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Universität
Oldenburg

DEPARTMENT OF PSYCHOLOGY
CARL VON OSSIETZKY UNIVERSITY OLDENBURG

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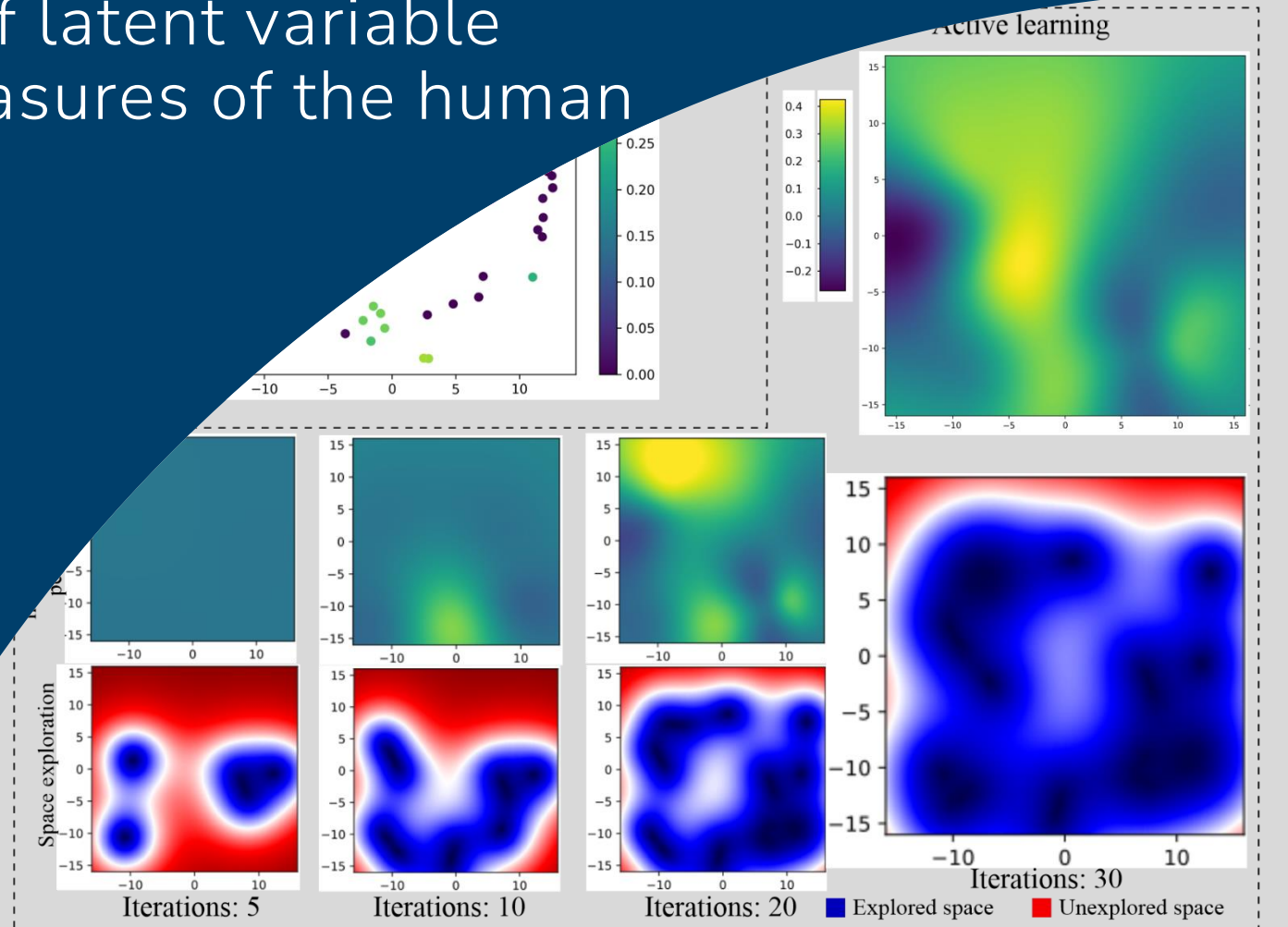
Approximating the multiverse of latent variable predictions by graph theory measures of the human connectome – An extended active learning approach

Daniel Kristanto, et al.
University of Oldenburg

Guardians, 2023



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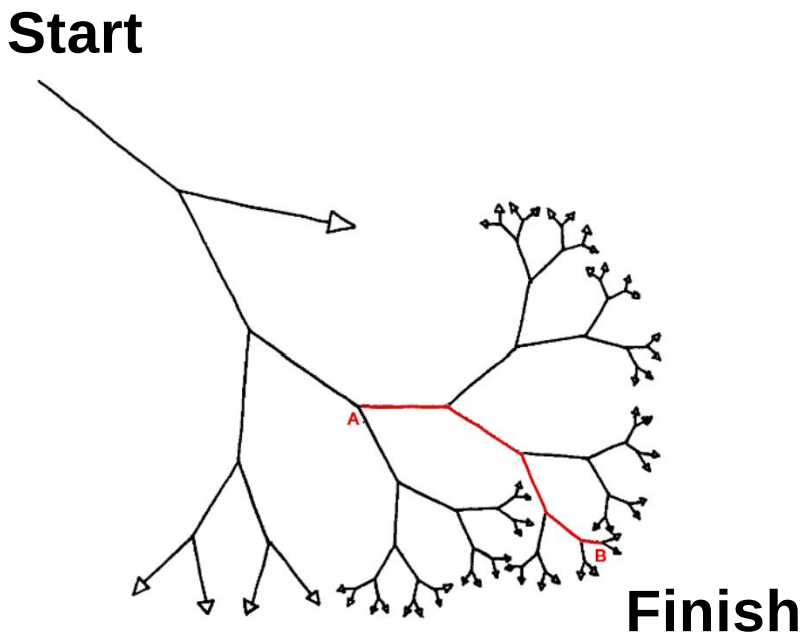
A garden of forking path

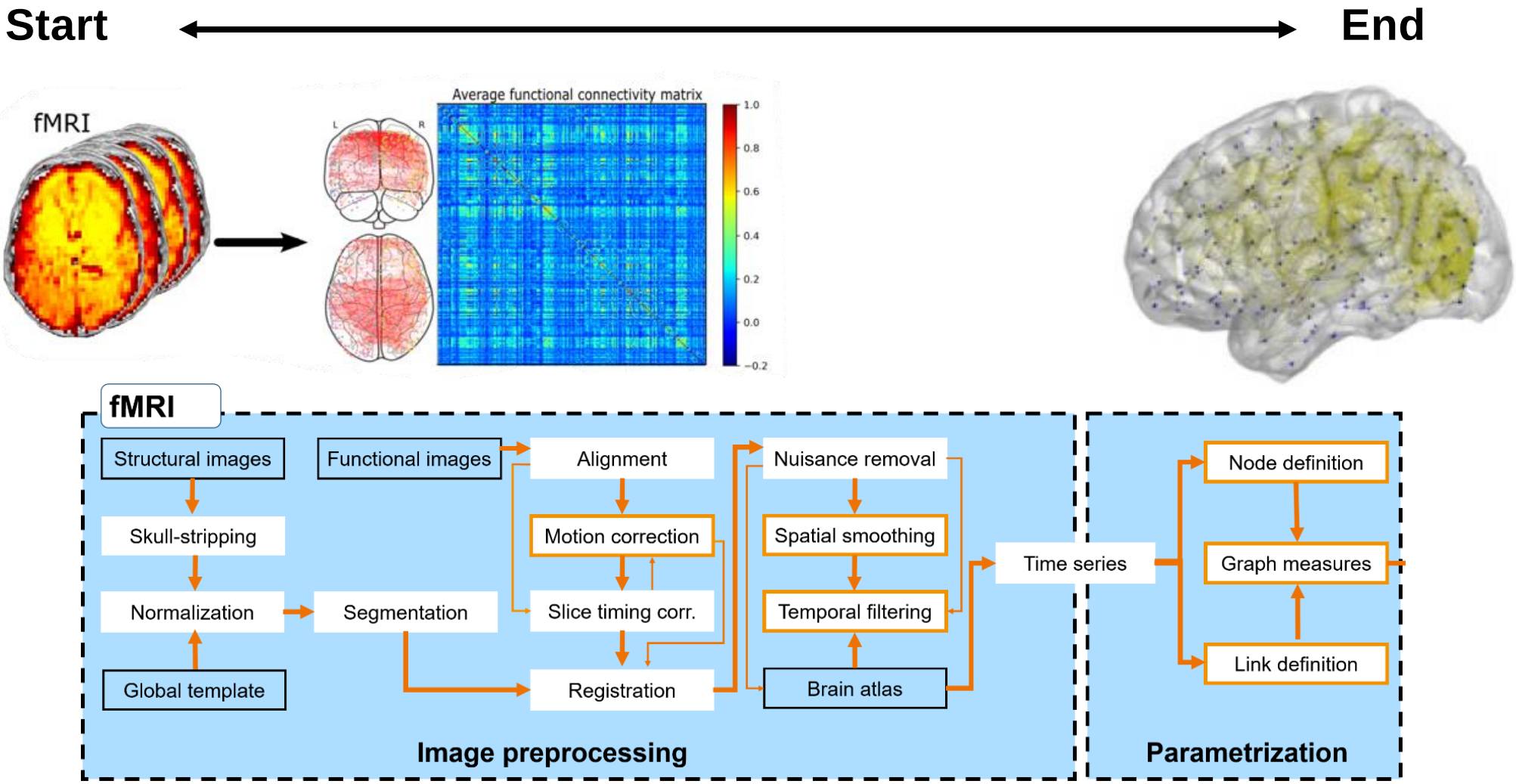


The Graden of Forking Paths
By Jorge Luis Borger

- Every methodological decision creating a unique forking path (universe) is potentially impactful
- A group of the forking paths (universes) creates a **multiverse of potential analyses** ranging from the raw data to the outcome of a statistical association

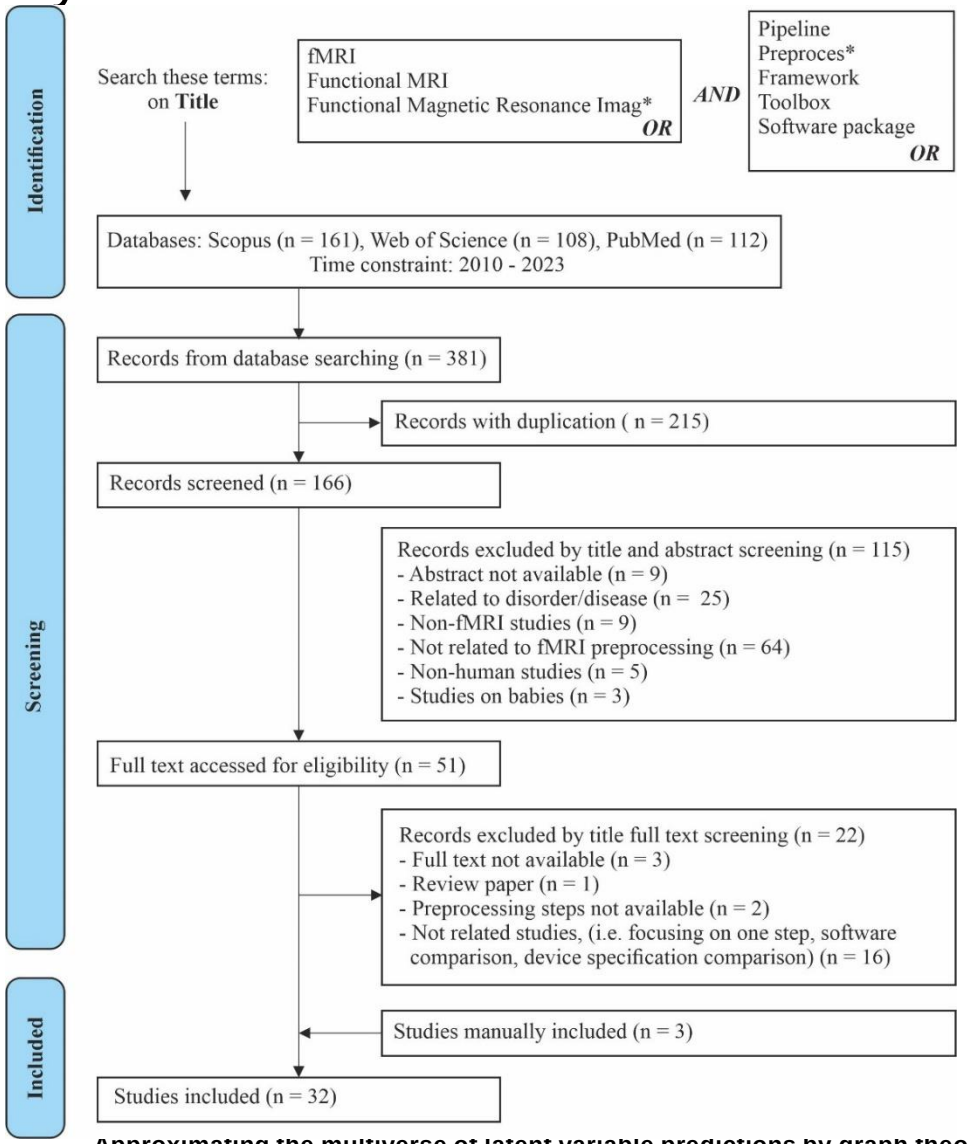
. . .

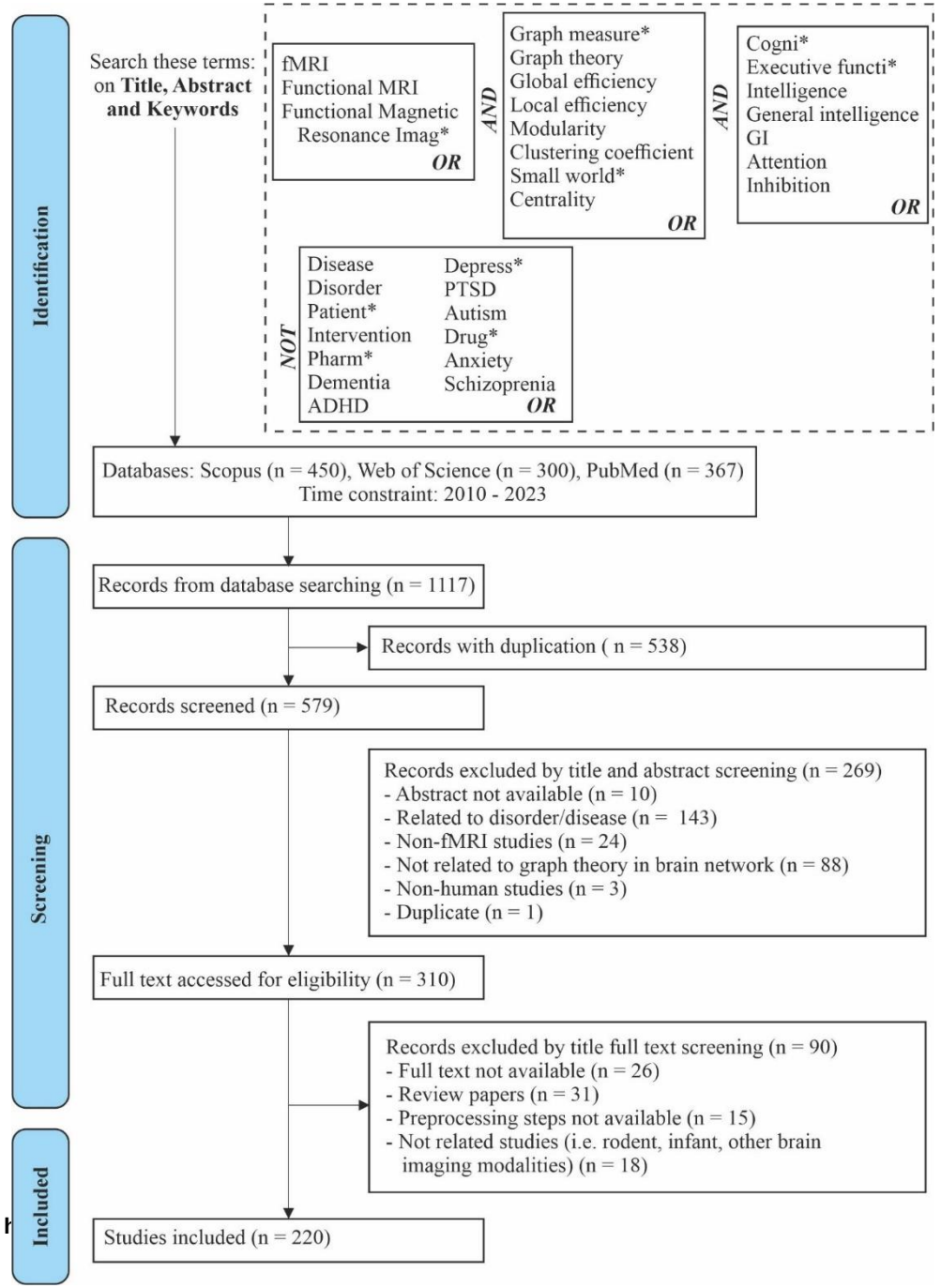
The garden of forking paths in fMRI-based graph definition (and its association with behavioral outcomes)



Defining the forking paths

Systematic literature review N = 252





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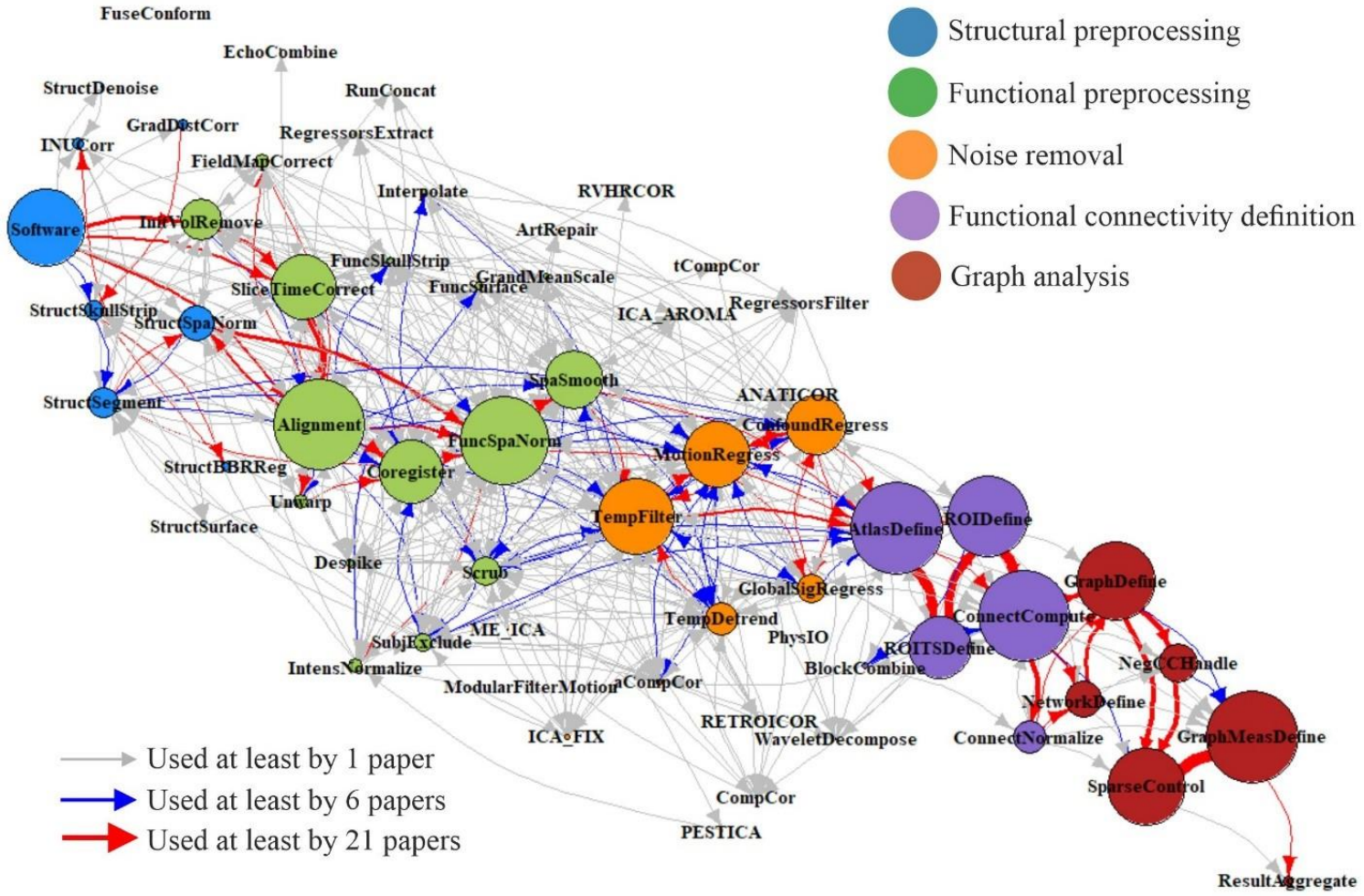
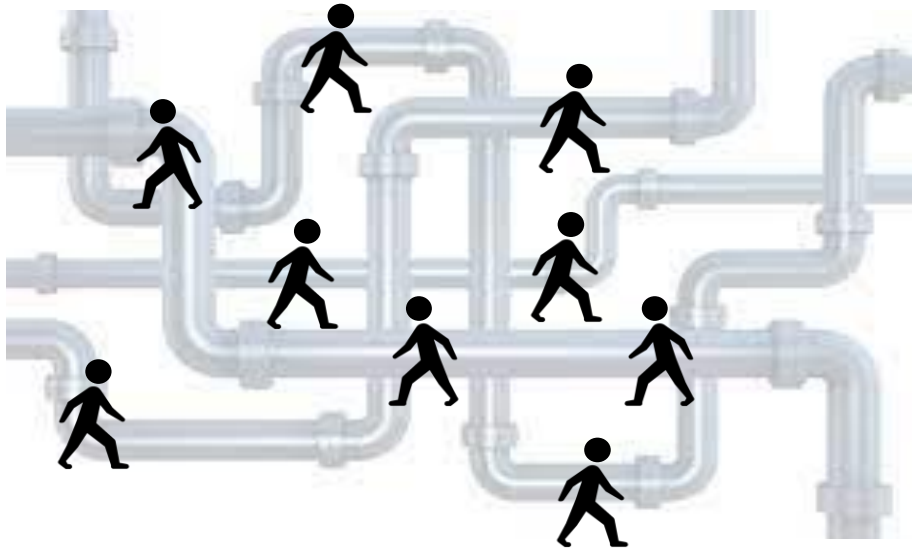
The forking paths

Aggregated forking paths (Kristanto et al, 2023, in prep.)



How to handle the forking paths?

A multiverse analysis



Perspectives on Psychological Science

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Increasing Transparency Through a Multiverse Analysis

Sara Steegen, Francis Tuerlinckx, [...], and Wolf Vanpaemel ✉ (+1) View all authors and affiliations

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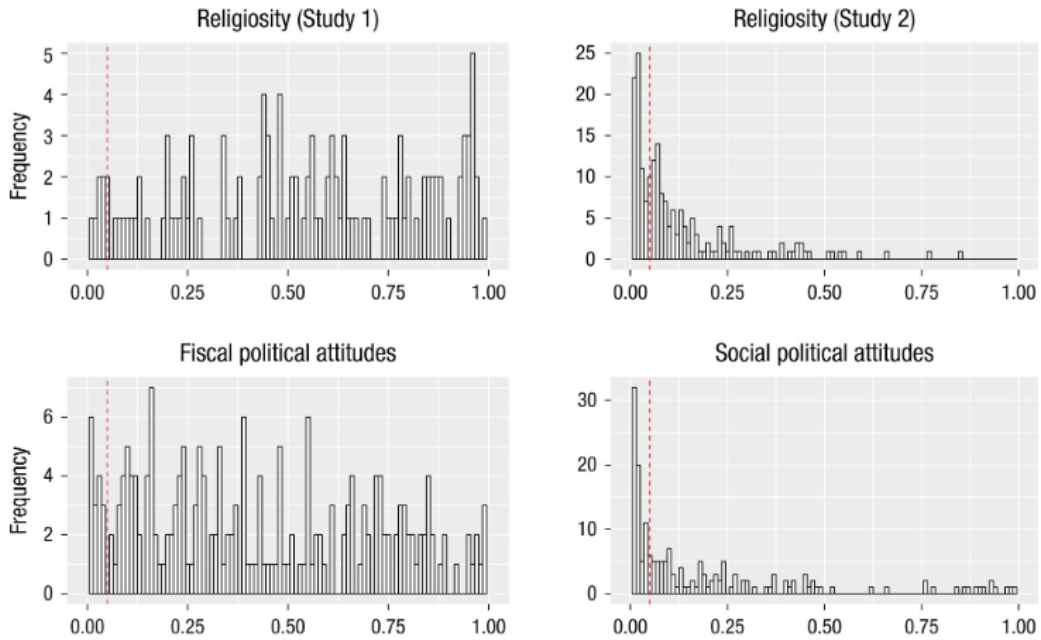
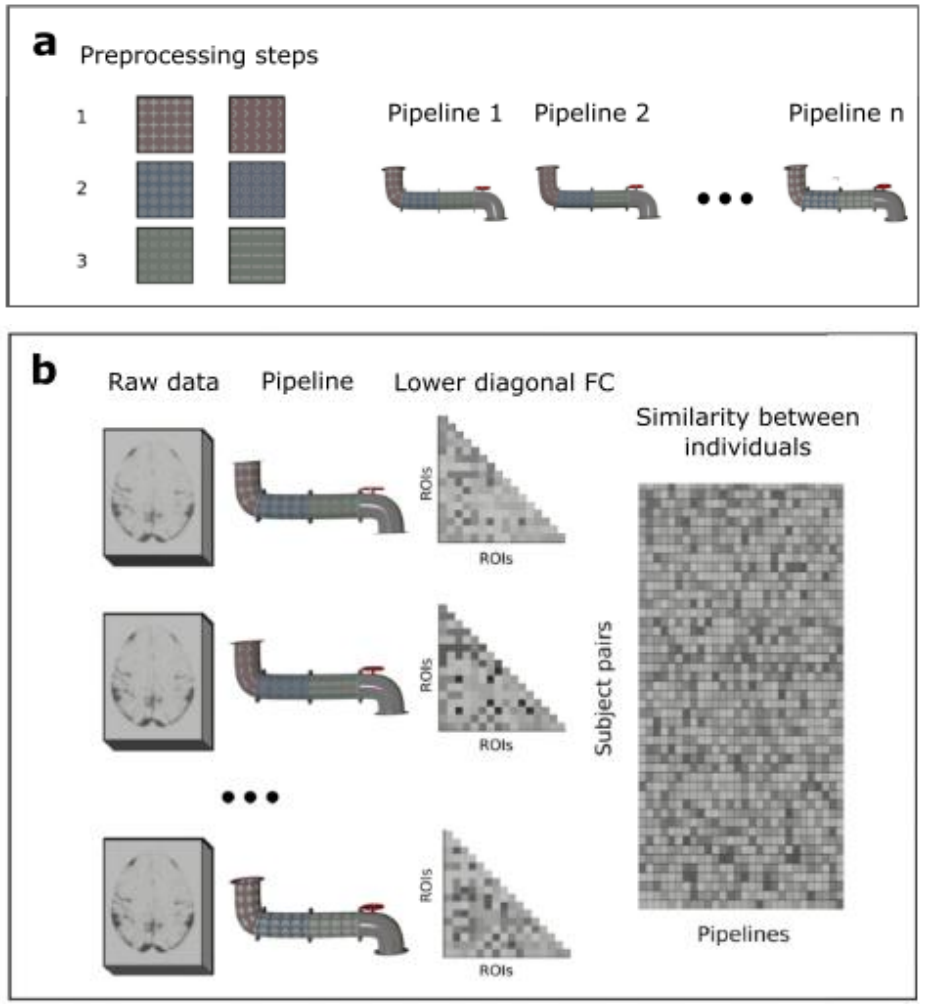


ation, righ

Computationally expensive!

An active learning approach



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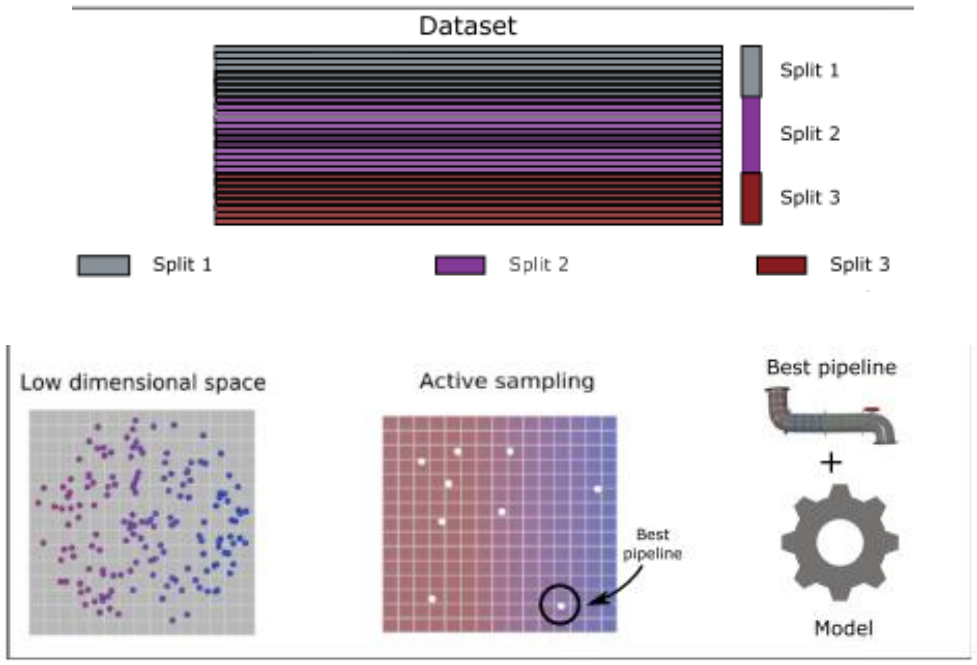
A guided multiverse study of neuroimaging analyses

Jessica Dafflon, Pedro F. Da Costa, František Váša, Ricardo Pio Monti, Danilo Bzdok, Peter J. Hellyer, Federico Turkheimer, Jonathan Smallwood, Emily Jones & Robert Leech



Approximating the multiverse of latent variable predictions by graph theory measures of the human connectome – An extended active learning approach (Daniel Kristanto — University of Oldenburg)

An active learning approach

Room for advancement, because:

1. The output of each pipeline or forking path must be a vector;
2. The predicted variable is single value observable;
3. There is only a static visualization of the multiverse of analysis results.

An extended active learning approach

Predicting a latent variable reflecting attitudes towards alcohol by using fMRI-based graph measures

The forking paths

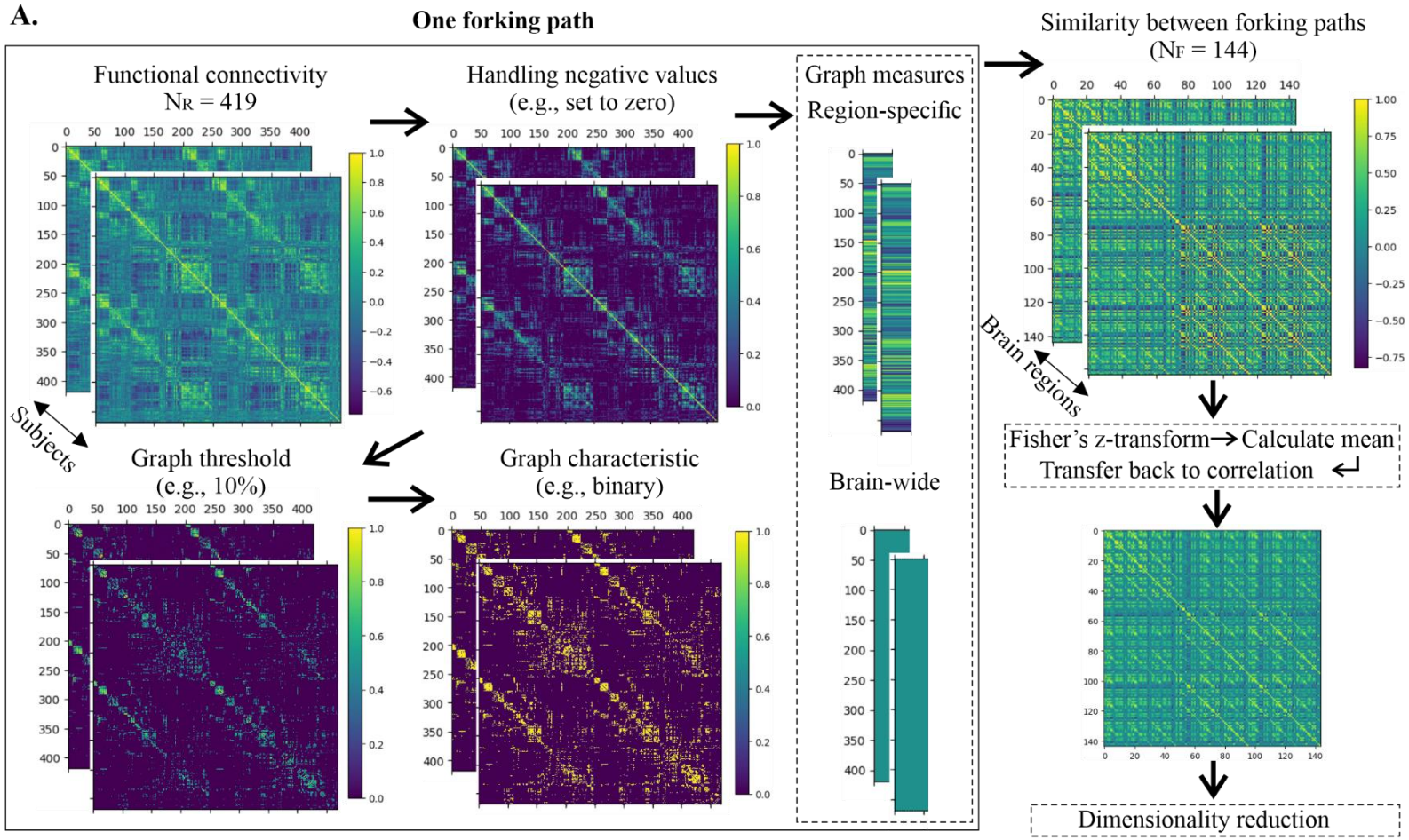
Negative correlation	Threshold	Edges	Measures
Absolute	0.5	Weighted	Strength
Keep	0.2	Binarized	Betweenness centrality
Zero	0.01		Clustering coef.
			Eigenvector centrality
			Local eff.
			Global eff.
			Modularity
			Participation coef.

N = 838 adolescents

A total of 144 forking paths

An extended active learning approach

Developing the search space that handles both brain-wide and region-specific graph measures

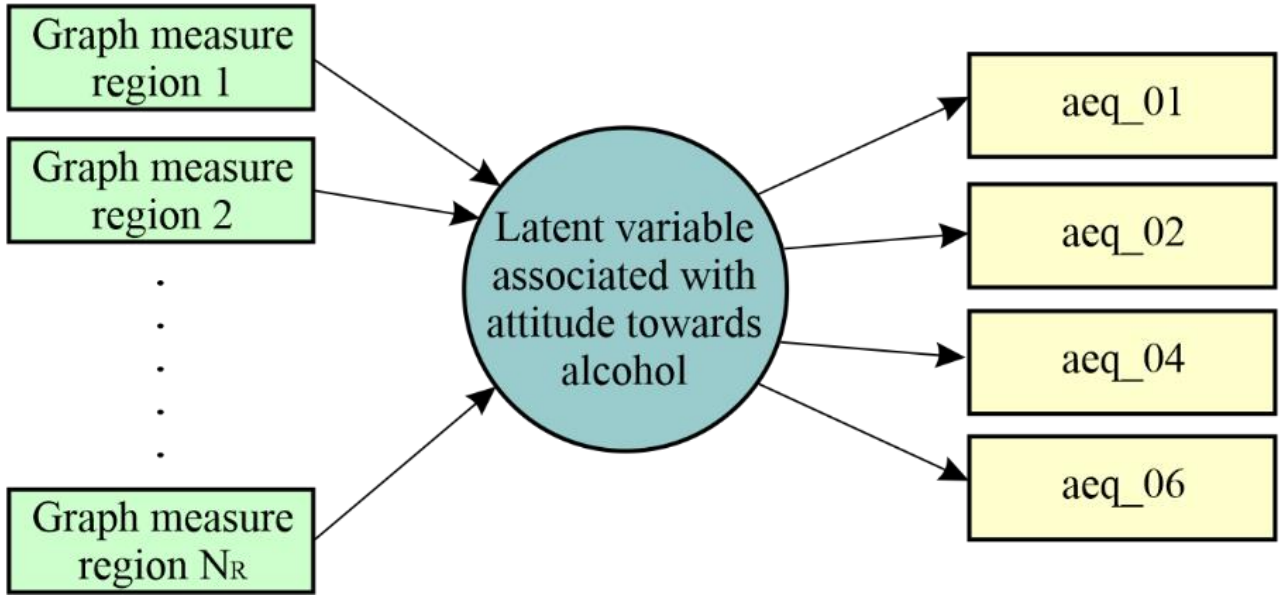


An extended active learning approach

Integrating Structural Equation Modeling to predict a latent variable instead of an observable only

Latent variable

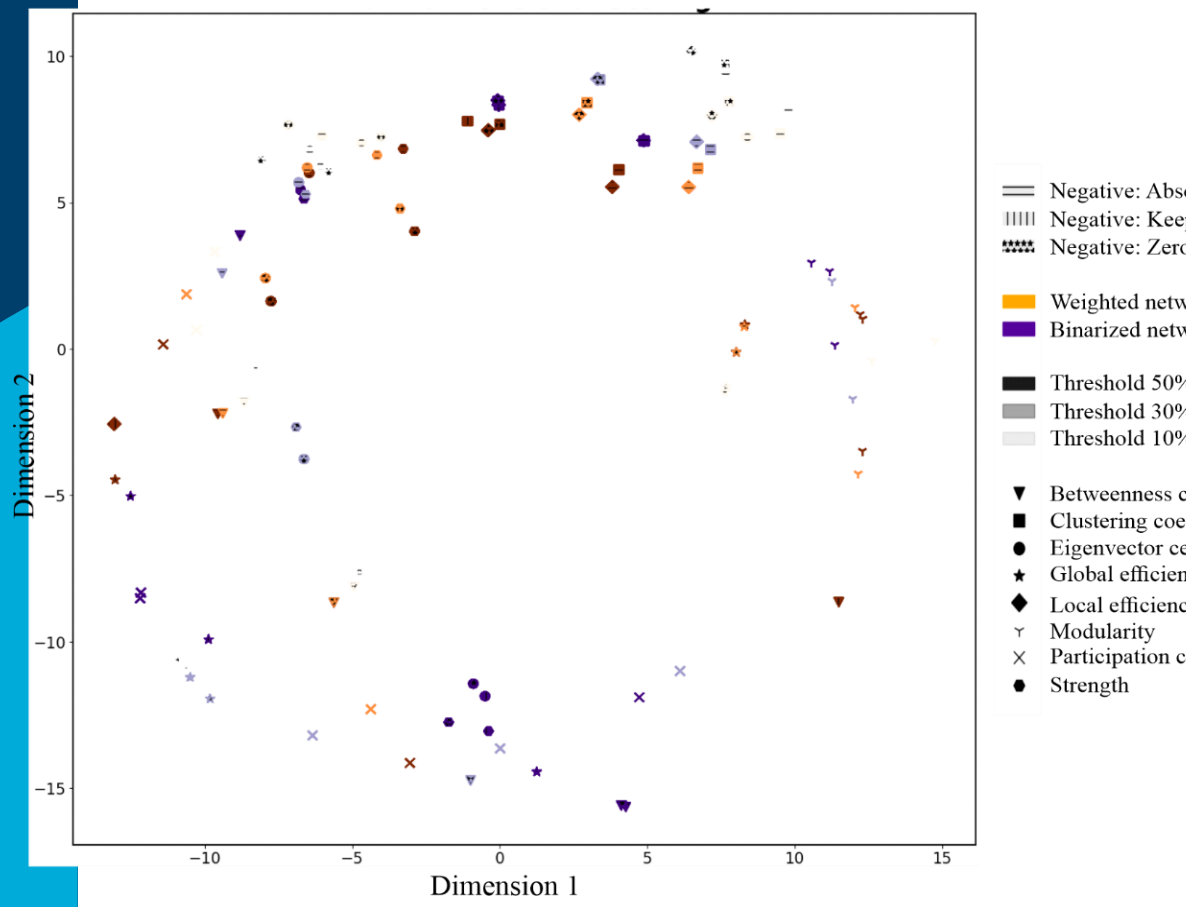
(semopy package,
https://pypi.org/project/semopy/)



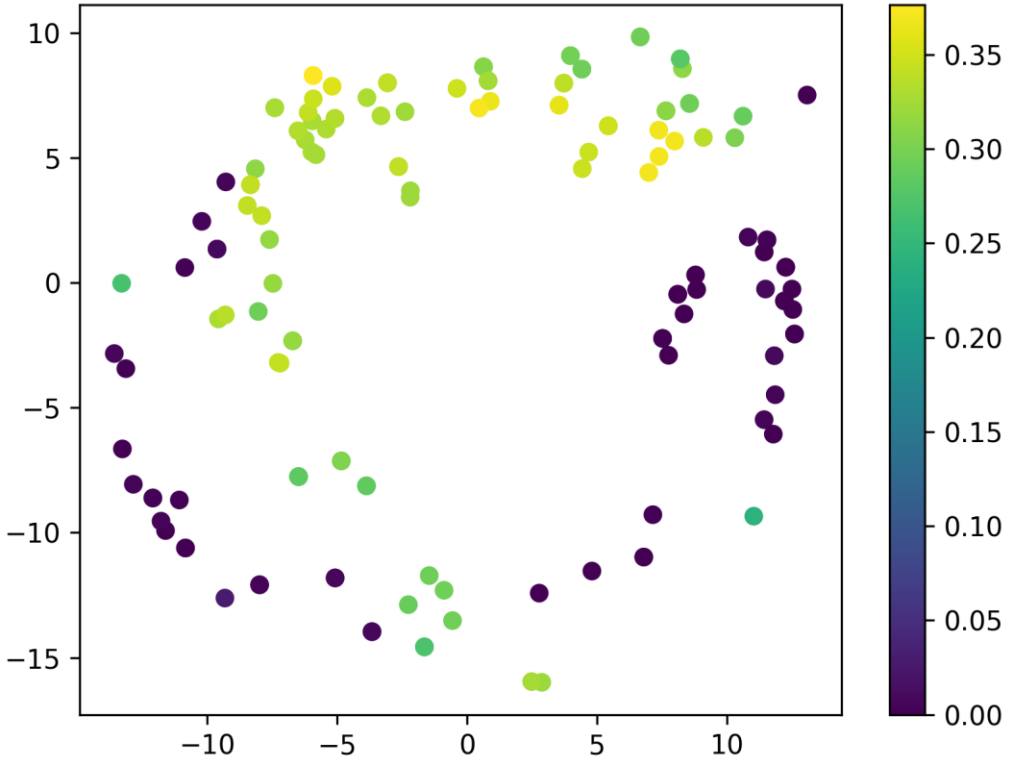
An extended active learning approach

Results – The space and the exhaustive search

The space



Predicted variance of the latent variable



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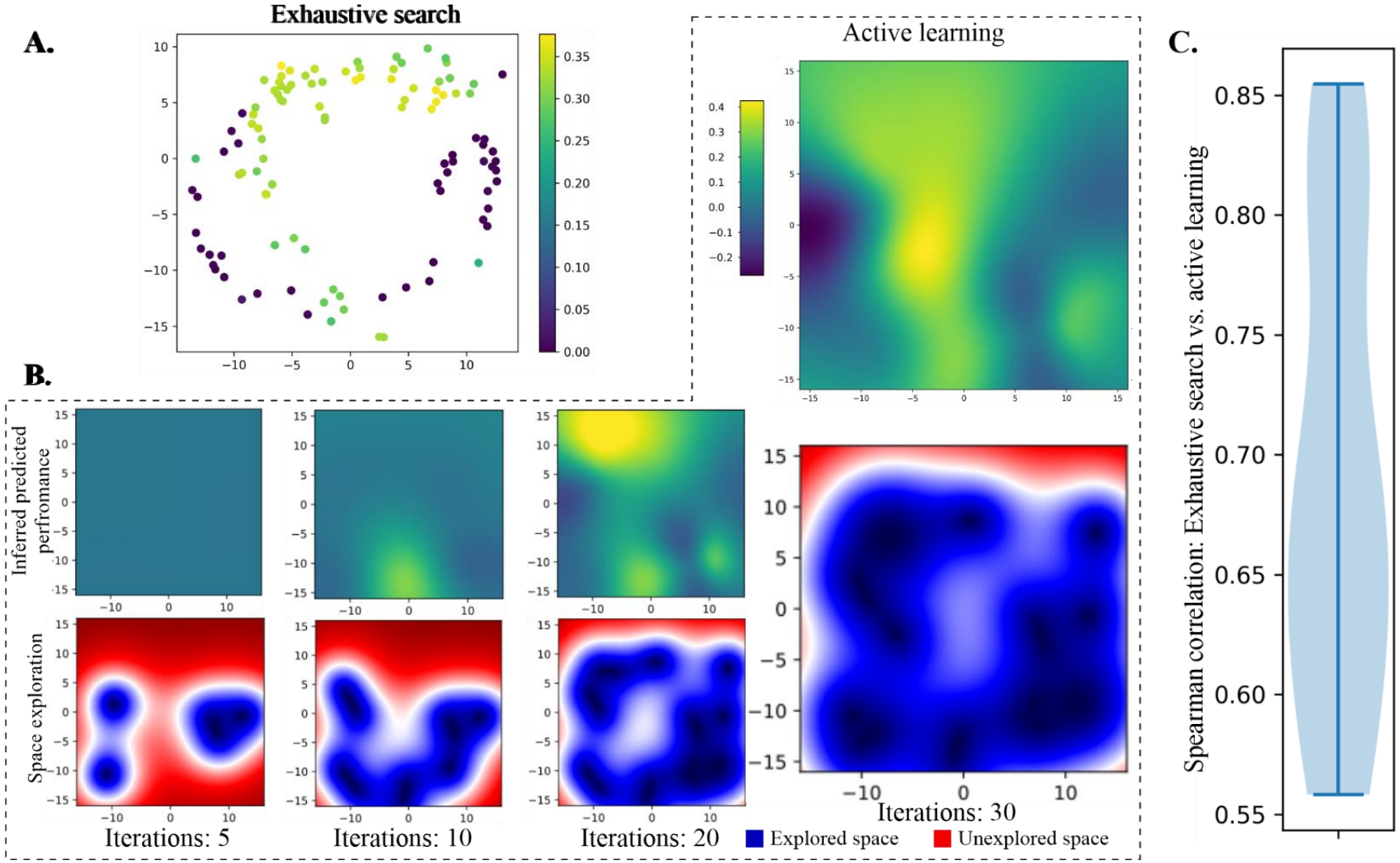
An extended active learning approach

Results – The active learning approach



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Implementing the forking paths

Results – The interactive visualization

Shiny App Demo: https://meteor-oldenburg.shinyapps.io/BrainSubstance/

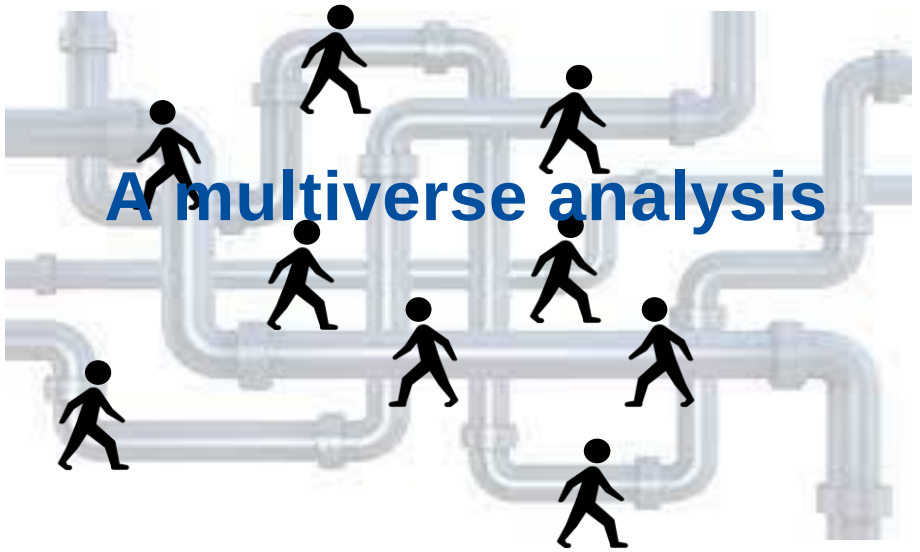
Final remarks

We extended the previously proposed active learning-based approach to aid the implementation of multiverse analysis by:

1. Developing a search space which can handle both vector and single value output from each forking path;
2. Integrating Structural Equation Modeling to allow the prediction of a latent variable;
3. Visualizing the multiverse of analyses results in an interactive way.

Test the robustness

Explore the unexplored



A multiverse analysis

It is a dangerous place

Carl von Ossietzky
Universität
Oldenburg

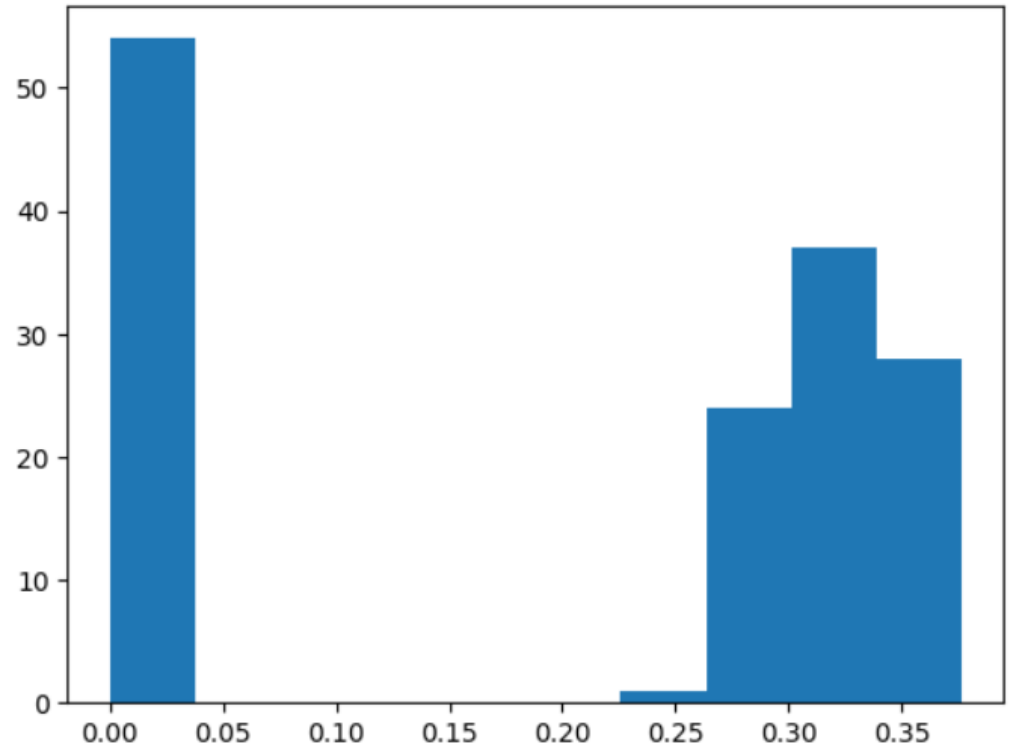
Discussion

App link:
https://meteor-oldenburg.shinyapps.io/BrainSubstance/

daniel.kristanto@uni-oldenburg.de

ABCD Youth Alcohol Measures (abcd_yam01)	aeq_section_q01	Alcohol helps a person relax, feel happy, feel less tense, and can keep a person's mind off of mistakes at school or work.	1 = Disagree Strongly; 2 = Disagree Somewhat; 3 = Uncertain; 4 = Agree Somewhat; 5 = Agree Strongly / tlfb_alc_l == '1' || tlfb_alc_c_l == '1'
	aeq_section_q02	Alcohol can help how well a person gets along with others (makes people want to have fun together).	1 = Disagree Strongly; 2 = Disagree Somewhat; 3 = Uncertain; 4 = Agree Somewhat; 5 = Agree Strongly / tlfb_alc_l == '1' || tlfb_alc_c_l == '1'
	aeq_section_q03	Alcohol can hurt how well a person gets along with others (makes people mean to others).	1 = Disagree Strongly; 2 = Disagree Somewhat; 3 = Uncertain; 4 = Agree Somewhat; 5 = Agree Strongly / tlfb_alc_l == '1' || tlfb_alc_c_l == '1'
	aeq_section_q04	Alcohol helps people think better and helps coordination (people understand things better; can do things better).	1 = Disagree Strongly; 2 = Disagree Somewhat; 3 = Uncertain; 4 = Agree Somewhat; 5 = Agree Strongly / tlfb_alc_l == '1' || tlfb_alc_c_l == '1'
	aeq_section_q05	Alcohol hurts how people think and it hurts their coordination (run into things, act silly, have a hangover).	1 = Disagree Strongly; 2 = Disagree Somewhat; 3 = Uncertain; 4 = Agree Somewhat; 5 = Agree Strongly / tlfb_alc_l == '1' || tlfb_alc_c_l == '1'
	aeq_section_q06	Alcohol makes a person feel stronger and more powerful (easier to fight, speak in front of others, stand up to others).	1 = Disagree Strongly; 2 = Disagree Somewhat; 3 = Uncertain; 4 = Agree Somewhat; 5 = Agree Strongly / tlfb_alc_l == '1' || tlfb_alc_c_l == '1'
	aeq_section_q07	Alcohol can make people more careless or do things that could get them into trouble (do things they feel bad about; do things they regret).	1 = Disagree Strongly; 2 = Disagree Somewhat; 3 = Uncertain; 4 = Agree Somewhat; 5 = Agree Strongly / tlfb_alc_l == '1' || tlfb_alc_c_l == '1'

```
mod = f"""
    alc_pos =~ a*aeq_section_q01 + b*aeq_section_q02 + c*aeq_section_q04 + d*aeq_section_q06
    alc_pos ~~ 1*alc_pos
    alc_pos ~ {' + '.join([f"{col}" for col in brain_columns])}
    START(1.0) a b c d
    DEFINE(ordinal) aeq_section_q01 aeq_section_q02 aeq_section_q04 aeq_section_q06
"""
```



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Visualization of Multiver

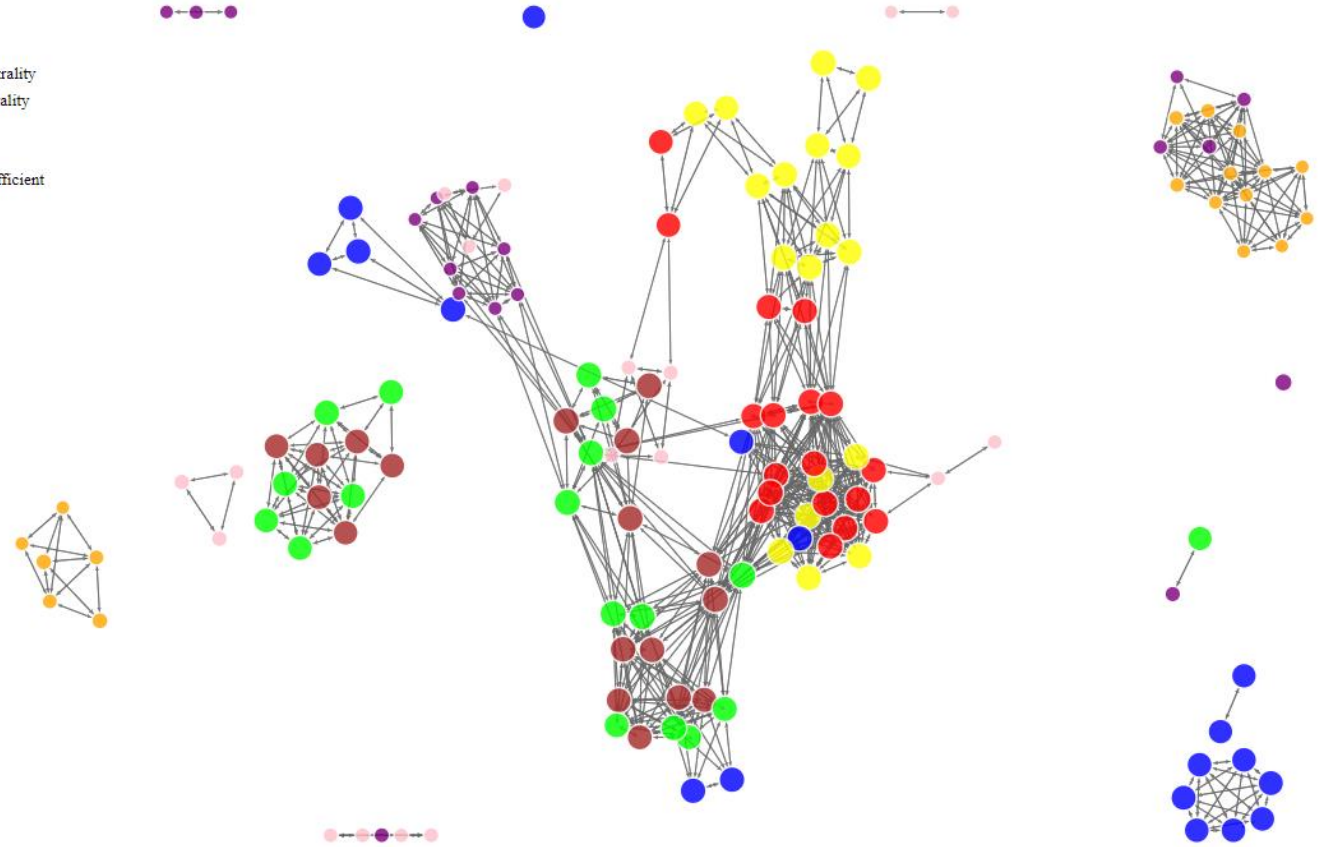
Options

Select the node you want to explore the connections

All

Threshold connection (correlation between forking paths). Please note that setting the threshold to small values lead to dense network which is heavy to deploy

0 0.7 1

0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1

strength
local efficiency
betweenness centrality
eigenvector centrality
global efficiency
modularity
participation coefficient
clustering