

# Characterizing the Stability of Neuroimaging Analyses Through Perturbations in Experimental Design

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2017 McGill University Healthy Brains for Healthy Lives Fellow,  
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B.Eng Carleton University



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# Overview

- Re-introduction to broad thesis topic
- Progress to date
- Next steps
- Timeline for graduation

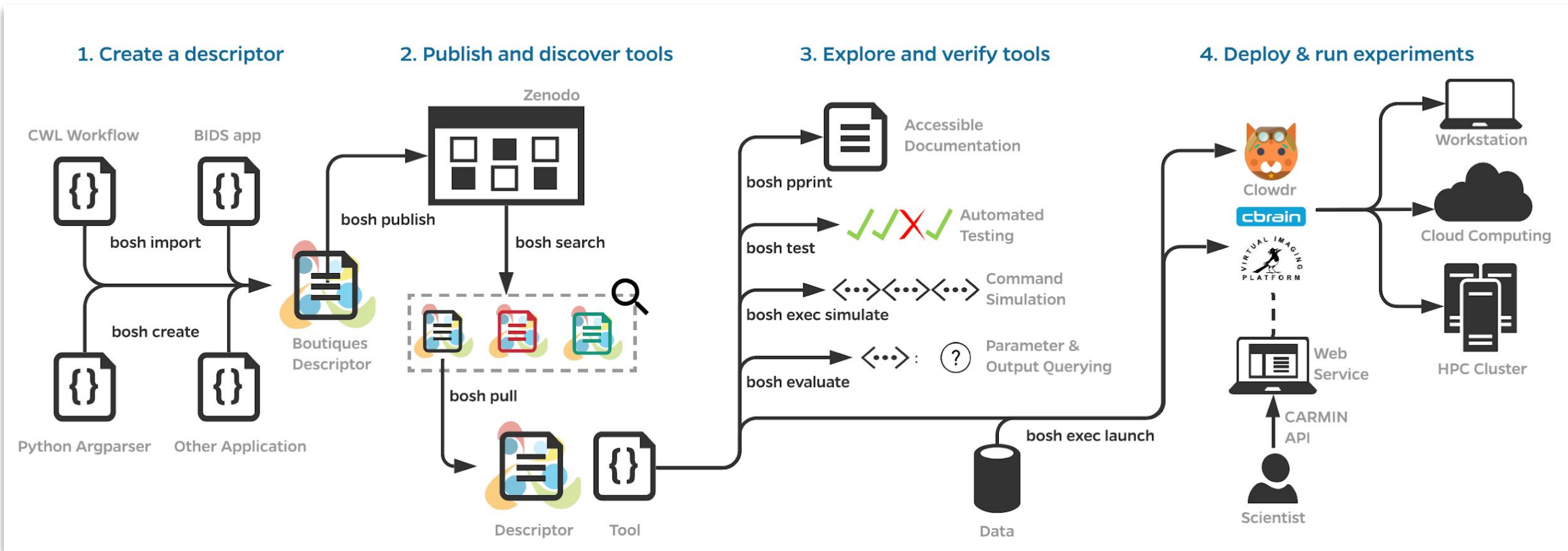
# Thesis Objective

To explore and evaluate the effect that minor perturbations have on neuroimaging pipelines, thereby shedding light on the state of stability in neuroimaging and possible paths forward.

# Chapter 1: Facilitating FAIR Tool Creation, Consumption, and Deployment

Complete

# Boutiques & Clowdr Enable FAIR Tooling

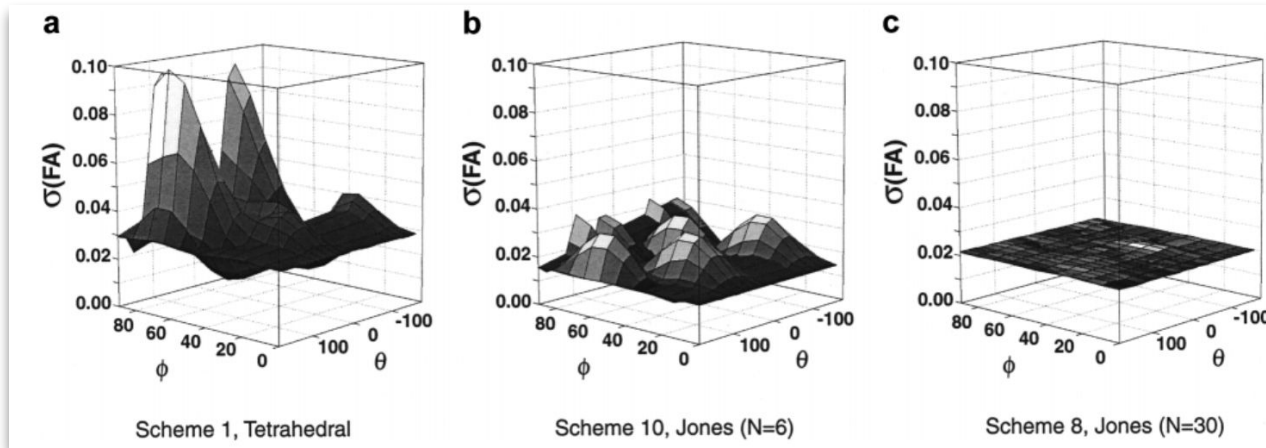


(Kiar, 2019)

# Chapter 2: Comparing Methods for Identifying Instabilities in Pipelines

Complete

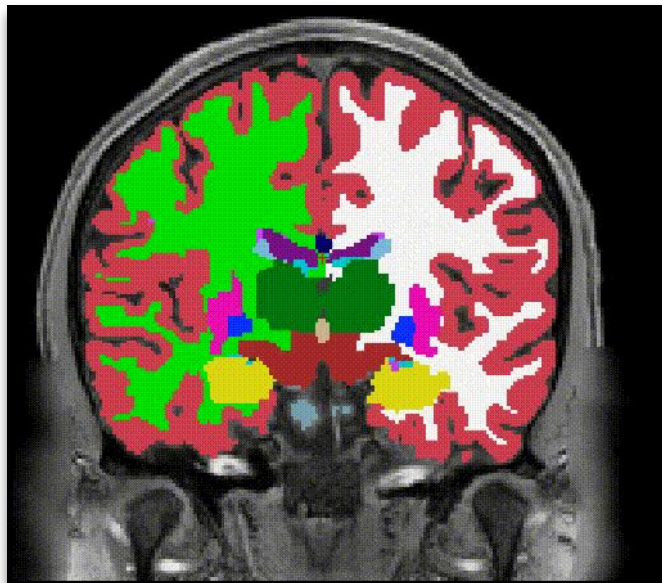
# Identifying Instabilities in Neuroimaging



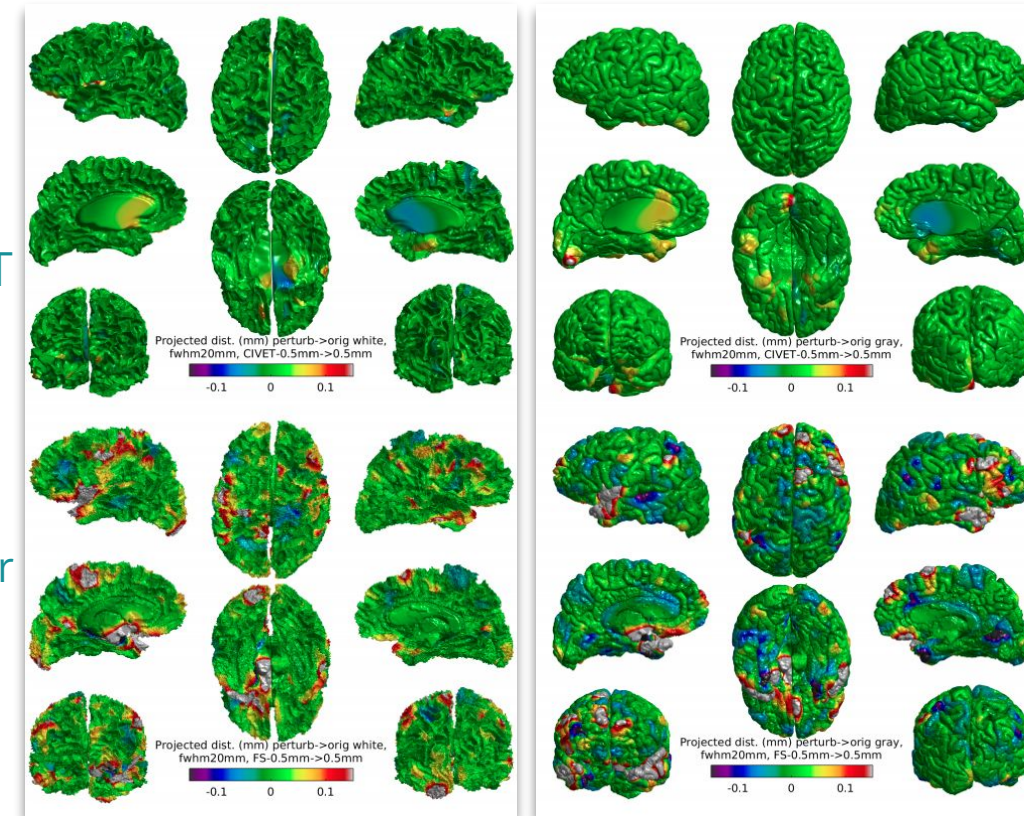
(Skare, 2000)

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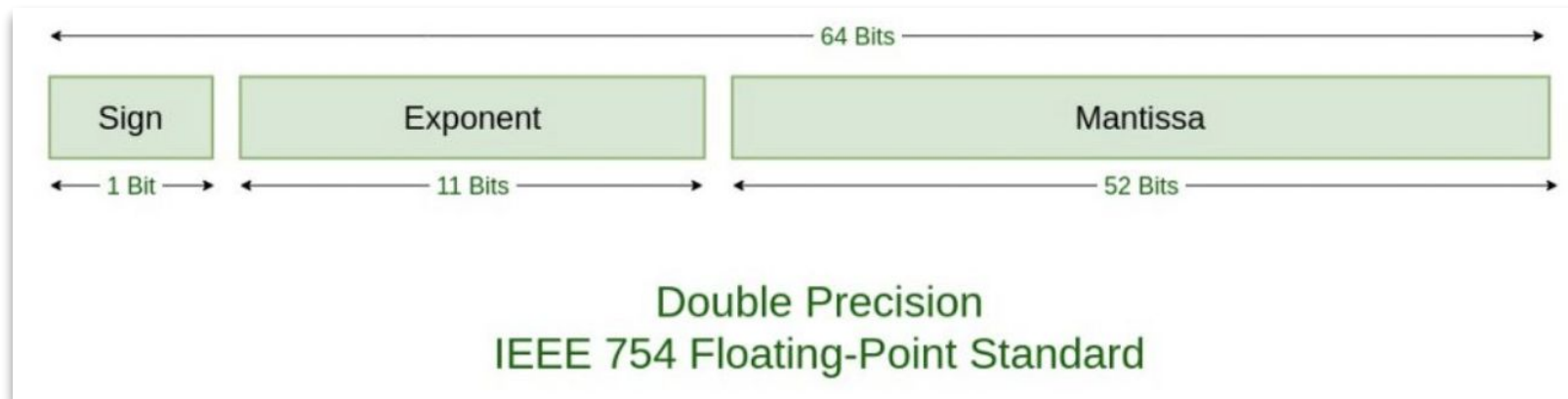
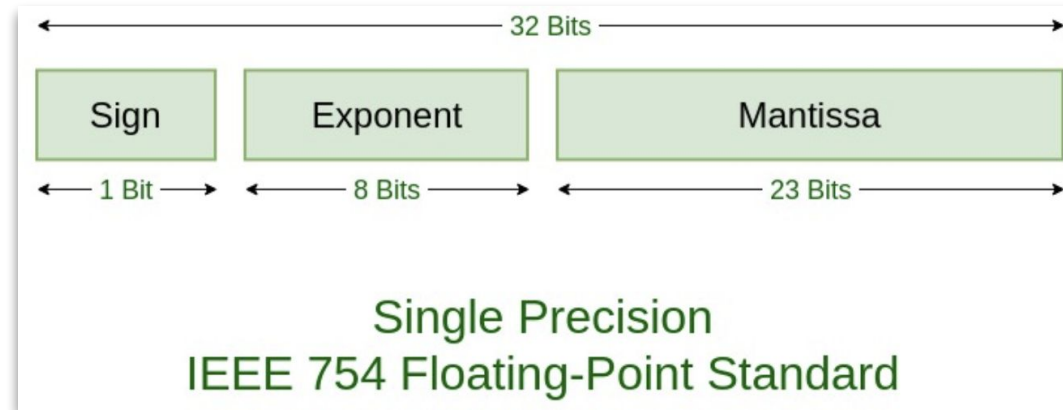
(Scaria, 2017)



(Lewis, 2017)



# Floating Point Representations are Finite



<https://www.geeksforgeeks.org/ieee-standard-754-floating-point-numbers/>



# Floating Point Arithmetic is Inexact

E.g. addition is non associative for the following with 8-digits

$$\begin{aligned} (11111113. \oplus -11111111.) \oplus 7.5111111 &= 2.0000000 \oplus 7.5111111 = 9.5111111; \\ 11111113. \oplus (-11111111. \oplus 7.5111111) &= 11111113. \oplus -11111103. = 10.000000. \end{aligned}$$

(Parker, 1997)

# Monte Carlo Arithmetic (MCA)

Inexact quantities become random variables

$$\tilde{x} = \text{inexact}(x, s, \xi) = x + 2^{e-s} \xi \quad \text{where } e \text{ is the order of magnitude of } x$$

$$t\_digit\_precision(x) = \begin{cases} x & \text{if } x \text{ can be expressed exactly with } t \text{ digits} \\ \text{inexact}(x, t, \xi) & \text{otherwise.} \end{cases}$$

(Parker, 1997)

## Setup

Compile C/C++/Fortran lib with Verificarlo

## Instrumentation

*launch pipeline...*

1. if floating point operation:
2.     convert {float, double} -> {double, quad}
3.     (PB) simulate unrounding/rounding
4.     perform operation
5.     (RR) simulate unrounding/rounding
6.     truncate {double, quad} -> {float, double}
7. endif

*... re-run pipeline N times*

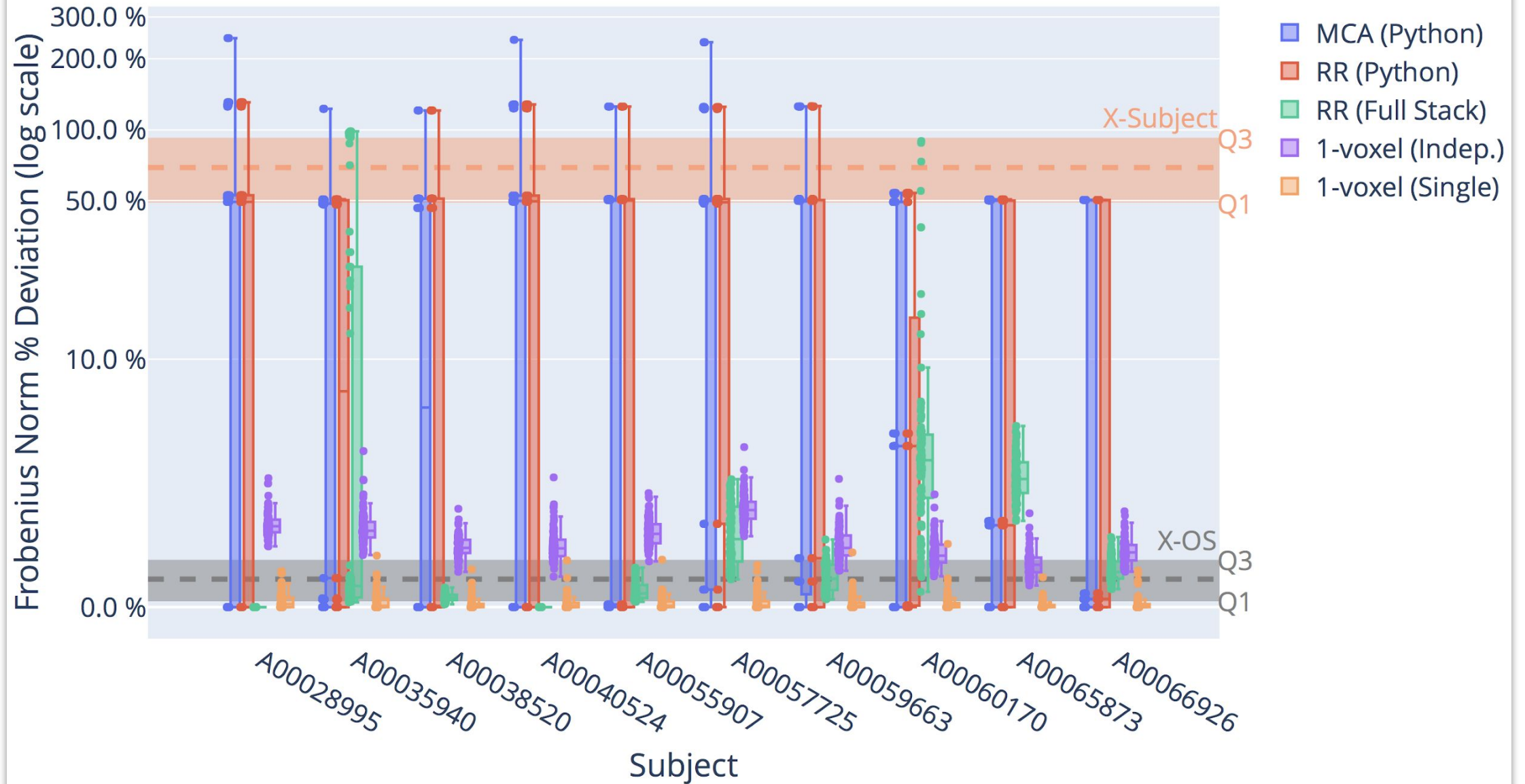


**Verificarlo v0.2.3**

build passing DOI 10.5281/zenodo.3370928

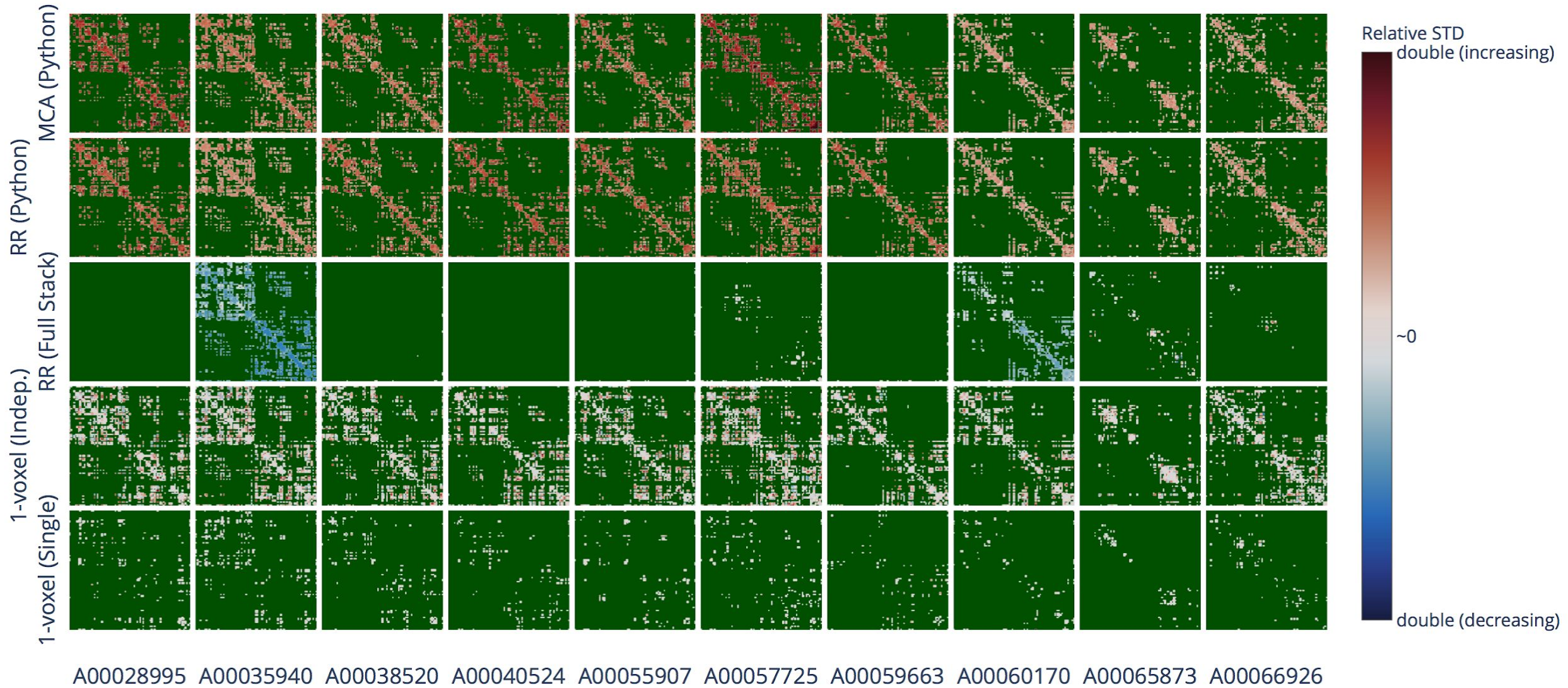
A tool for automatic Montecarlo Arithmetic analysis.

# Differences in Perturbed Structural Connectomes

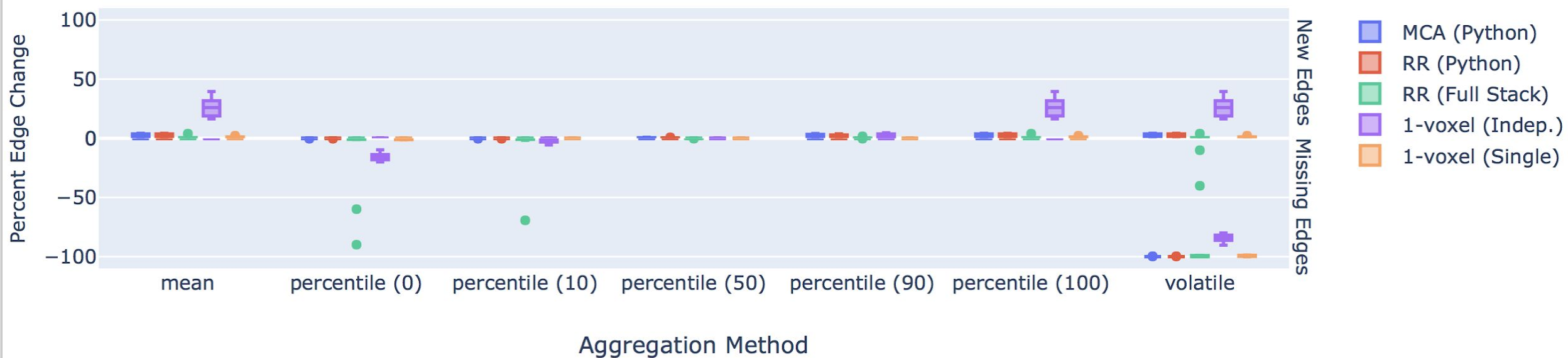




# Structural Differences Across Perturbation Modes and Subjects



## Deviations in Aggregated Edge Count from Reference



# Chapter 3: Evaluating Analytical Impact of Instabilities

In Progress

# Chapter 4: Improving Pipeline Stability Through Statistical Aggregation

In Progress

# Chapter 5: Informing Tool Selection Based on the Stability of Pipelines

ToDo



# Thesis Outline

Chapter 1: Facilitating FAIR Tool Creation, Consumption, and Deployment

Chapter 2: Comparing Methods for Identifying Instabilities in Pipelines

Chapter 3: Evaluating Analytical Impact of Instabilities

Chapter 4: Improving Pipeline Stability Through Statistical Aggregation

Chapter 5: Informing Tool Selection Based on the Stability of Pipelines

# Timeline



Ph.D. Start (September, 2017)



Ch. {1, 2, 3, 4, 5}

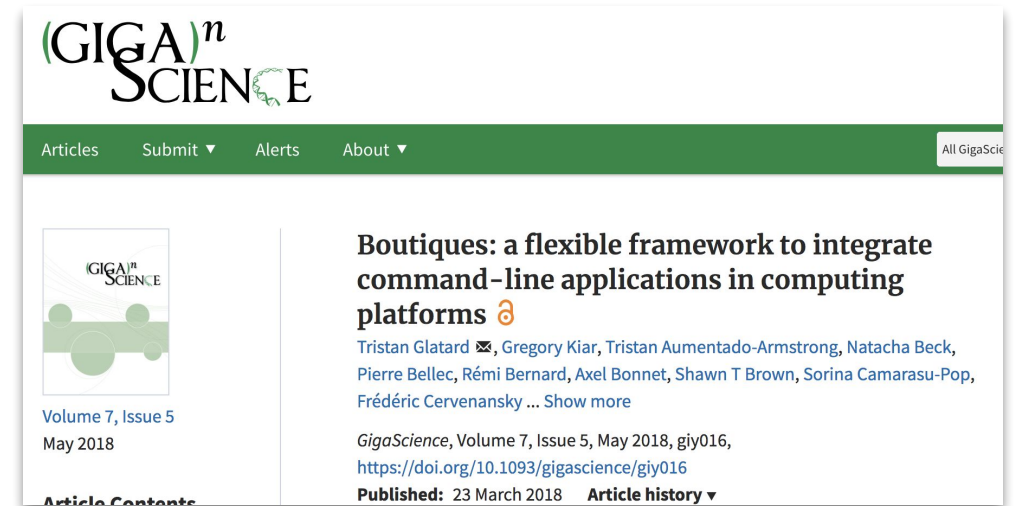


Ph.D. Start (September, 2017)

NSERC CGS-D (March, 2018)

Boutiques (2nd author; March, 2018)

Clowdr (March, 2019)



Ch. {1, 2, 3, 4, 5}



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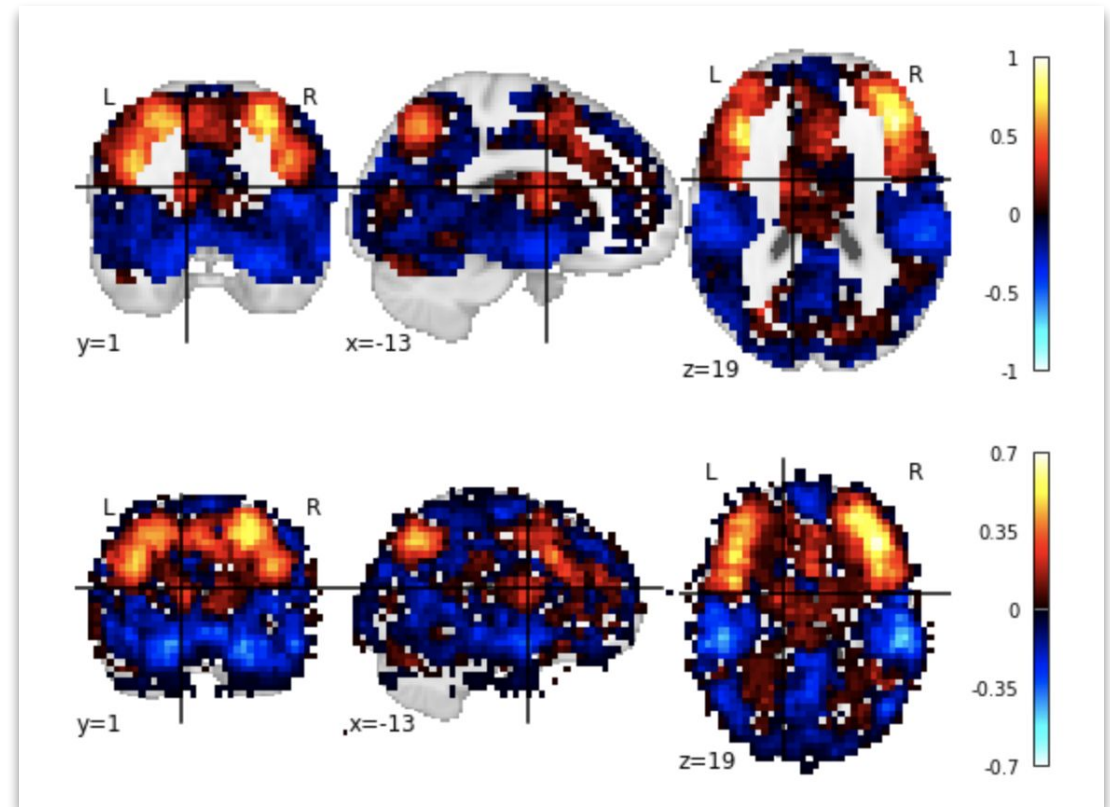
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NSERC MS-FSS (December, 2018)

Mitacs Globalink (February, 2019)

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DL Aggregation Method (April, 2019)



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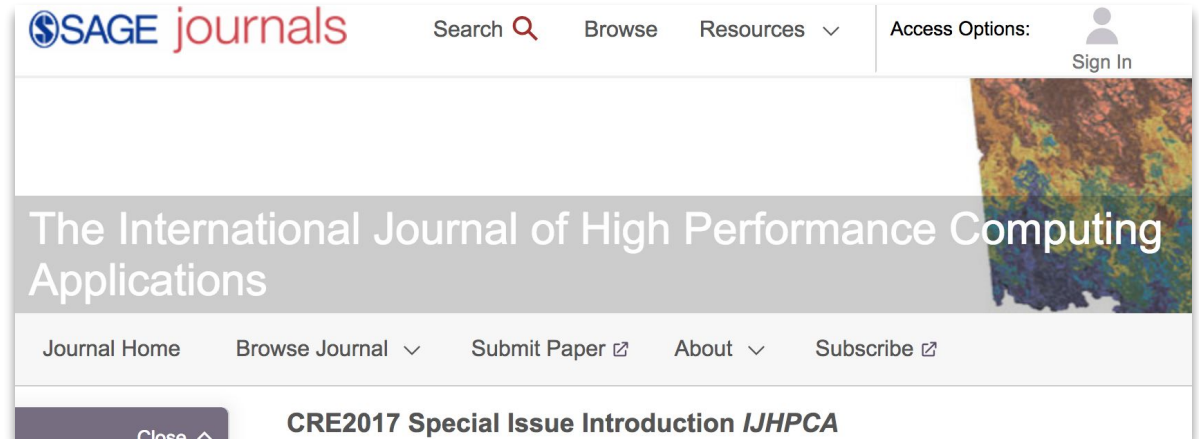
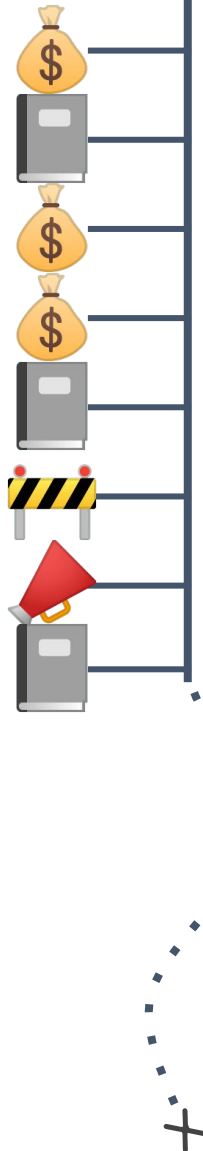
Mitacs Globalink (February, 2019)

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DL Aggregation Method (April, 2019)

Exploring Perturbations (Nov, 2019)

Exploring Perturbations (Dec, 2019)



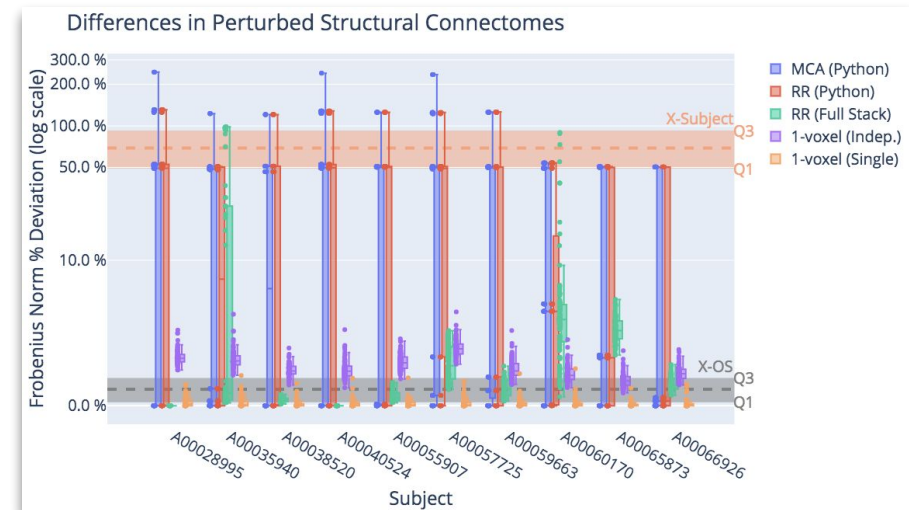
arXiv.org > q-bio > arXiv:1908.10922

Quantitative Biology > Neurons and Cognition

## Comparing Perturbation Models for Evaluating Stability of Neuroimaging Pipelines

Gregory Kiar, Pablo de Oliveira Castro, Pierre Rioux, Eric Petit, Shawn T. Brown, Alan C. Evans, Tristan Glatard

(Submitted on 28 Aug 2019 (v1), last revised 17 Oct 2019 (this version, v2))





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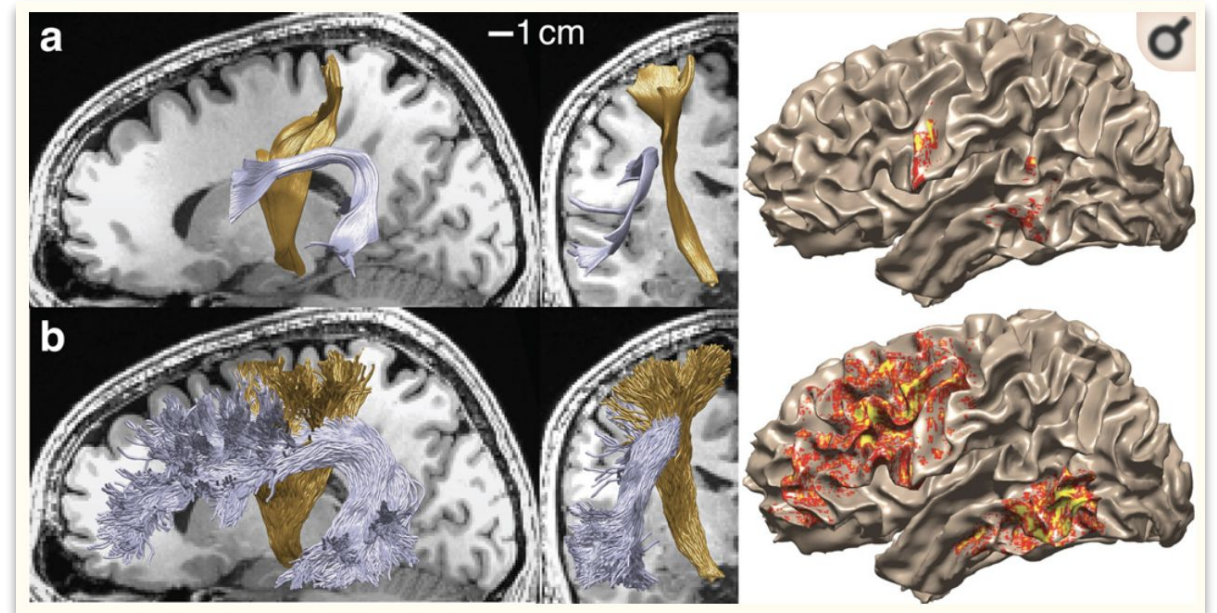
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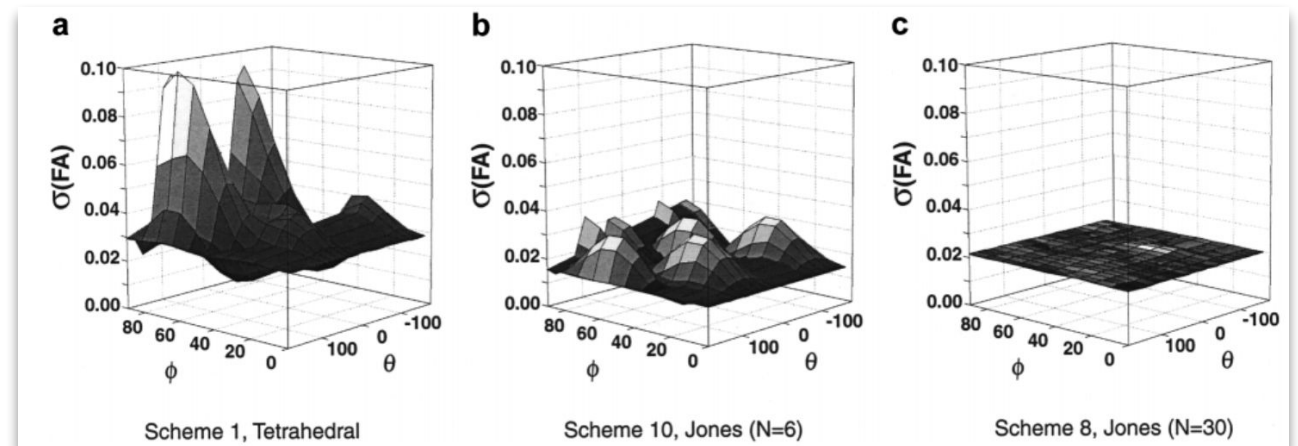
Exploring Perturbations (Dec, 2019)

Exploring Analytic Impact (2019)

Relative Algorithmic Stability (2020)



(Pestilli, 2015)



(Skare, 2000)





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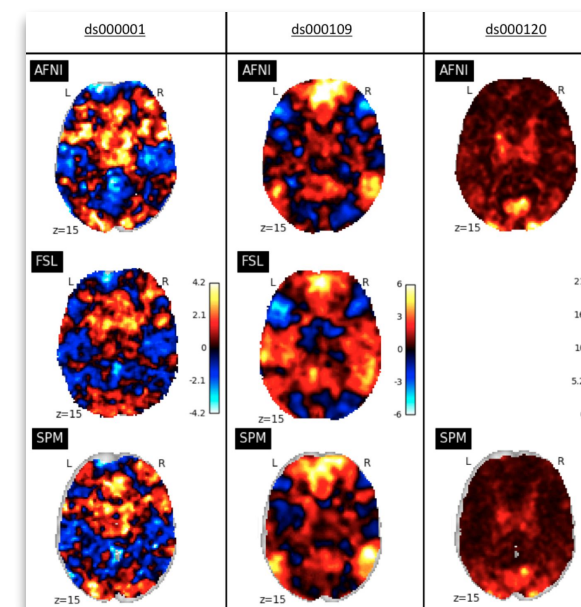
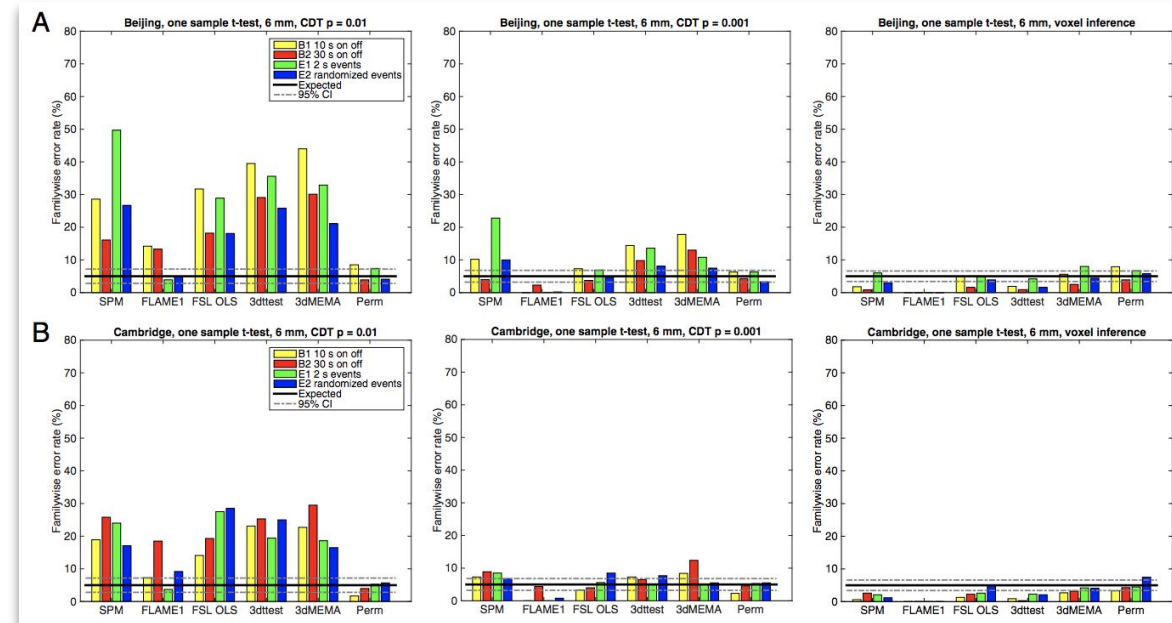
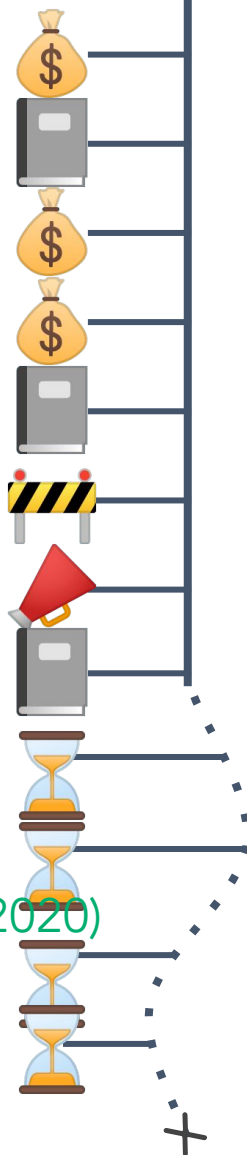
Exploring Perturbations (Dec, 2019)

Exploring Analytic Impact (2019)

Relative Algorithmic Stability (2020)

Evaluating Aggregation Methods (2020)

Tool Comparison & Ranking (2020)



(Eklund, 2016)

(Bowring, 2019)

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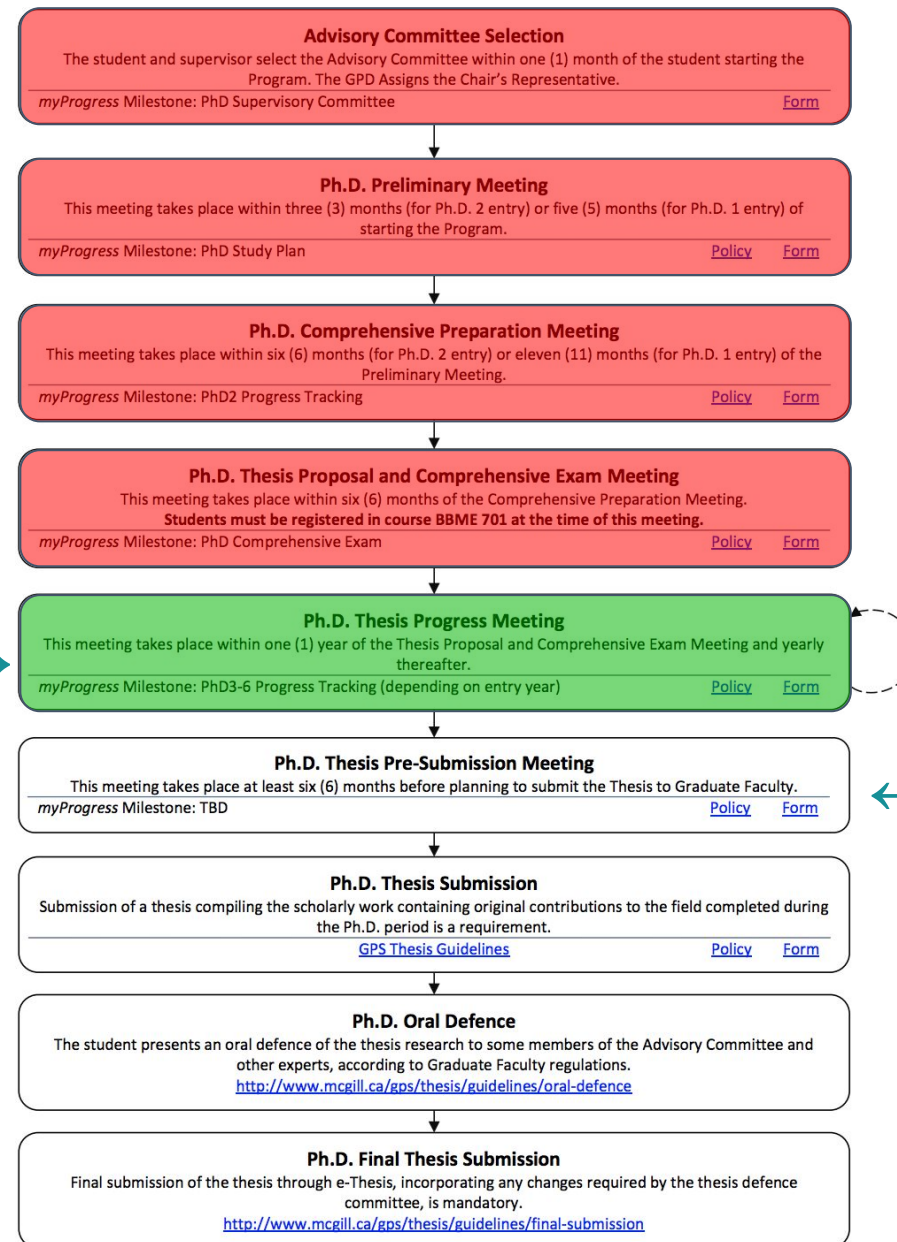
Tool Comparison & Ranking (2020)

Ph.D. Defence (March, 2021)

Total Time: 3.5 years



we are here →



← approval required 6 months pre-defense

i.e. this time next year

All code mentioned in this presentation is publicly available on GitHub.

Thanks!

Find me @

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 g\_kiar

 greg.kiar@mail.mcgill.ca



# Acknowledgements



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# Questions?