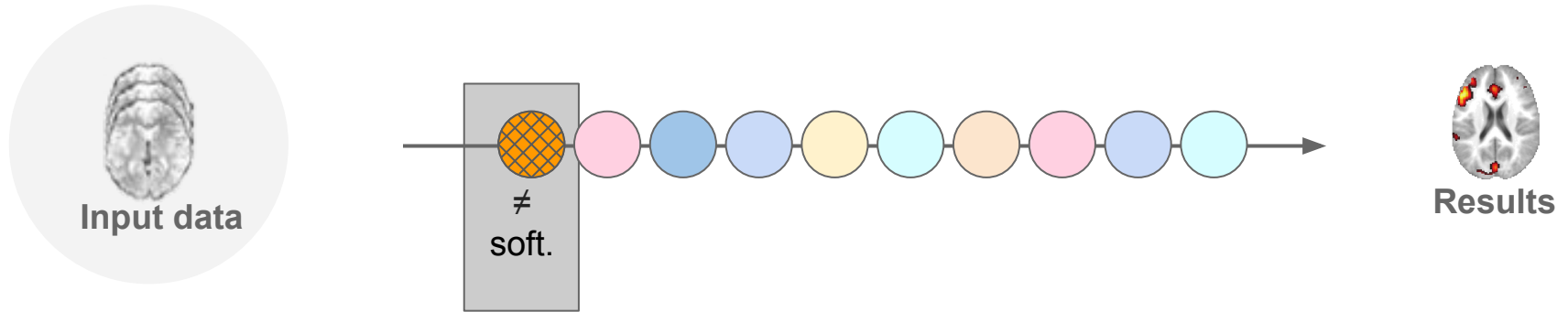
A multiplicity of analysis pipelines



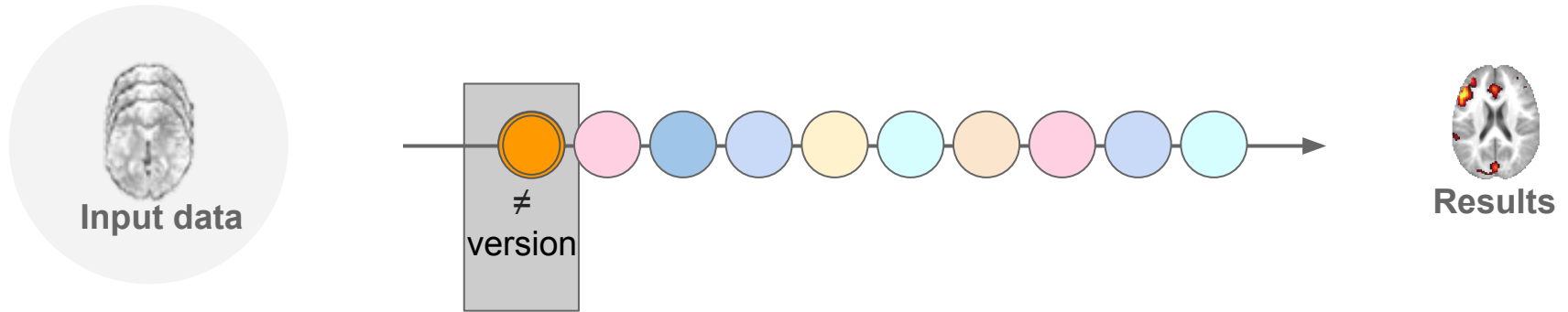
A multiplicity of analysis pipelines



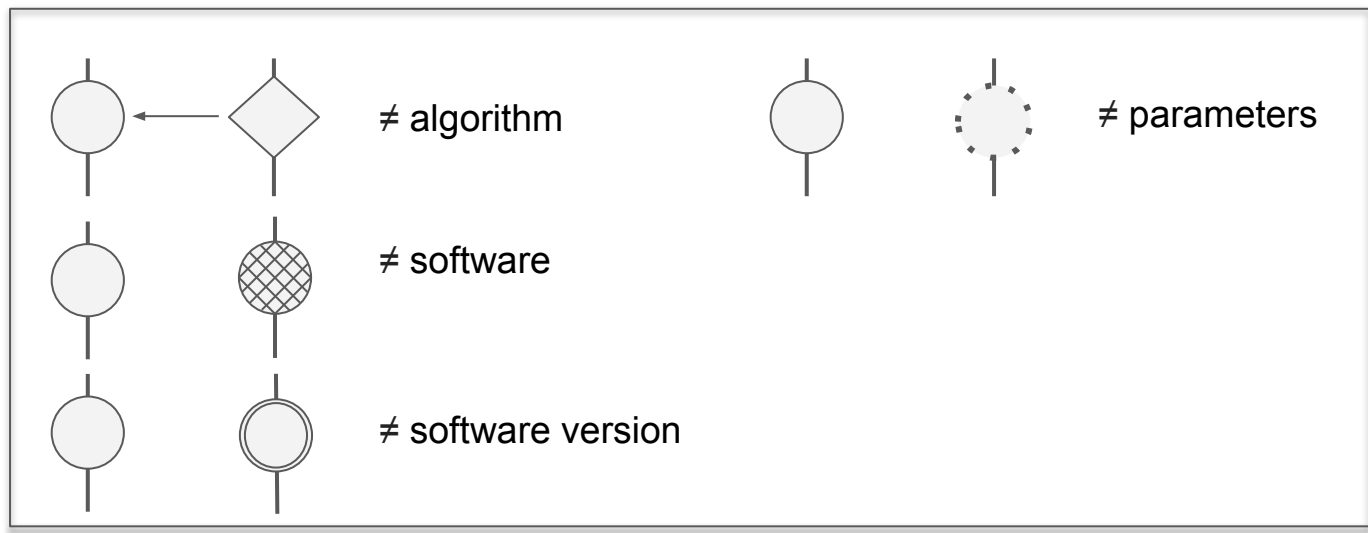
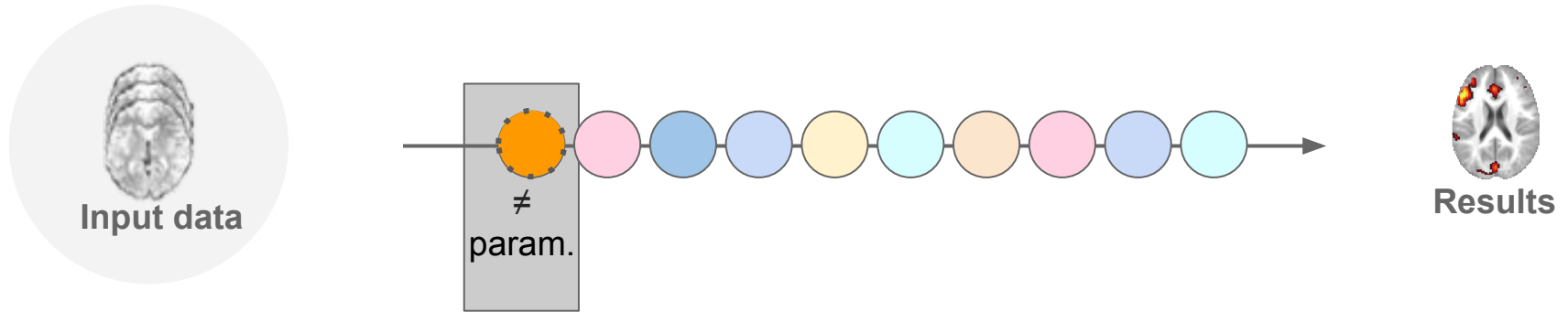
A multiplicity of analysis pipelines



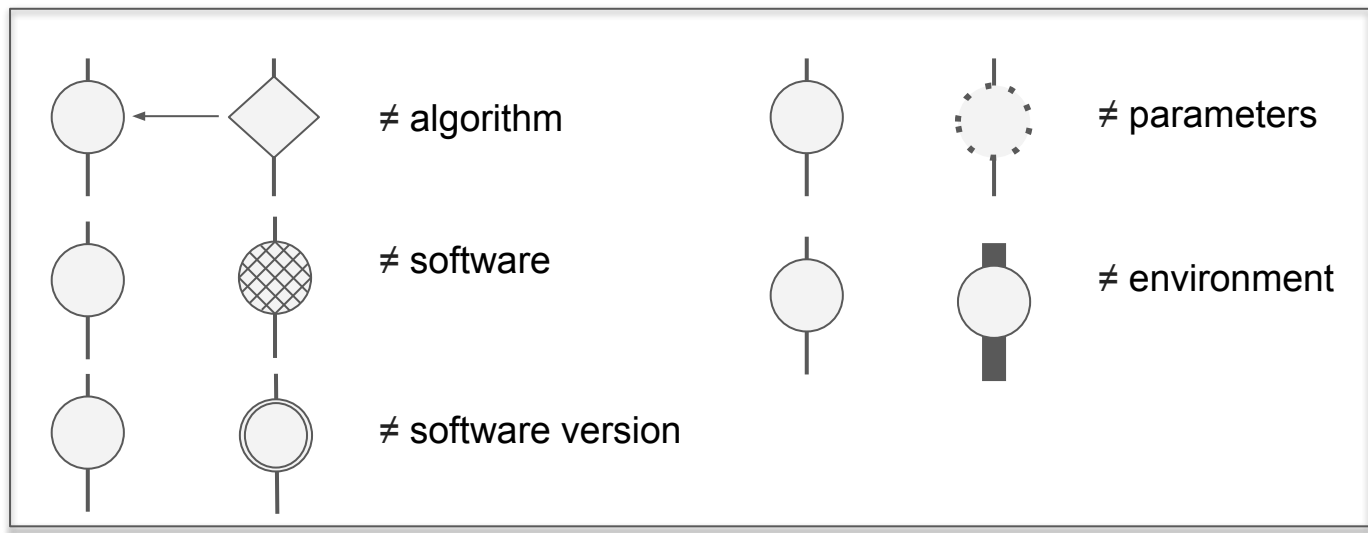
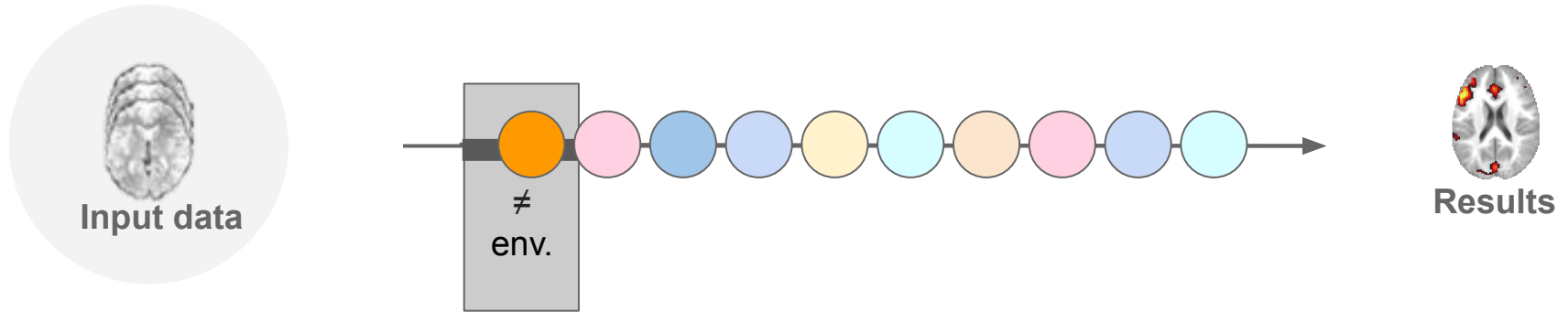
A multiplicity of analysis pipelines



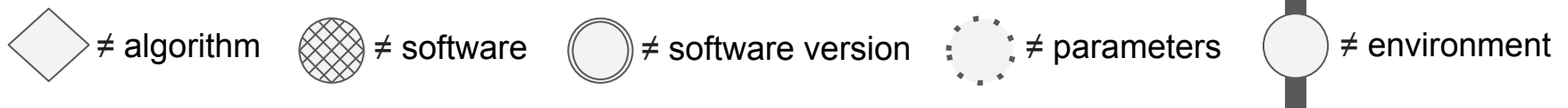
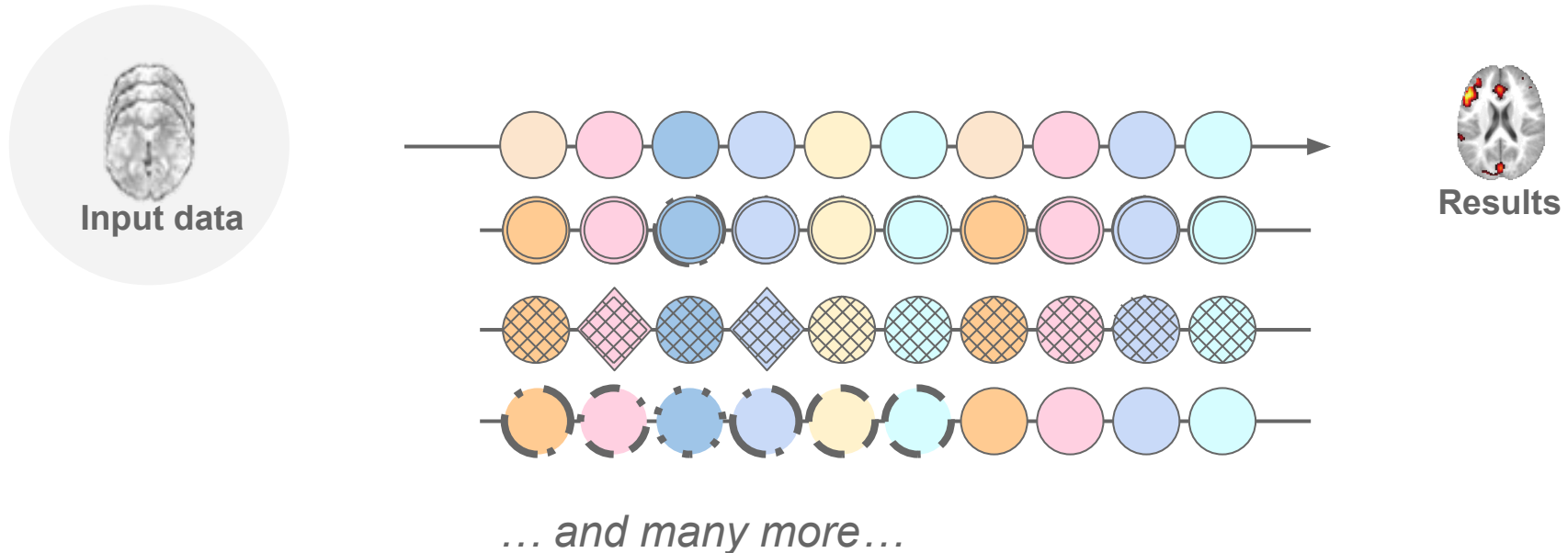
A multiplicity of analysis pipelines



A multiplicity of analysis pipelines

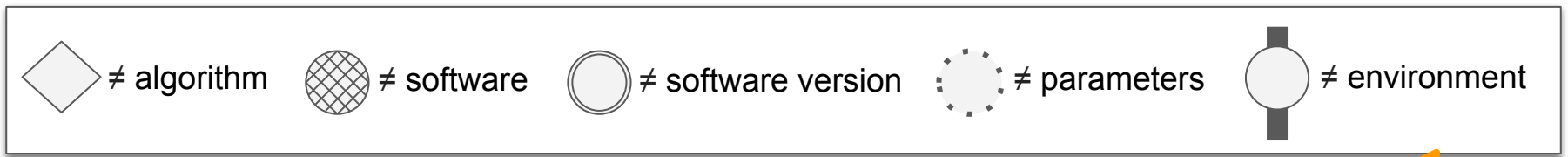
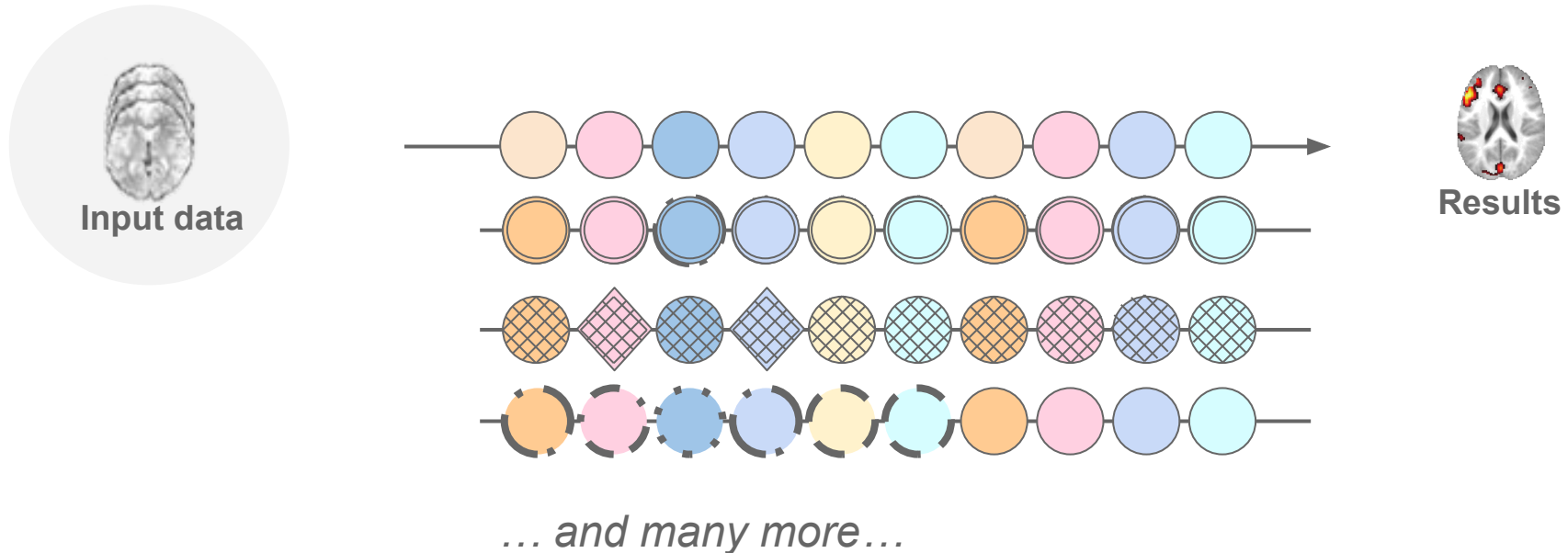


A multiplicity of analysis pipelines



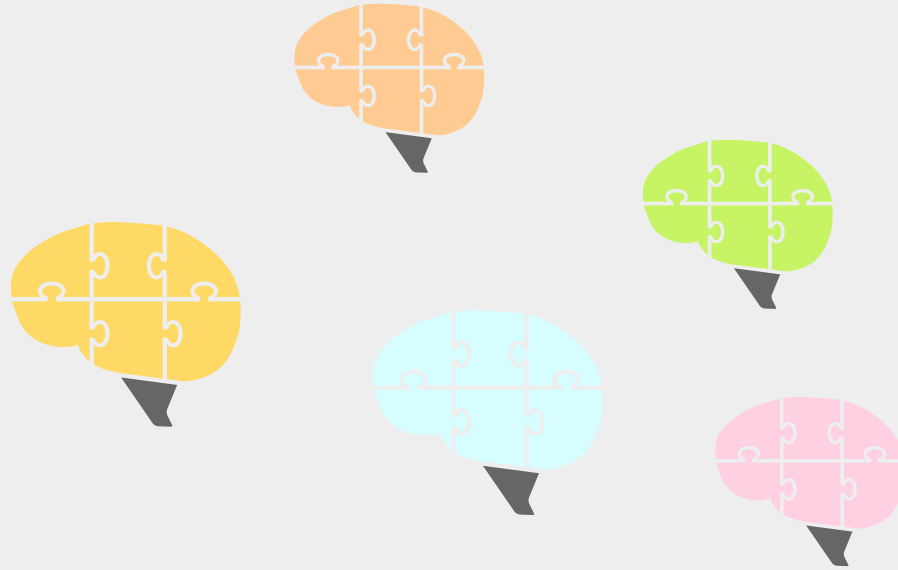
A family of acceptable pipelines
over 10^{30} combinations...

A multiplicity of analysis pipelines



A family of acceptable pipelines
over 10^{30} combinations...

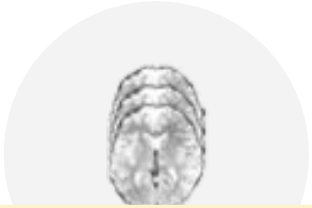
**Software
Variants**



Variability in pipelines...

Variability in results?

Many-analyst project : NARPS

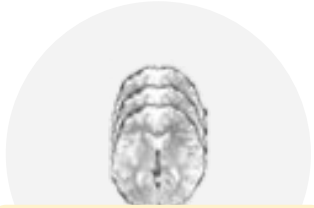


1 dataset

**9 'yes/no'
questions**

[Botvinik-Nezer et. al, Nature 2020]

Many-analyst project : NARPS



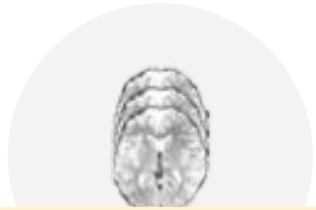
1 dataset

9 'yes/no'
questions

Question 1: *Is there a **parametric effect of gain:** Positive effect in **ventromedial prefrontal cortex** - for the equal indifference group?*

[Botvinik-Nezer et. al, Nature 2020]

Many-analyst project : NARPS



1 dataset



9 'yes/no' questions

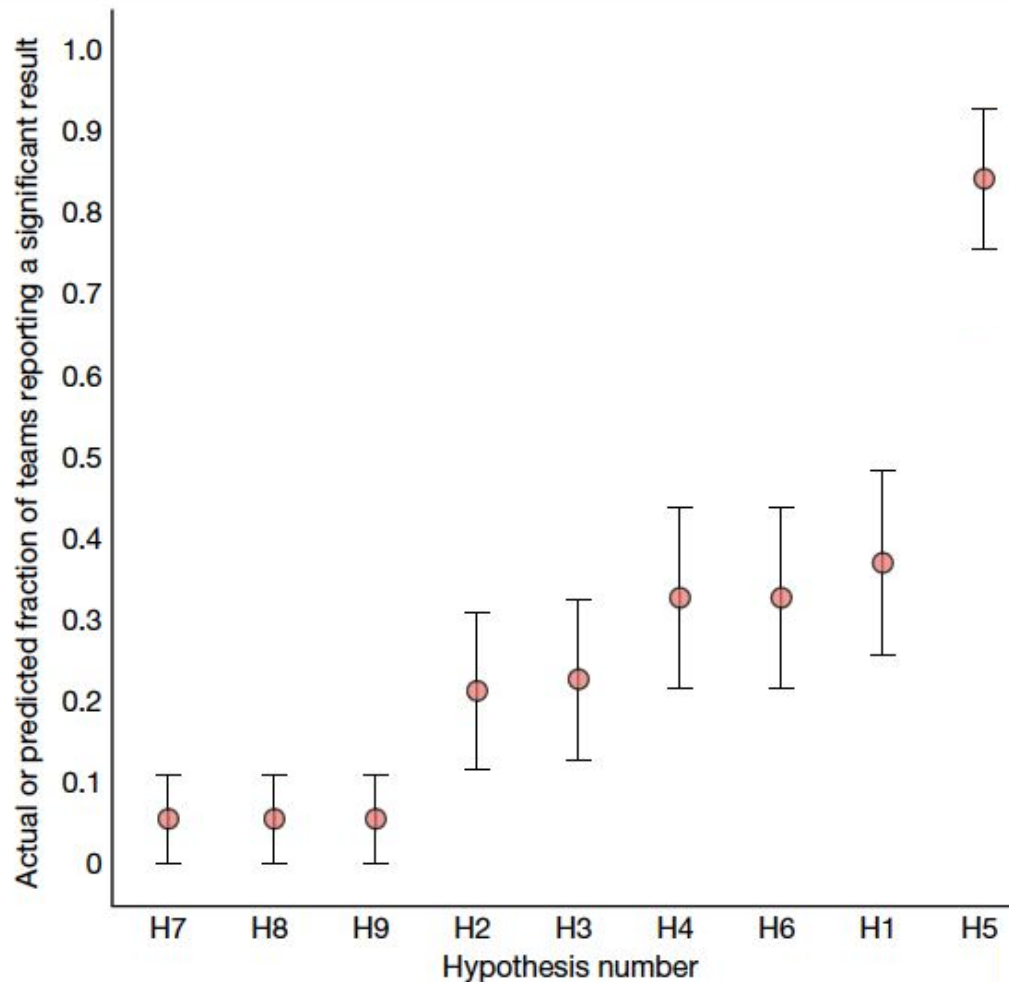


70 analysis pipelines
by different teams

[Botvinik-Nezer et. al, Nature 2020]

Many-analyst project : NARPS

Results over the **70 post-processing pipelines**:

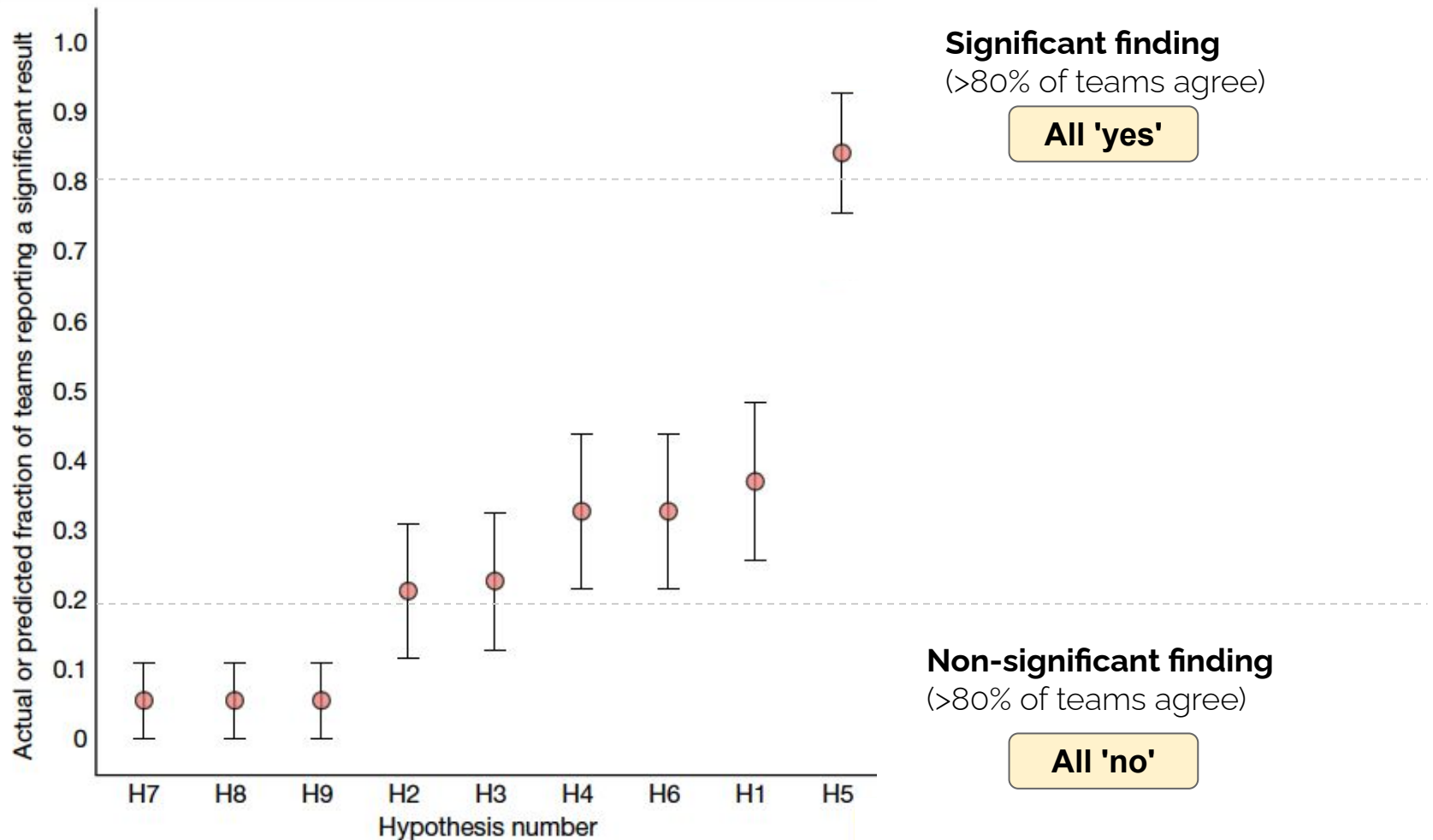


9 'yes/no' questions

[Botvinik-Nezer et. al, Nature 2020]

Many-analyst project : NARPS

Results over the **70 post-processing pipelines**:

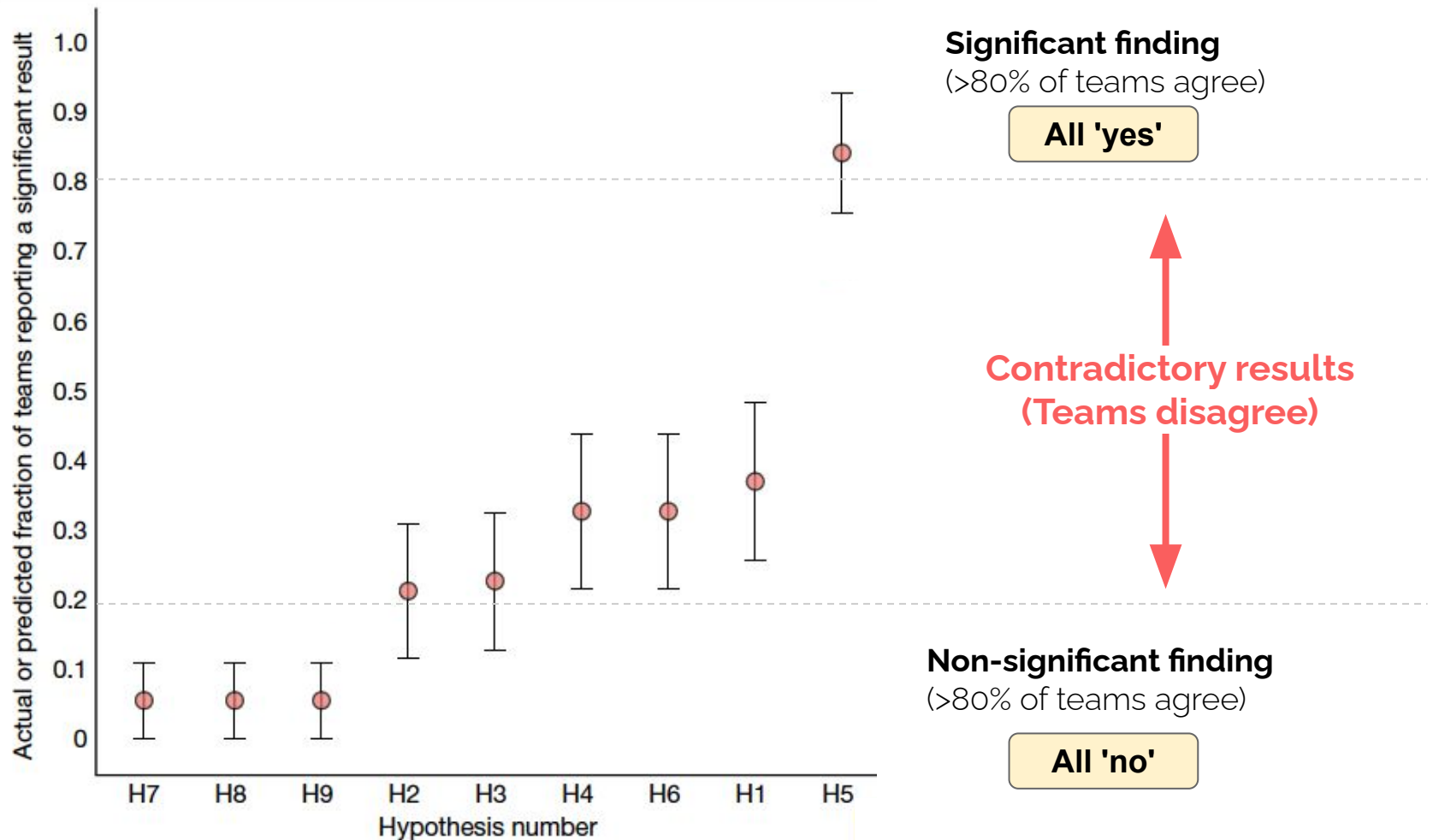


9 'yes/no' questions

[Botvinik-Nezer et. al, Nature 2020]

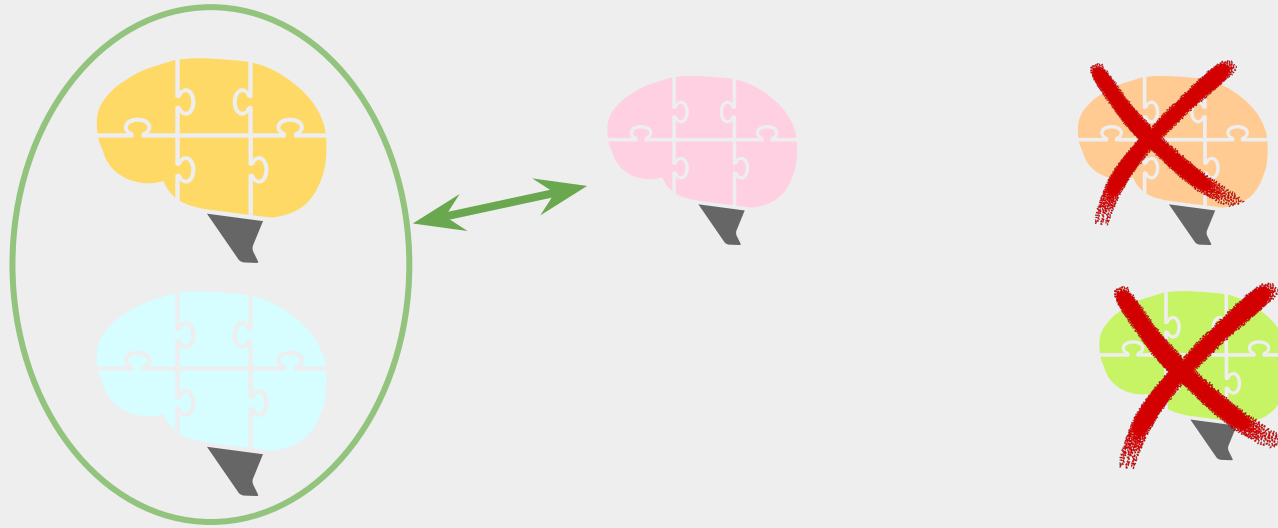
Many-analyst project : NARPS

Results over the **70 post-processing pipelines**:



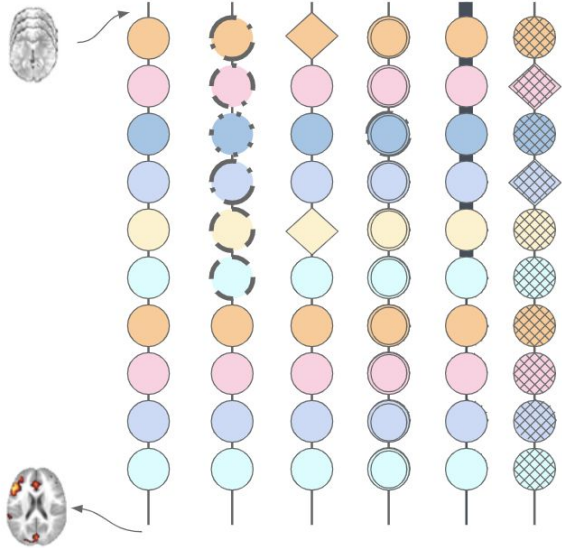
9 'yes/no' questions

[Botvinik-Nezer et. al, Nature 2020]



Understanding
analytical variability

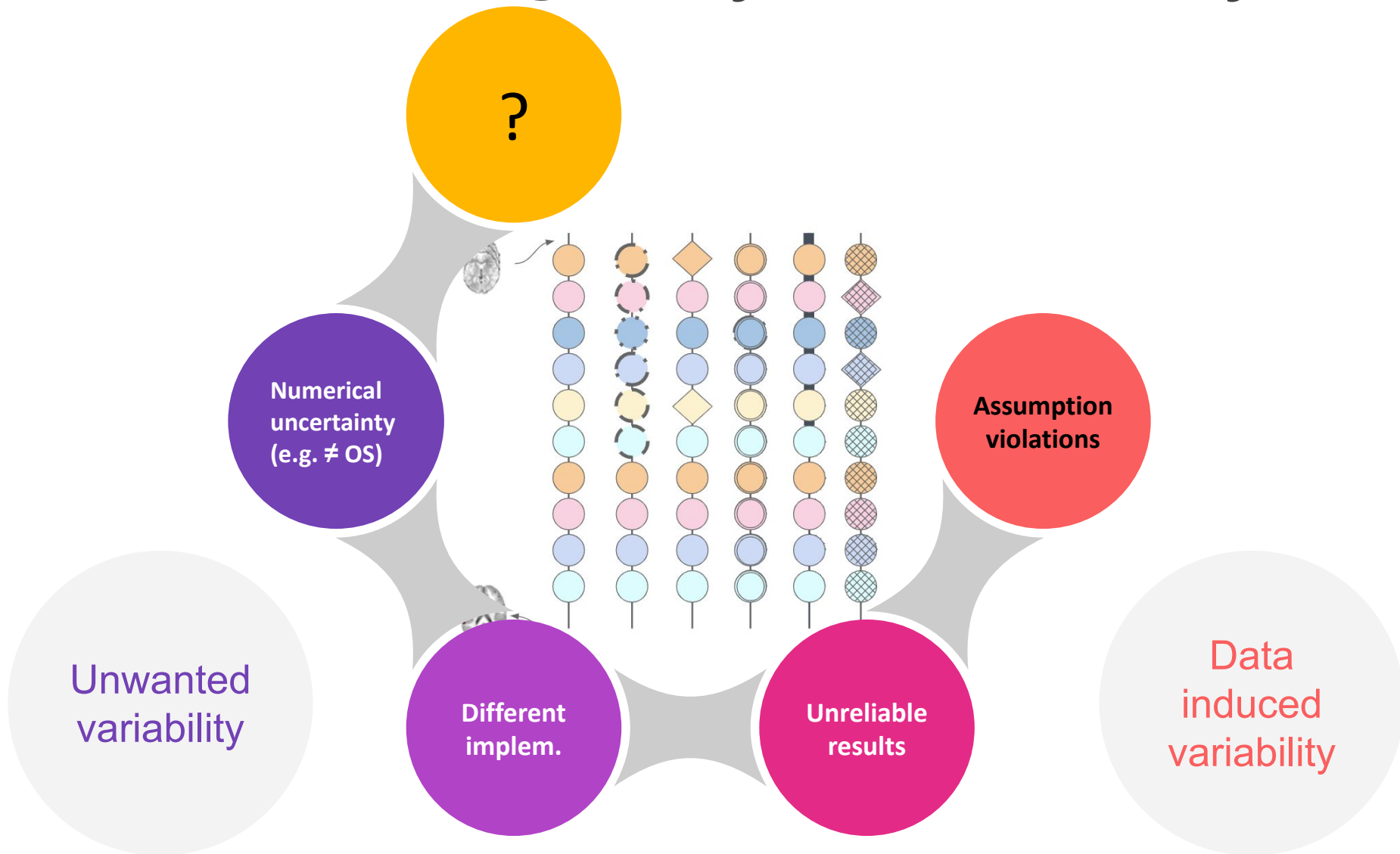
Understanding analytical variability...



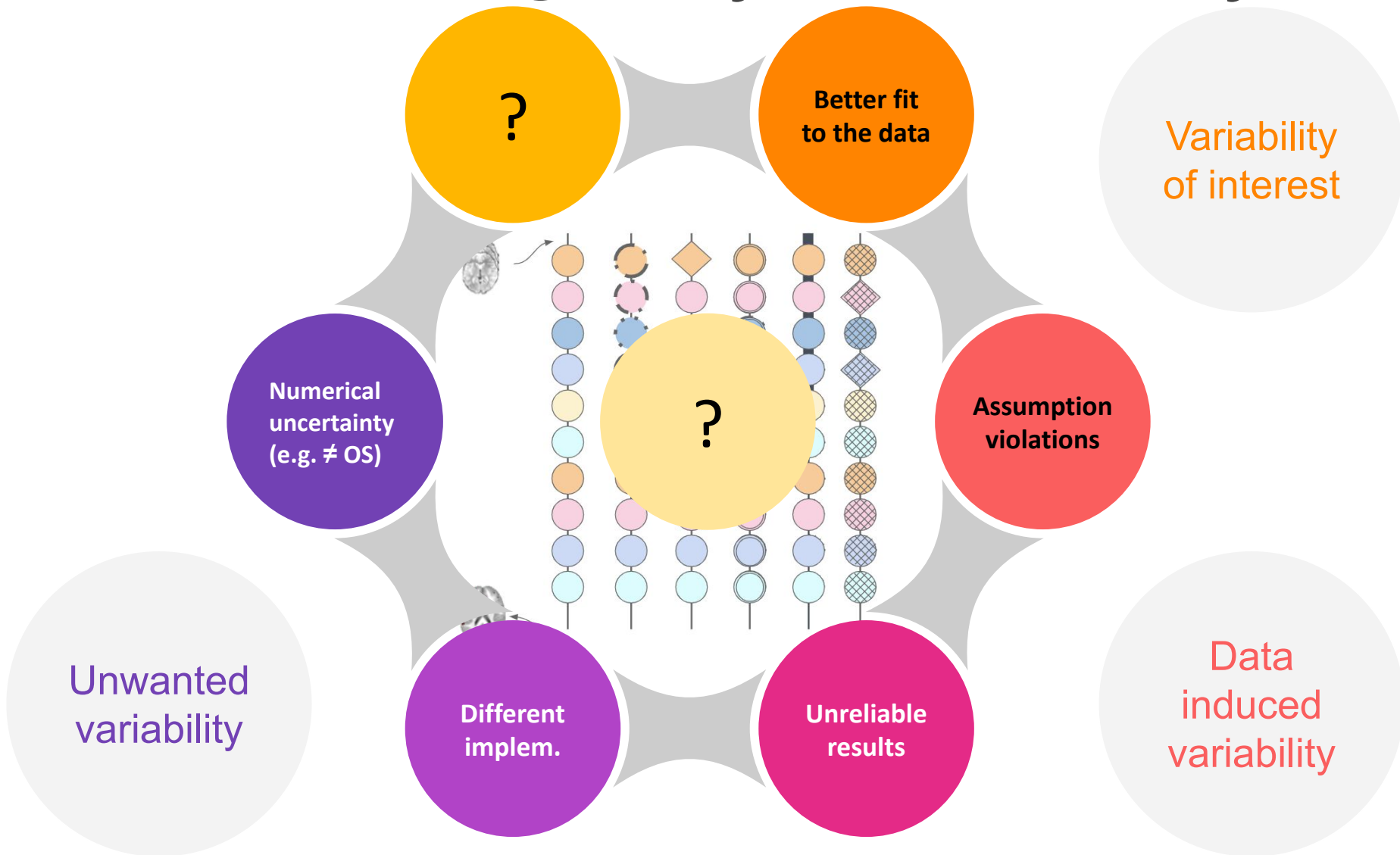
Understanding analytical variability...



Understanding analytical variability...



Understanding analytical variability...



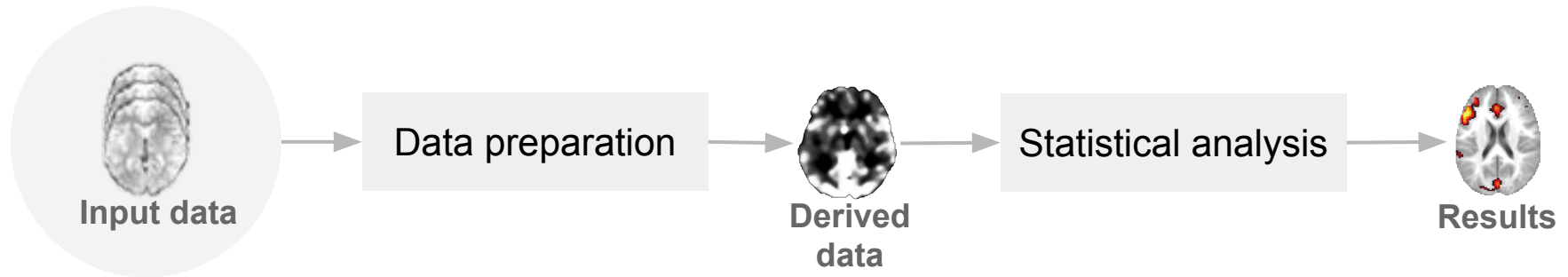
Variability across neuroimaging software



Alex Bowring



Tom Nichols
Oxford Uni. (UK)



Goal 1: Investigate the **variability** observed in brain imaging results when using **different domain software packages**

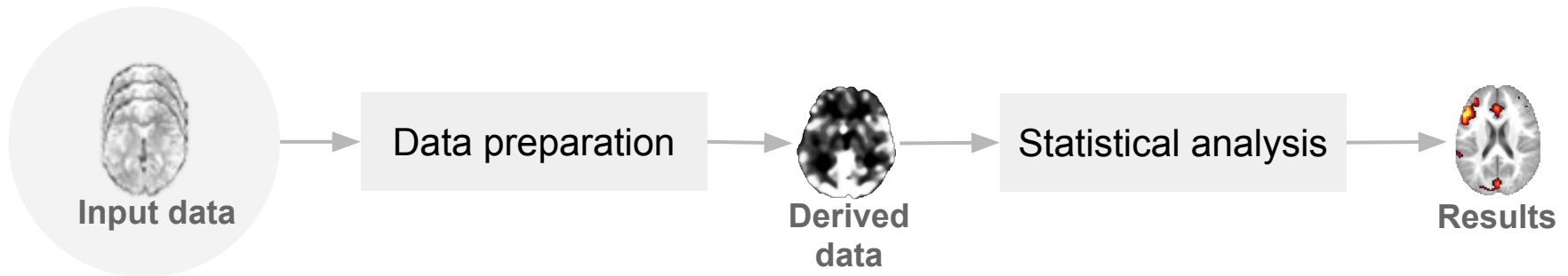
Variability across neuroimaging software



Alex Bowring



Tom Nichols
Oxford Uni. (UK)



Goal 1: Investigate the **variability** observed in brain imaging results when using **different domain software packages**

- **Reproduced 3 studies** from the literature
- Using **3 brain imaging software: AFNI, FSL, SPM**
(used in 80% literature [Carp, 2012])
- **Pipelines aligned** using available configurations.

Variability across neuroimaging software

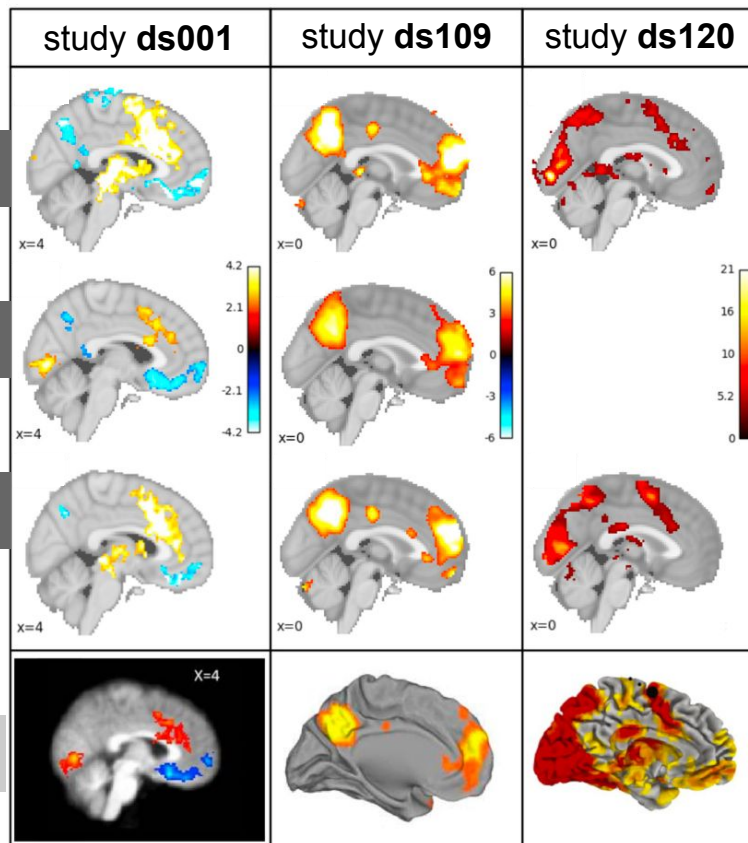


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Oxford Uni. (UK)

- Variability in the activation maps



[Bowring Maumet* Nichols*, HBM 2019]

Variability across neuroimaging software

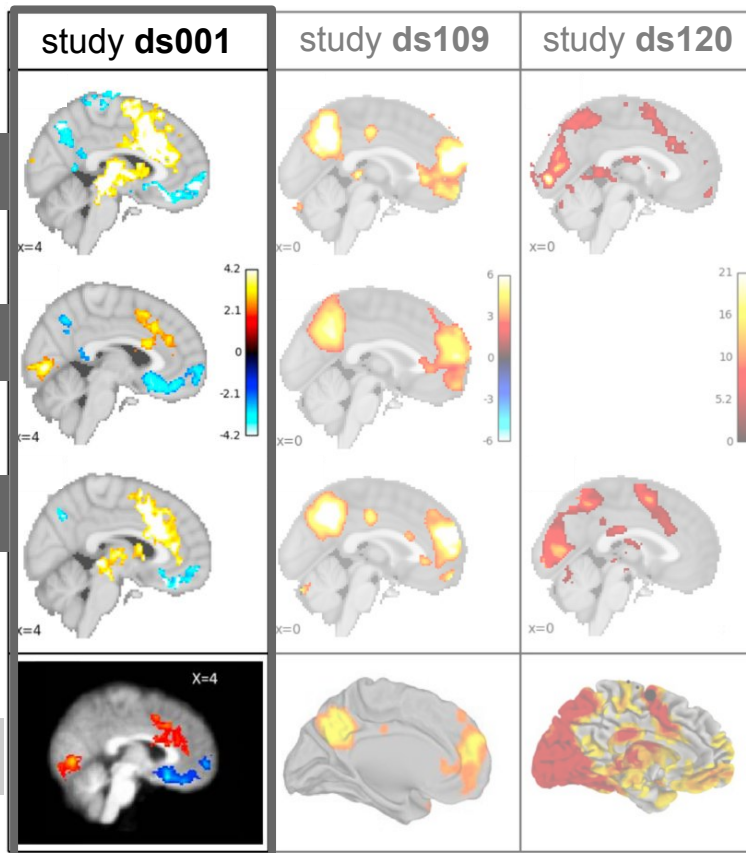


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- Variability in the activation maps



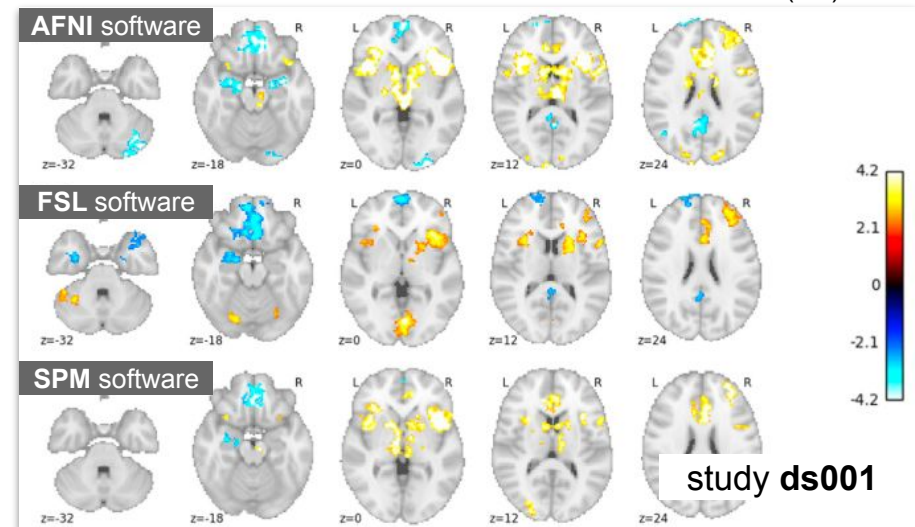
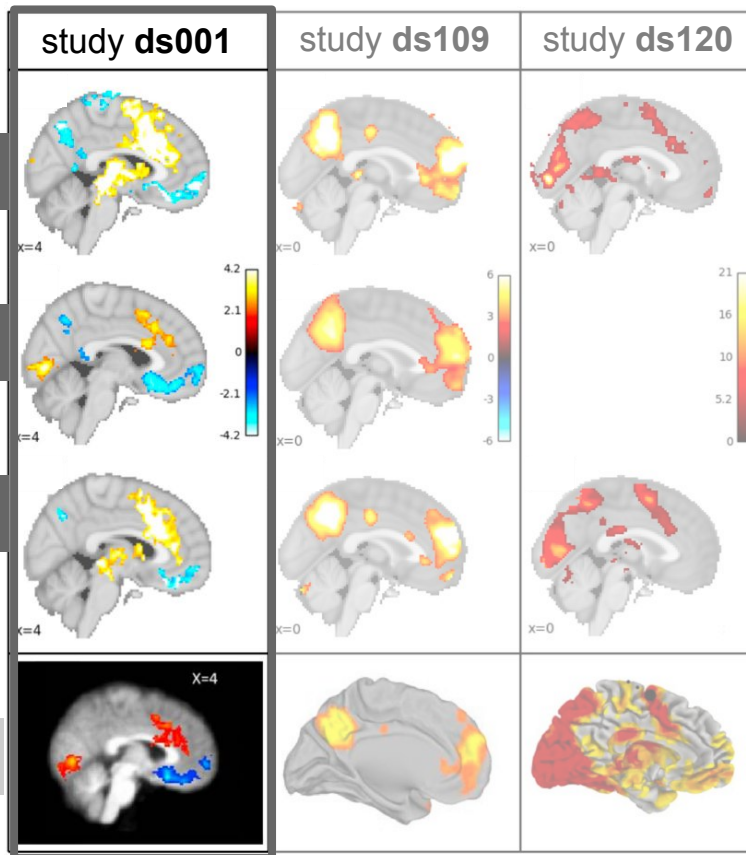
[Bowring Maumet* Nichols*, HBM 2019]

Variability across neuroimaging software



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Oxford Uni. (UK)

- Variability in the activation maps



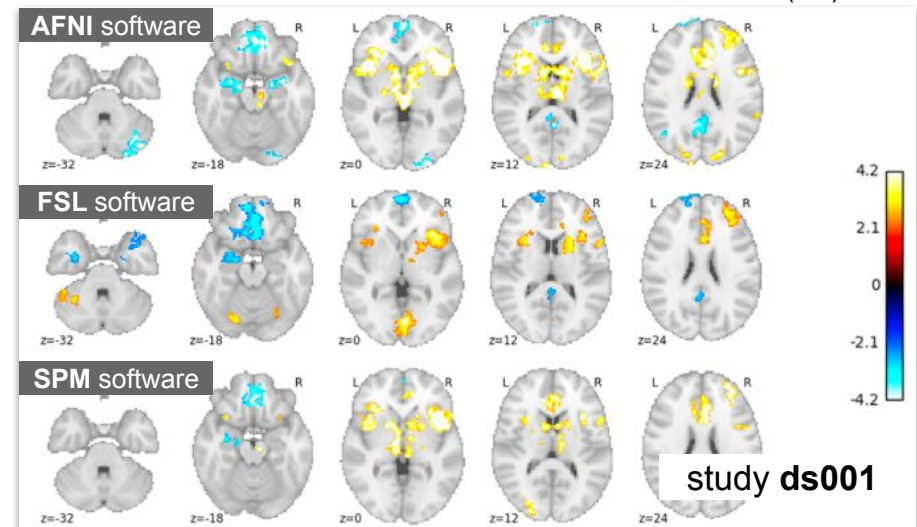
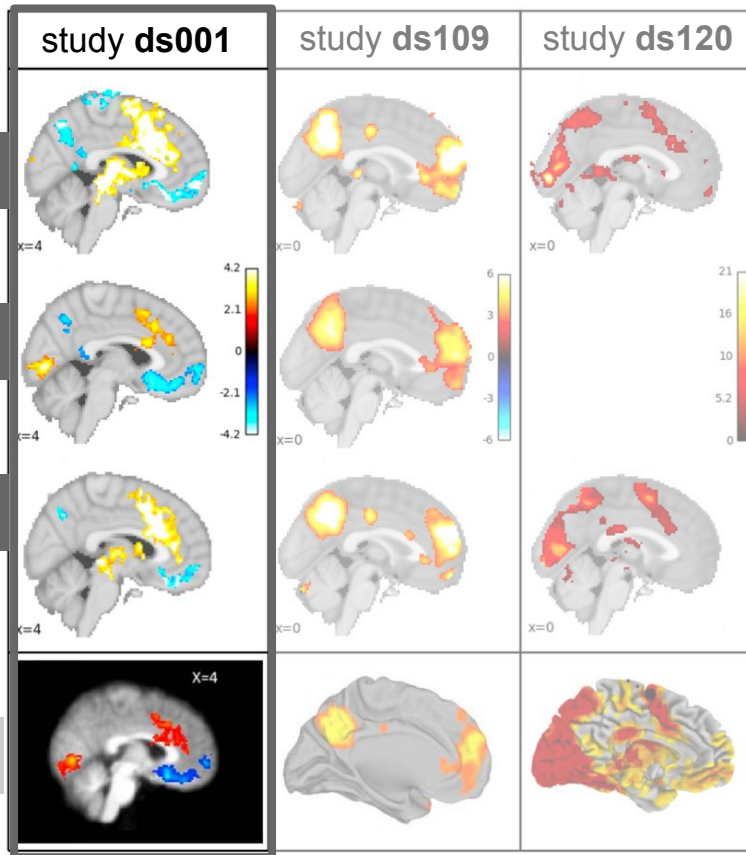
[Bowring Maumet* Nichols*, HBM 2019]

Variability across neuroimaging software

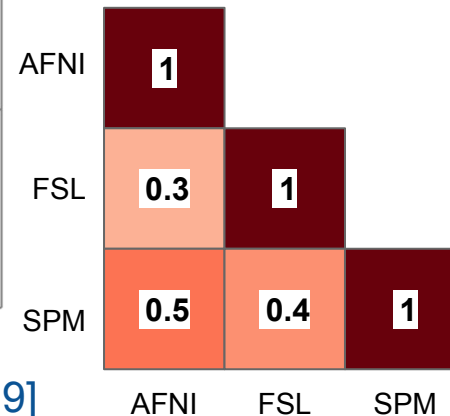


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- Variability in the activation maps



Dice coefficient



The choice of software impacts the activations

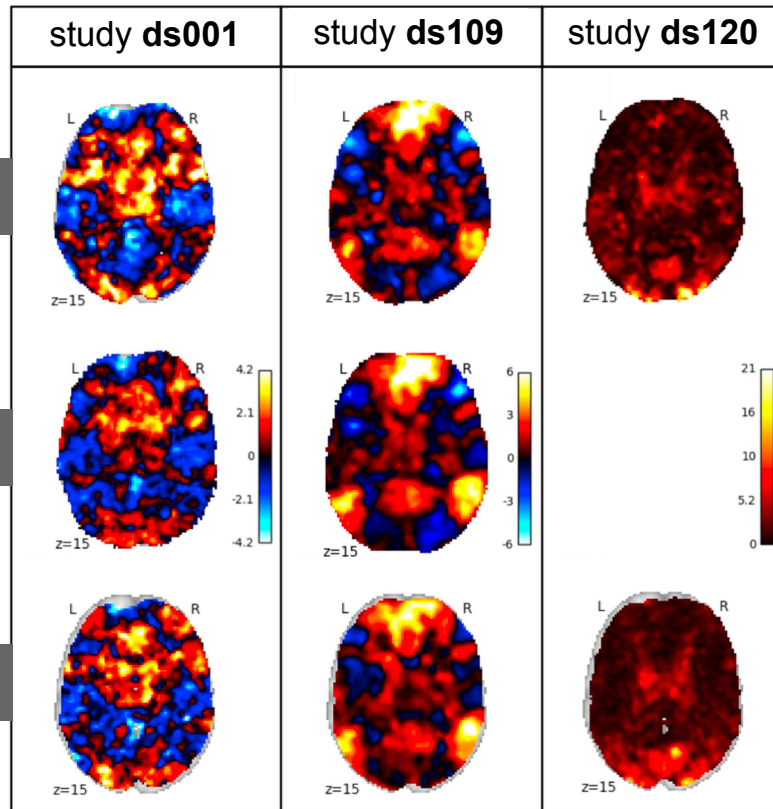
[Bowring Maumet* Nichols*, HBM 2019]

Variability across neuroimaging software



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- Variability in the unthresholded statistic maps



[Bowring Maumet* Nichols*, HBM 2019]

Variability across neuroimaging software

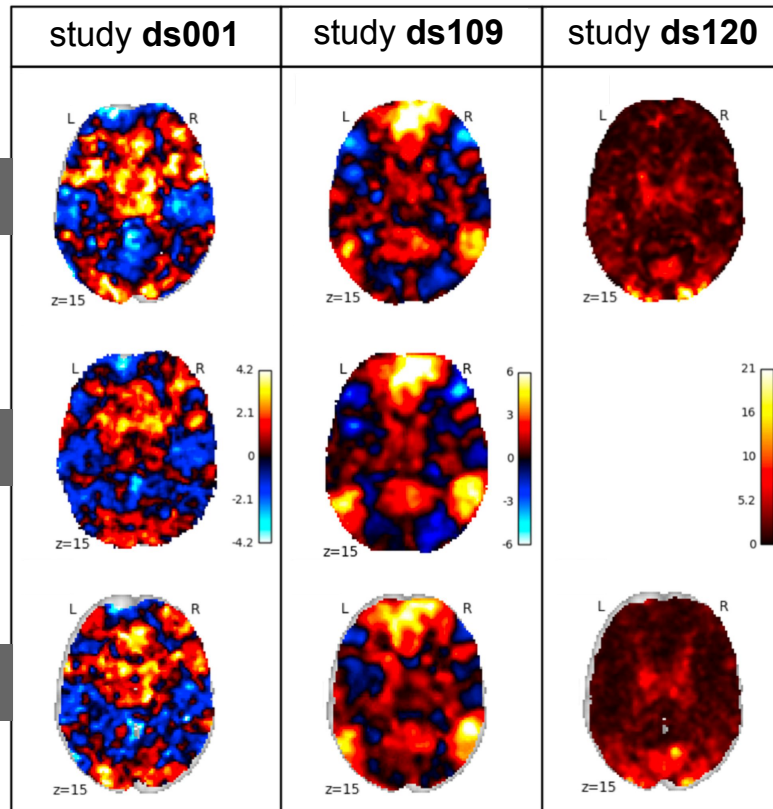


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- Variability in the unthresholded statistic maps



Correlations

AFNI vs. FSL	0.62
AFNI vs. SPM	0.61
FSL vs. SPM	0.68

[Bowring Maumet* Nichols*, HBM 2019]

Variability across neuroimaging software

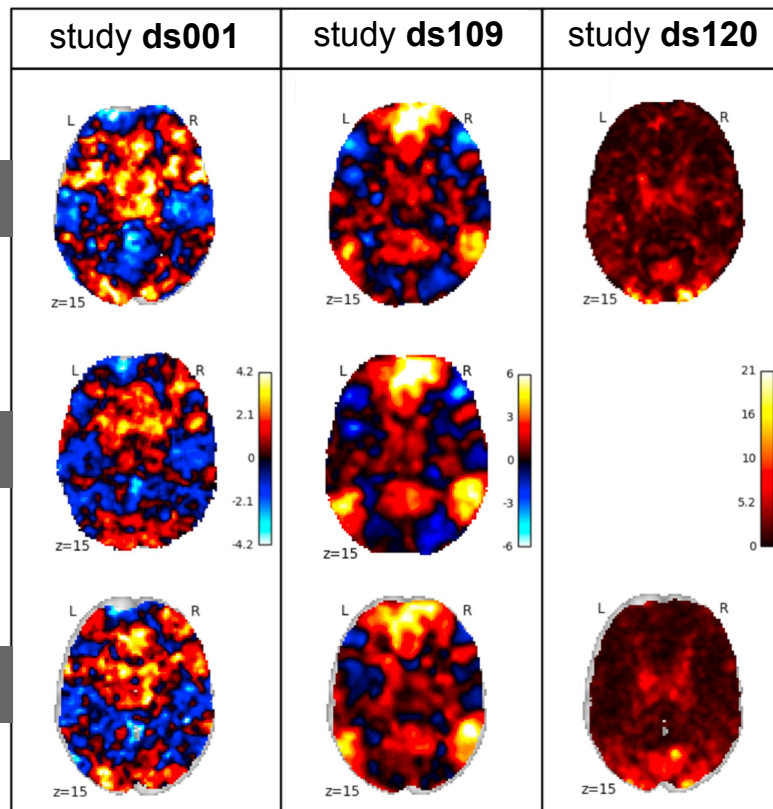


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- Variability in the unthresholded statistic maps



Correlations

AFNI vs. FSL	0.62
AFNI vs. SPM	0.61
FSL vs. SPM	0.68

The choice of software impacts both the final activation and statistic maps

[Bowring Maumet* Nichols*, HBM 2019]

Variability across neuroimaging software



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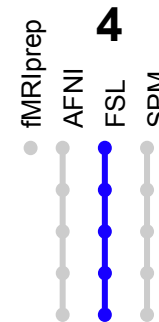
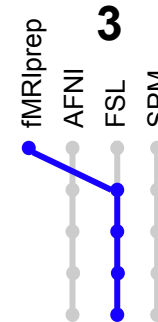
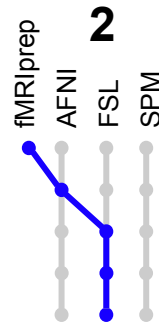
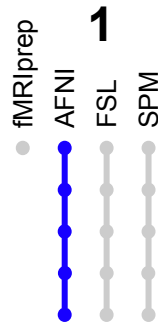


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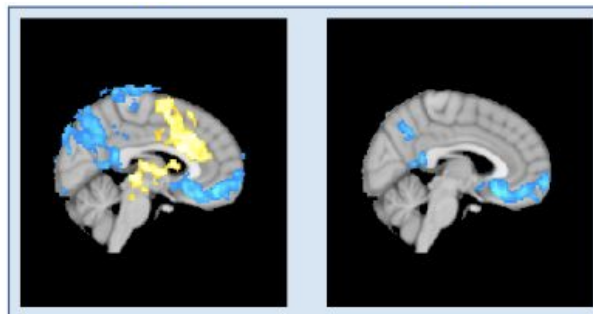
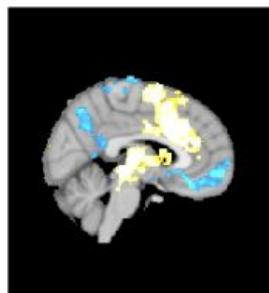
Goal 2: Investigate how remaining differences in software implementations can explain the observed differences

study ds001

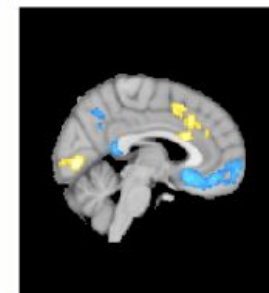
1. Preprocessing
2. Subject-level Signal
3. Subject-level Drift
4. Subject-level Noise
5. Group-level Stat



AFNI
software



FSL
software



[Bowring Nichols* Maumet*, HBM 2021]

Variability across neuroimaging software



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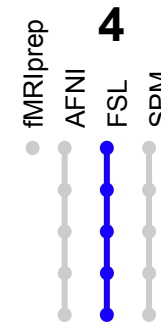
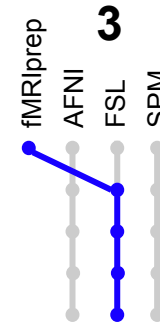
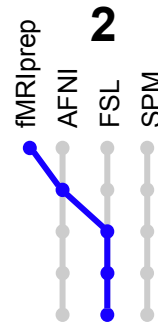
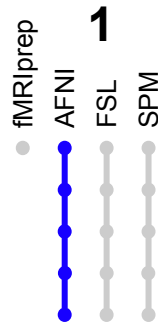


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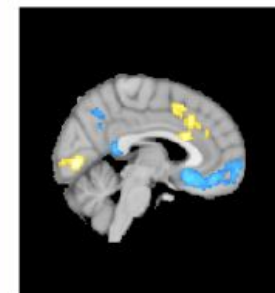
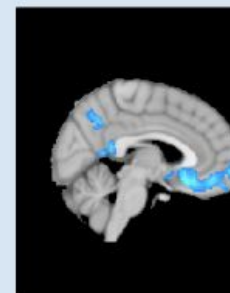
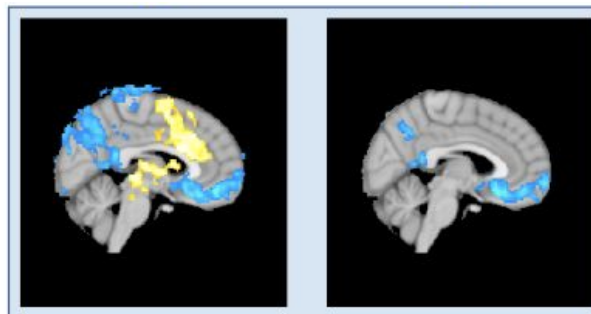
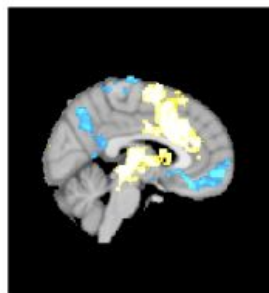
Goal 2: Investigate how remaining differences in software implementations can explain the observed differences

study ds001

1. Preprocessing
2. Subject-level Signal
3. Subject-level Drift
4. Subject-level Noise
5. Group-level Stat



AFNI
software



FSL
software

1 main contributing factor was found but different for each study

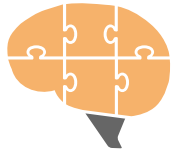
[Bowring Nichols* Maumet*, HBM 2021]



Towards
large-scale
exploration of the
pipeline space

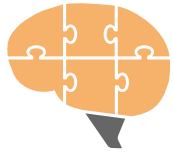
Open questions

Open questions

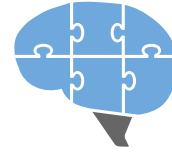


How many variants in
the brain imaging
pipeline space?

Open questions

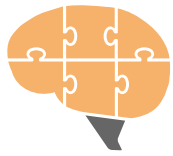


How many variants in the brain imaging pipeline space?

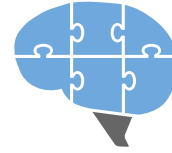


Which proportion of the pipeline space is **used by the community**?

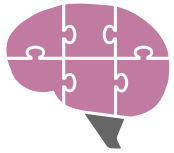
Open questions



How many **variants** in the brain imaging pipeline space?

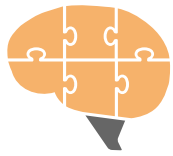


Which proportion of the pipeline space is **used by the community**?

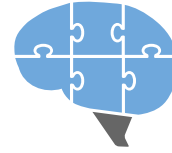


Are there **variants** that always lead to **large impact** in the results?

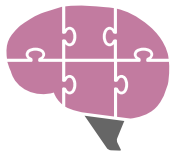
Open questions



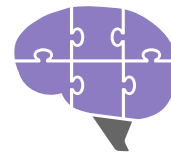
How many **variants** in the brain imaging pipeline space?



Which proportion of the pipeline space is **used by the community**?

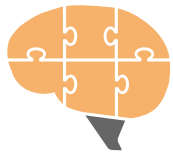


Are there **variants** that always lead to **large impact** in the results?

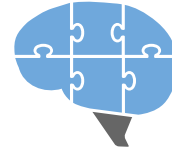


Are there **variants** that have a very **small impact** on the results?

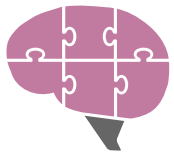
Open questions



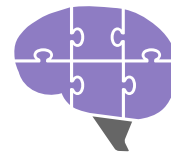
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Are there **variants** that have a very **small impact** on the results?

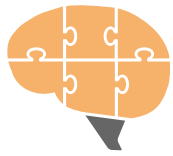


Youenn
Merel

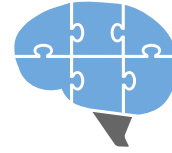


Mathieu
Acher

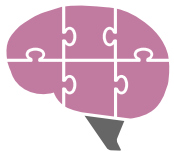
Open questions



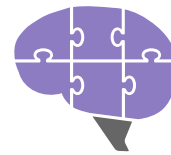
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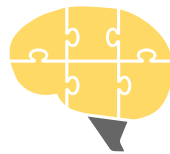
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Youenn Merel



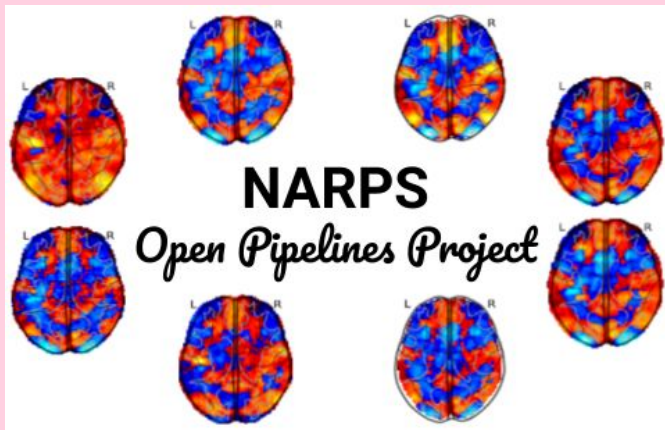
Mathieu Acher



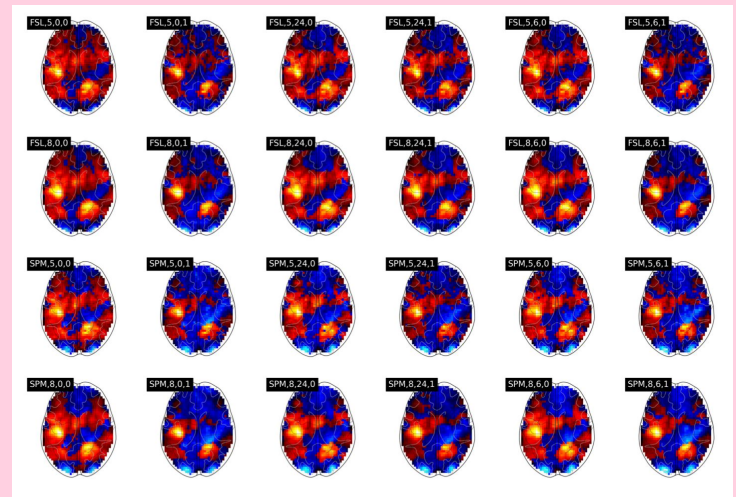
How well do **intuitions from expert brain imagers** map with the actual observed variability?

Open code and data to investigate analytical variability

Open code
NARPS open pipelines

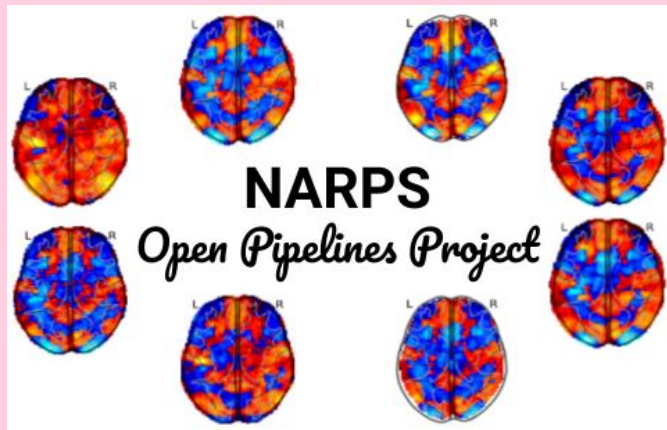


Open data
HCP many pipeline

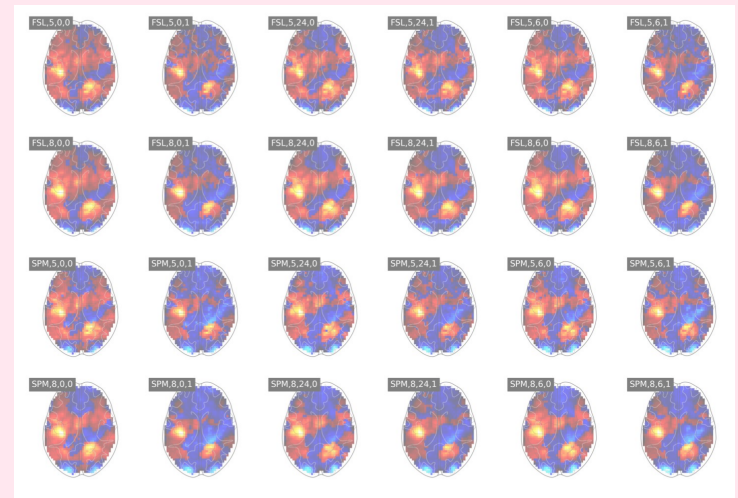


Open code and data to investigate analytical variability

Open code
NARPS open pipelines



Open data
HCP many pipeline



NARPS open pipelines



Boris Clenet



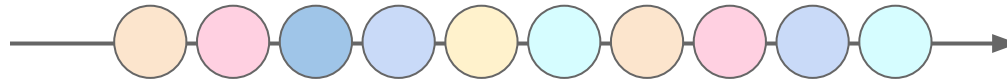
Elodie Germani



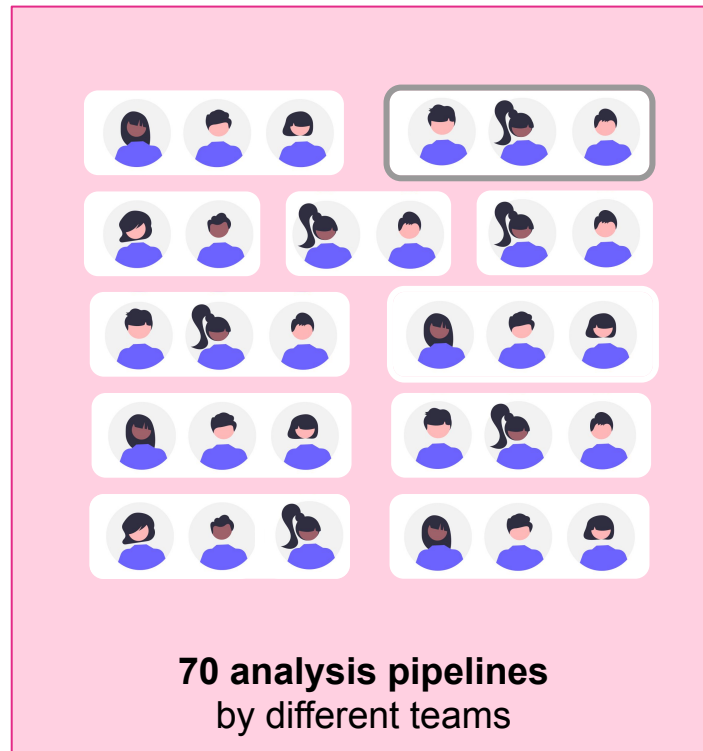
Jérémy Lefort-Besnard



1 dataset



9 'yes/no' questions



NARPS open pipelines



Boris Clenet



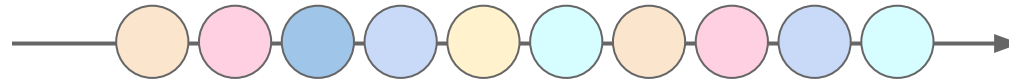
Elodie Germani



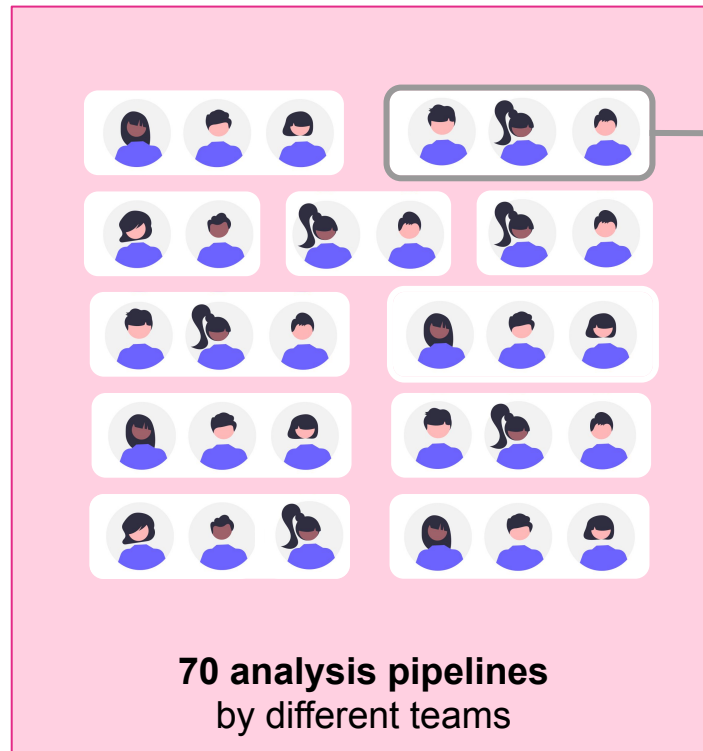
Jérémy Lefort-Besnard



1 dataset



9 'yes/no' questions



70 analysis pipelines
by different teams

NARPS open pipelines



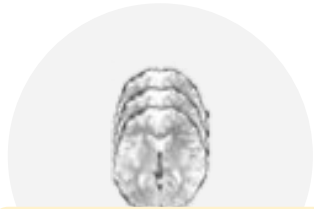
Boris Clenet



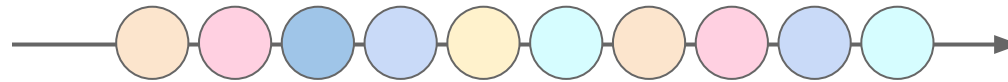
Elodie Germani



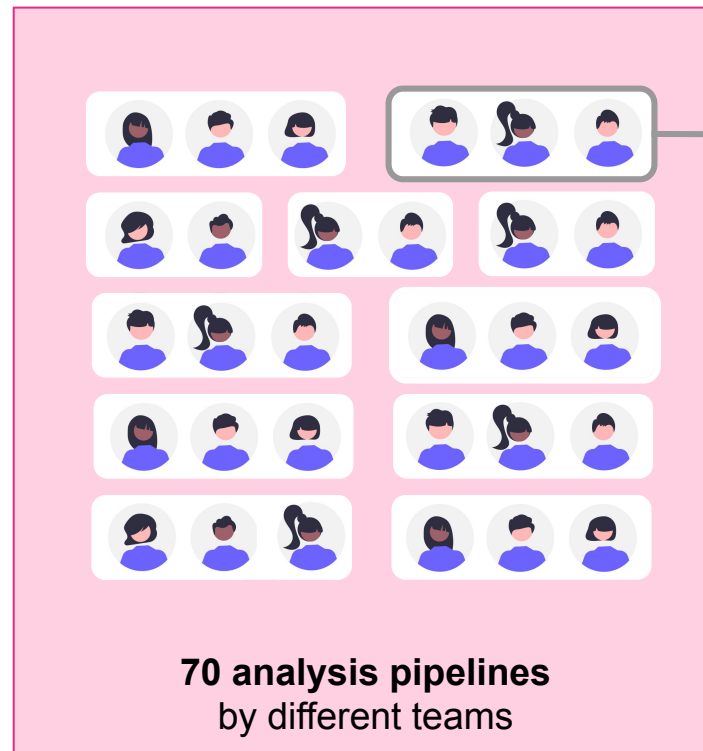
Jérémy Lefort-Besnard



1 dataset



9 'yes/no' questions



Yes/No answer + confidence level

Brain images

Pipeline COBIDAS compliant description (textual)

NARPS open pipelines



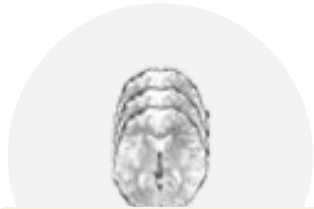
Boris Clenet



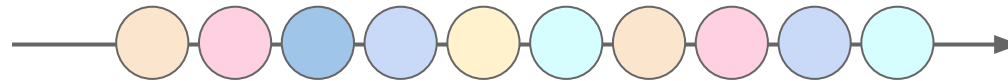
Elodie Germani



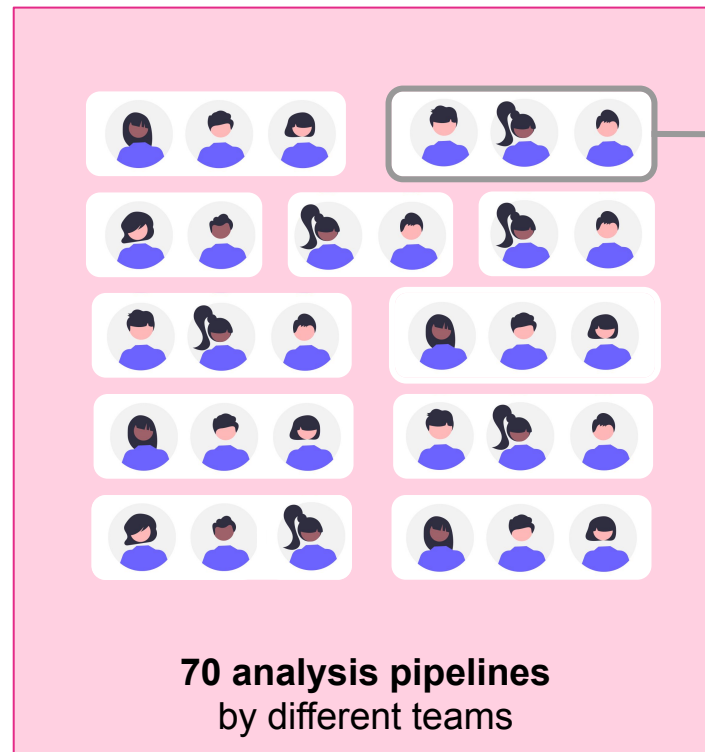
Jérémy Lefort-Besnard



1 dataset



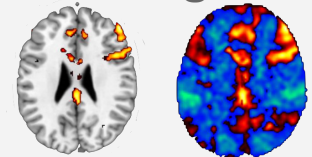
9 'yes/no' questions



70 analysis pipelines
by different teams

Yes/No answer +
confidence level

Brain images



Pipeline COBIDAS
compliant description
(textual)

x9 research
questions

NARPS open pipelines



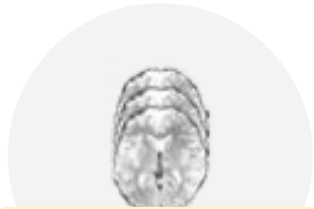
Boris Clenet



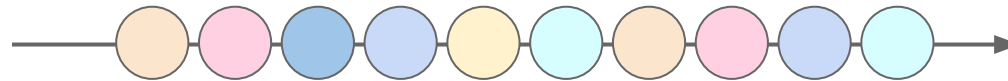
Elodie Germani



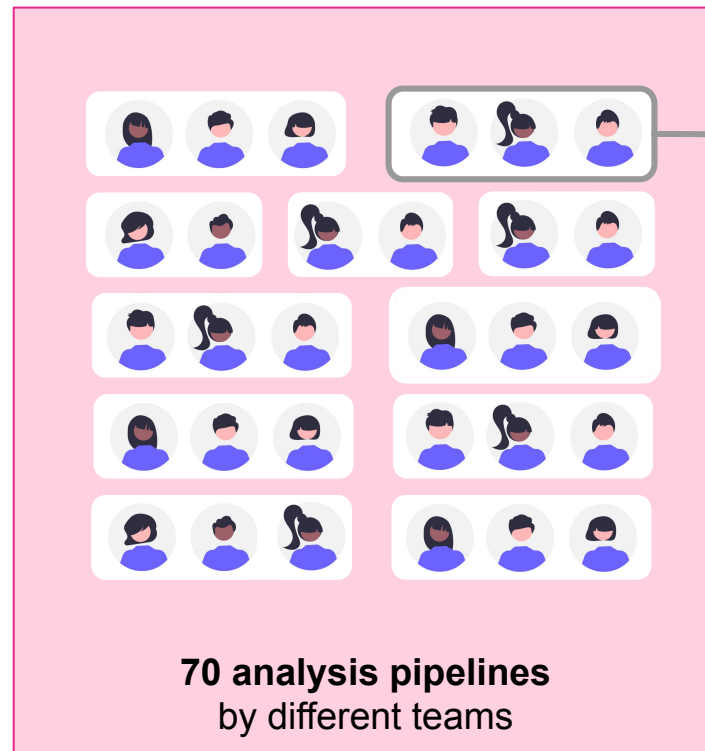
Jérémy Lefort-Besnard



1 dataset



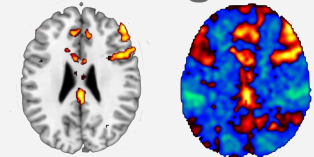
9 'yes/no' questions



70 analysis pipelines
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Yes/No answer +
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Pipeline COBIDAS
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~~Code~~

x9 research
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NARPS open pipelines



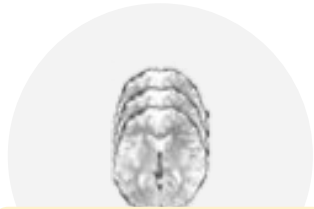
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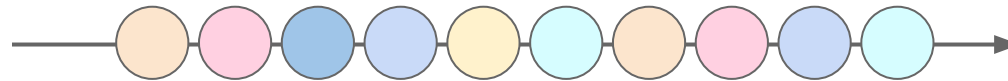
Elodie Germani



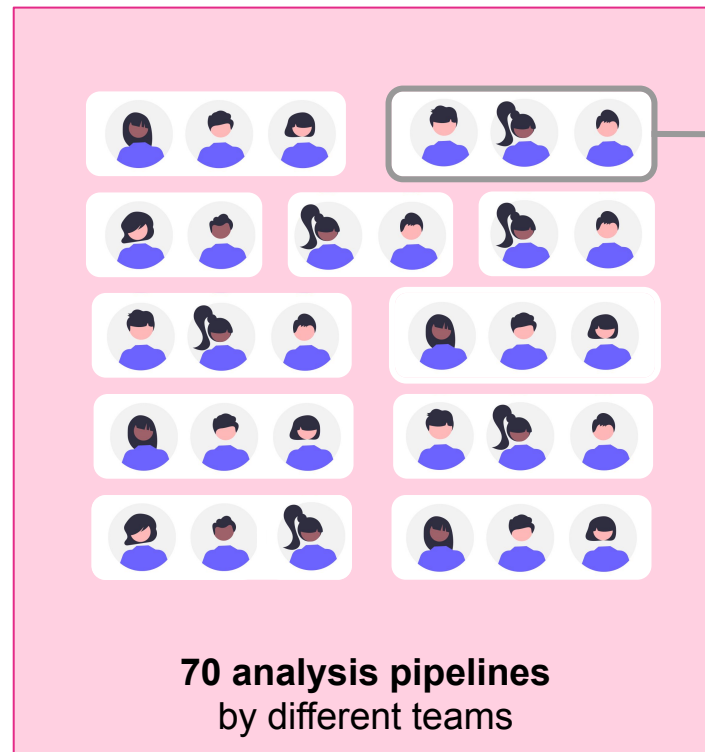
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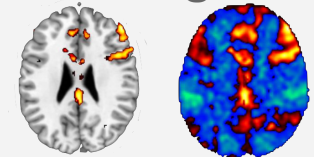
9 'yes/no' questions



70 analysis pipelines
by different teams

Yes/No answer +
confidence level

Brain images



Pipeline COBIDAS
compliant description
(textual)

✓ Code → NARPS
open

x9 research
questions

NARPS open pipelines



**Boris
Clenet**



**Elodie
Germani**



**Jérémy
Lefort-Besnard**

brainhack.org

Credits - This project was presented and received contributions during the following events:

- Empenn hackathon (February 2024)
- [Brainhack Marseille 2023](#) (December 2023)
- [ORIGAMI lab](#) hackathon (September 2023)
- [OHBM Brainhack 2023](#) (July 2023): Arshitha Basavaraj, Boris Clenet, Rémi Gau, Élodie Germani, Yaroslav Halchenko, Camille Maumet, Paul Taylor.
- [e-ReproNim FENS NENS Cluster Brainhack](#) (June 2023) : Liz Bushby, Boris Clenet, Michael Dayan, Aimee Westbrook.
- [OHBM Brainhack 2022](#) (June 2022): Elodie Germani, Arshitha Basavaraj, Trang Cao, Rémi Gau, Anna Menacher, Camille Maumet.

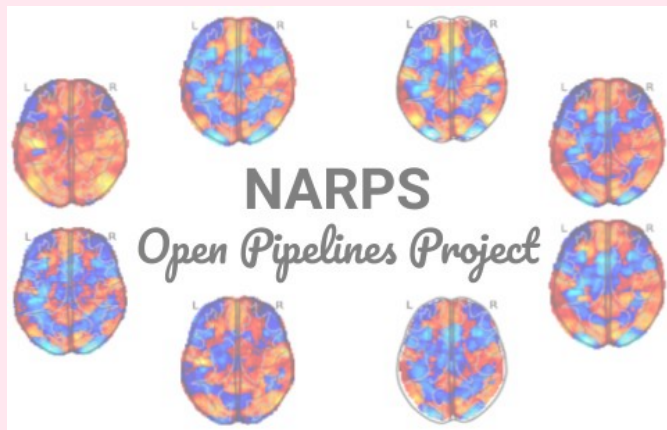
Open code



https://github.com/Inria-Empenn/narps_open_pipelines/

Open code and data to investigate analytical variability

Open code
NARPS open pipelines



Open data
HCP many pipeline



HCP many pipeline



Elodie Germani

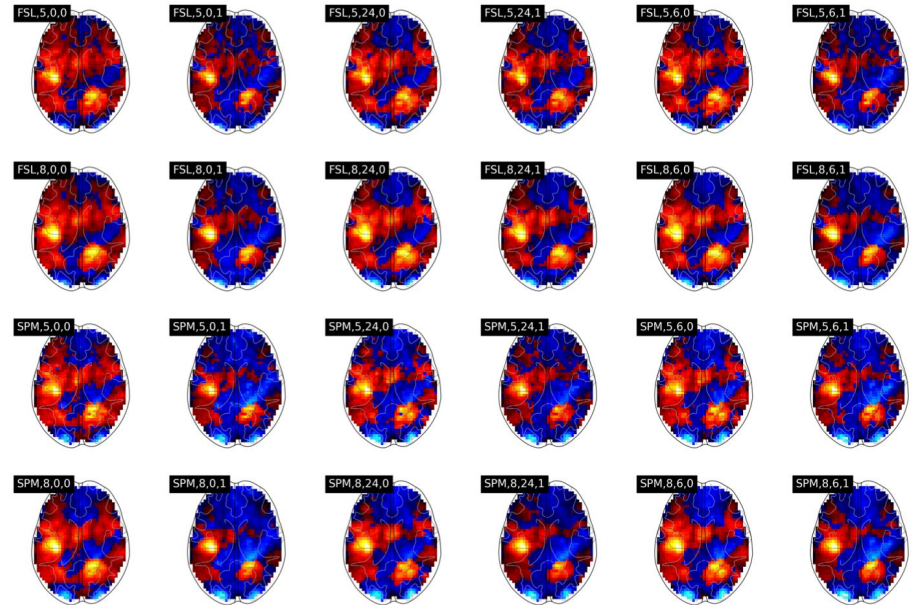


Pierre Maurel



Elisa Fromont

- **1 dataset**
 - Human Connectome Project (HCP) Young Adult
- **24 pipelines**
 - FSL, SPM / 2 HRF / 2 smoothing / 3 motion regressors
- **1080 participants and 1000 groups (50 subjects)**



Shared data (in compliance with GDPR)



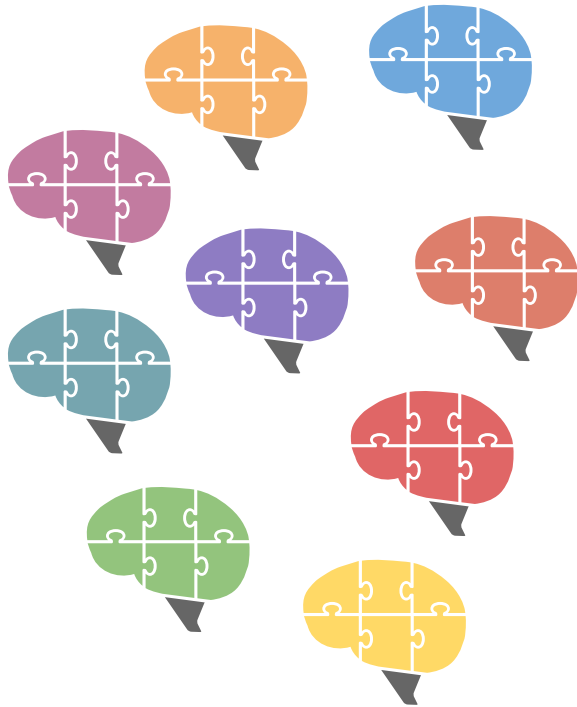
[HCP multi pipeline on Public-nEUro](#)

[Germani et al, preprint [hal:inserm-04356768](https://hal.inserm-04356768)]

February 4, 2025

VAMOS 2025

4 - 6 FEBRUARY
- RENNES, FRANCE



Variability in **brain imaging** studies across different **analysis pipelines**

Camille Maumet

Thank you!

Acknowledgments



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