Systematically comparing properties of **local dynamics** and **pairwise coupling** in the brain

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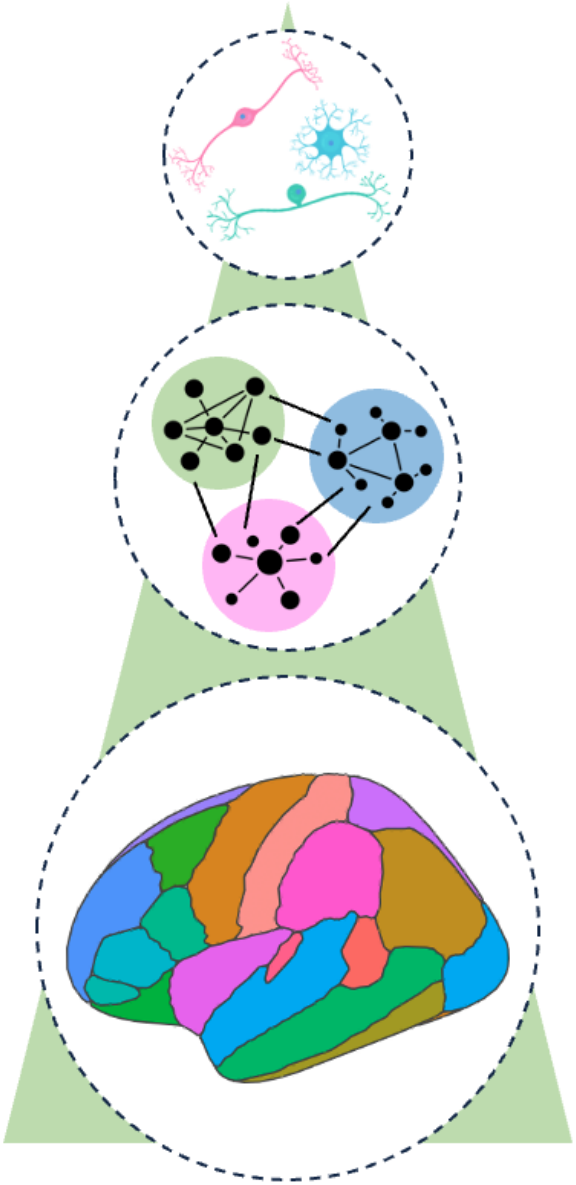
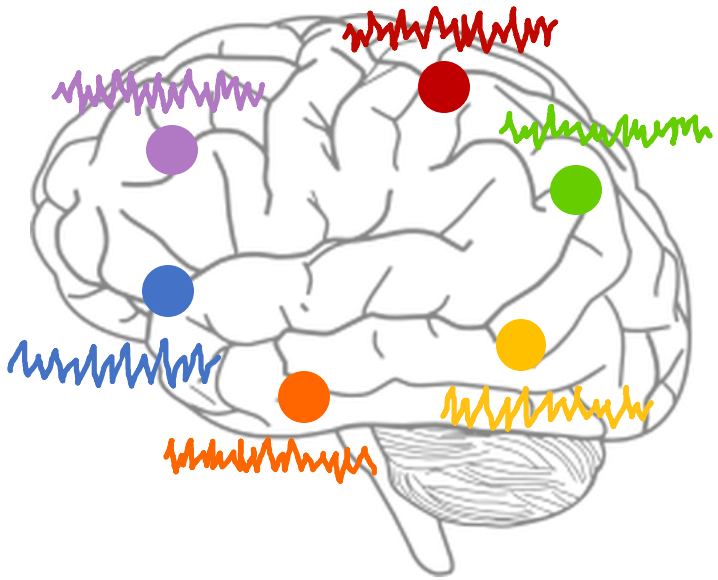
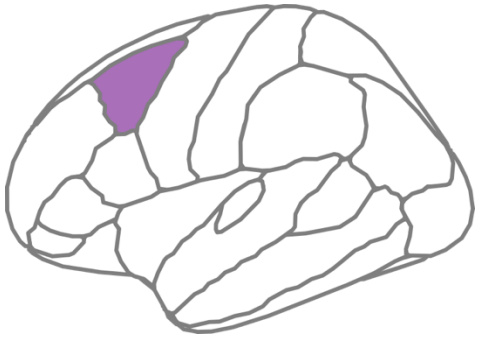
THE UNIVERSITY OF SYDNEY

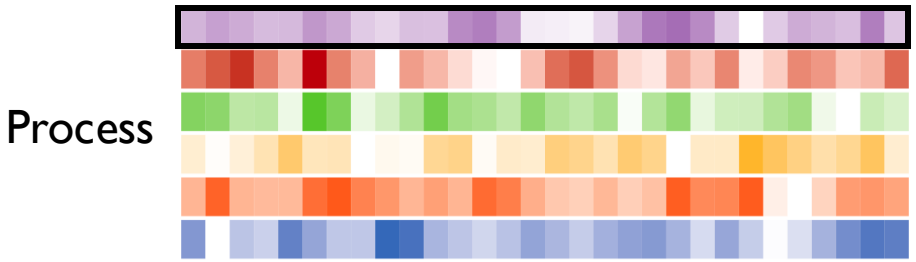
The **brain** is a **complex system** of great **biological interest**







Multivariate time series (**MTS**)



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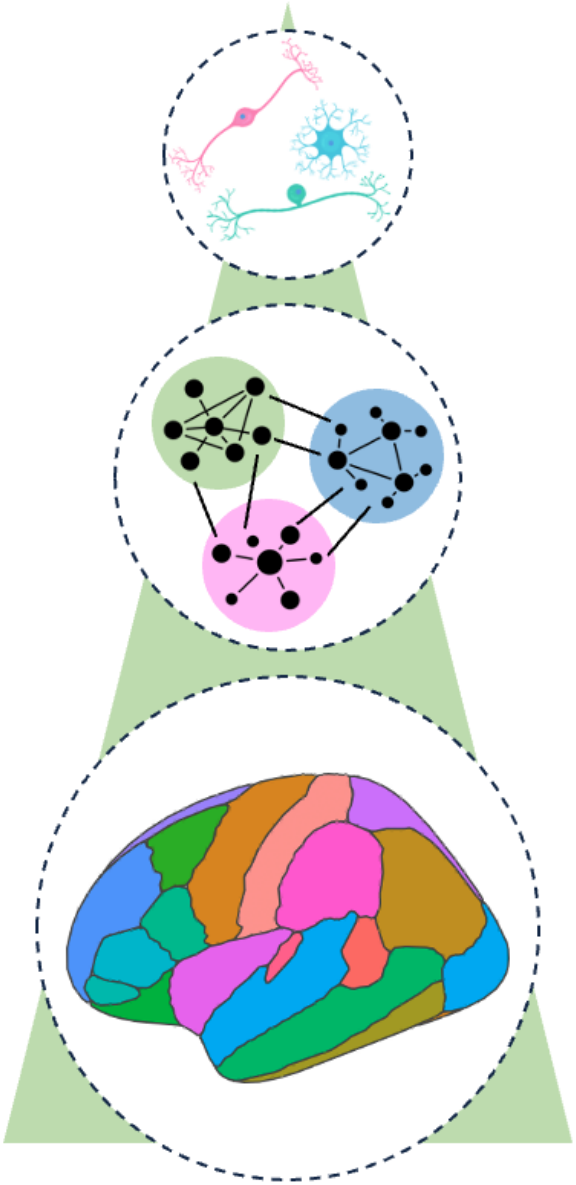

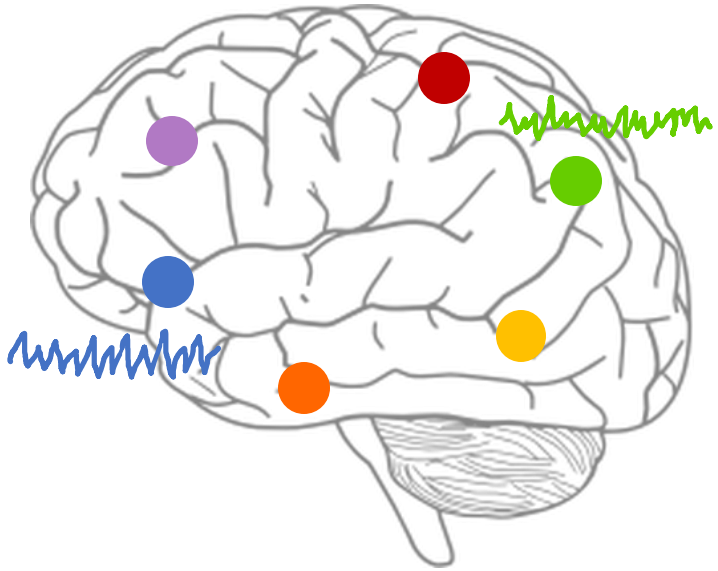

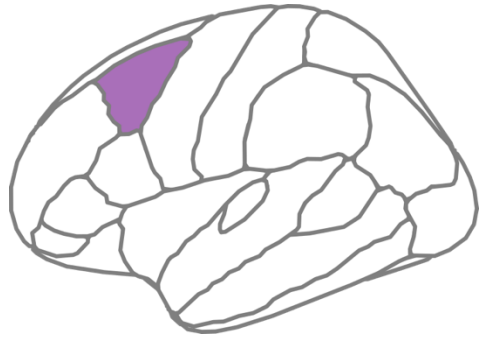

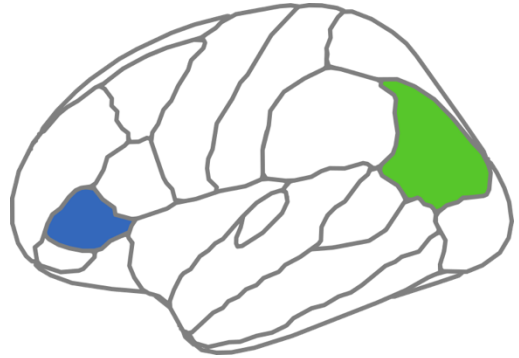

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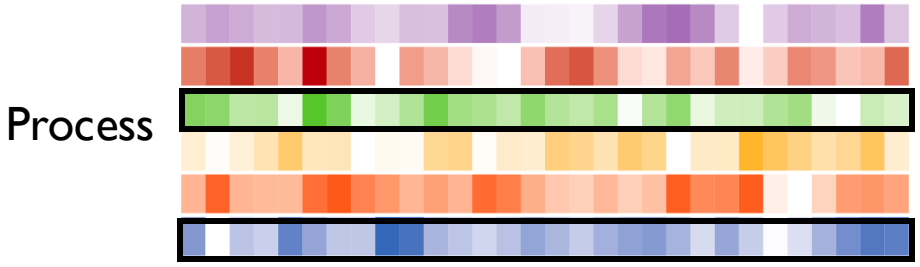

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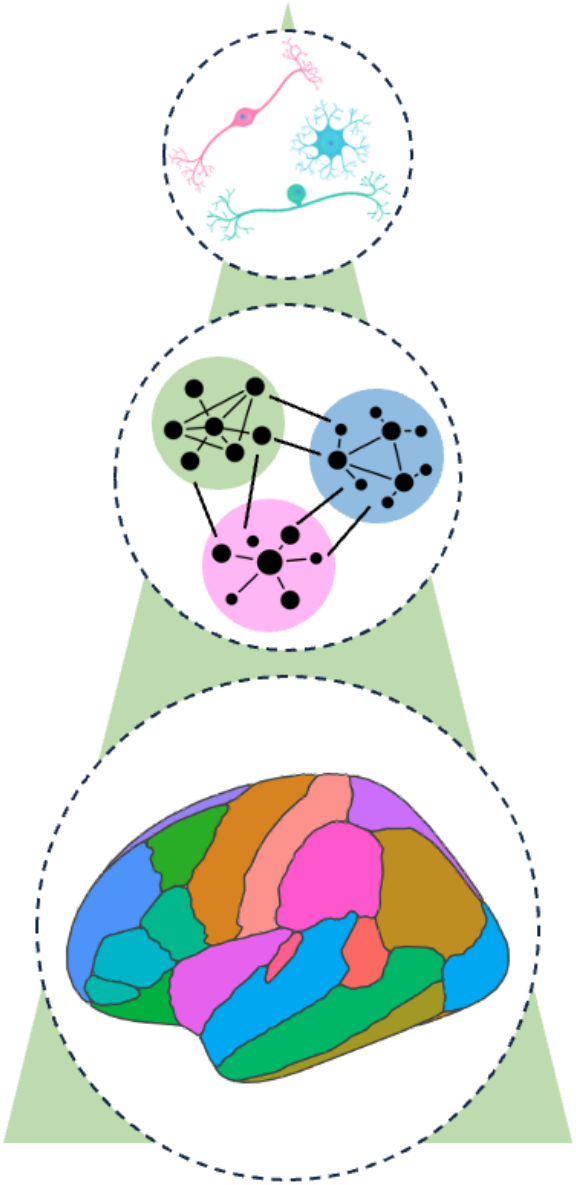

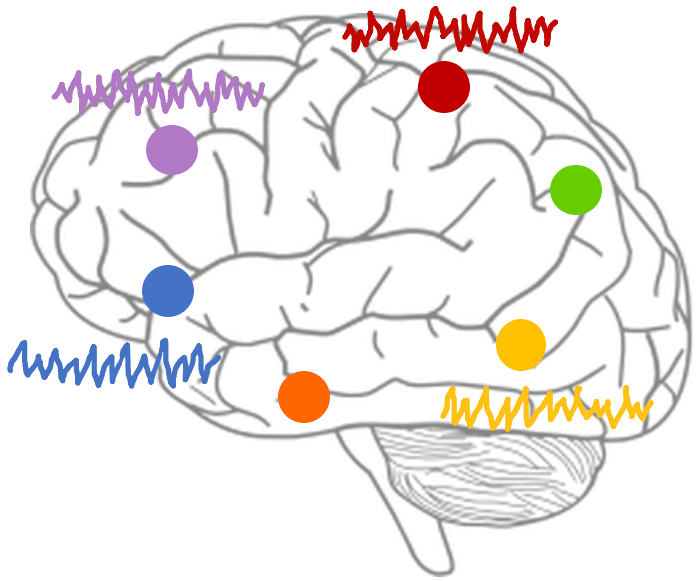

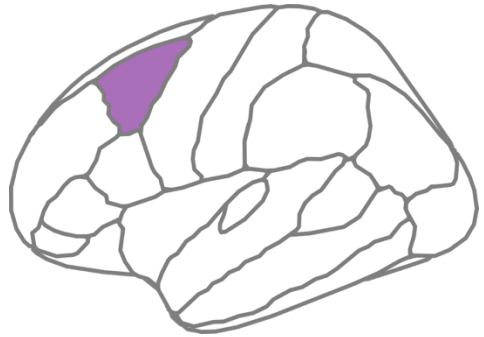

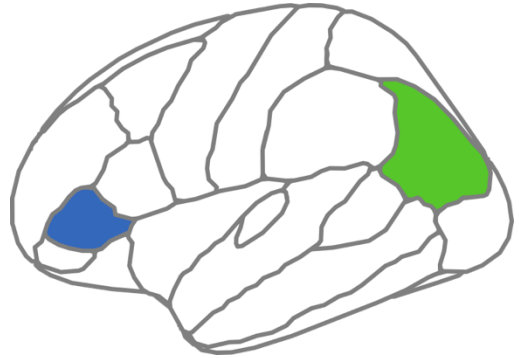

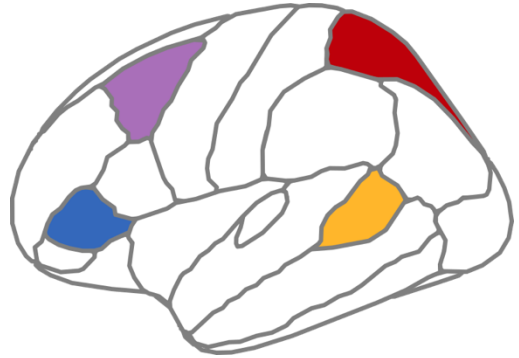

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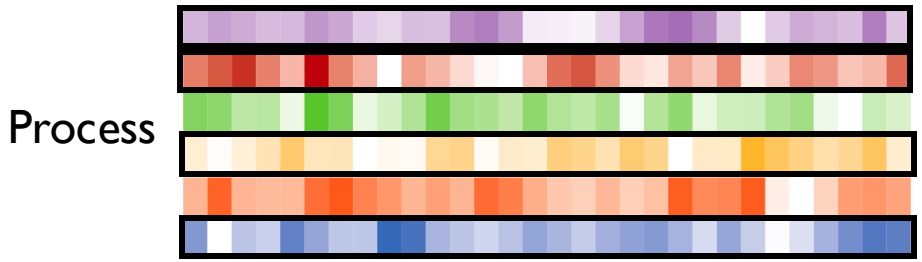

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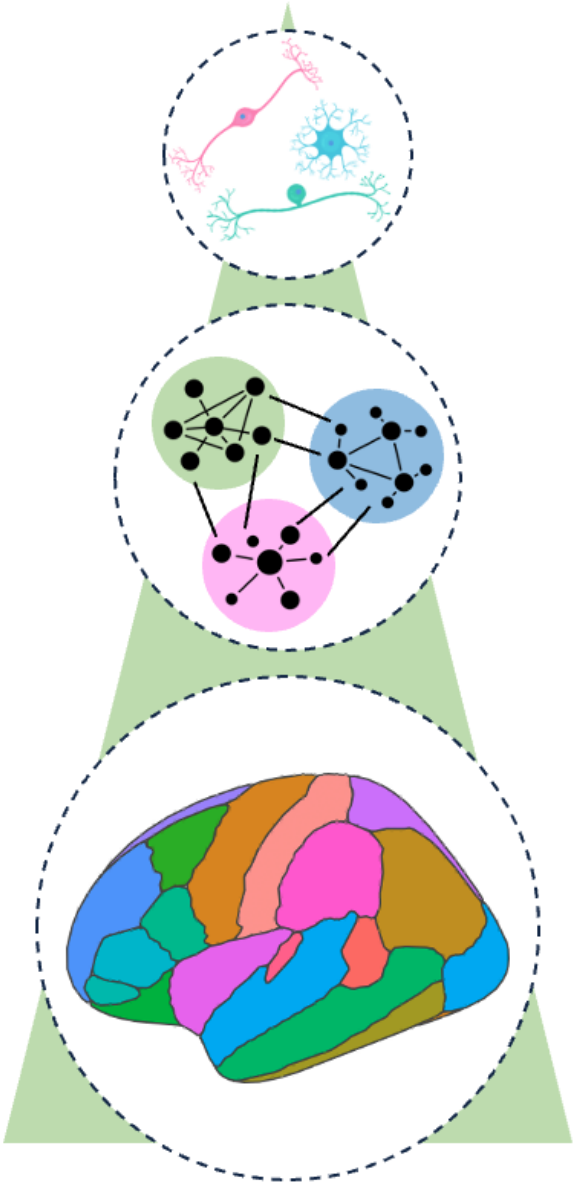
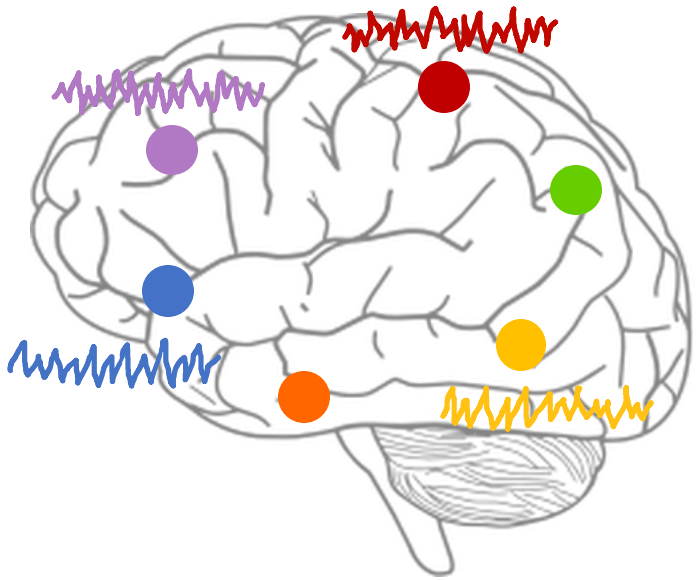
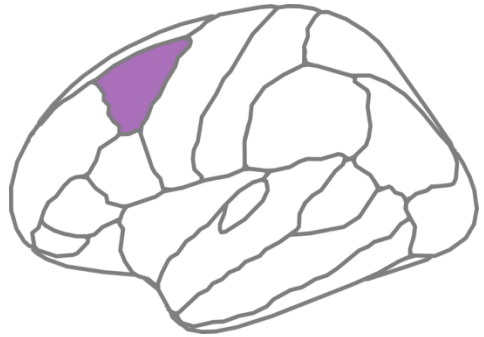
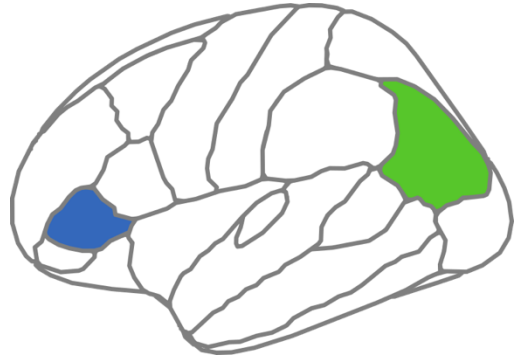
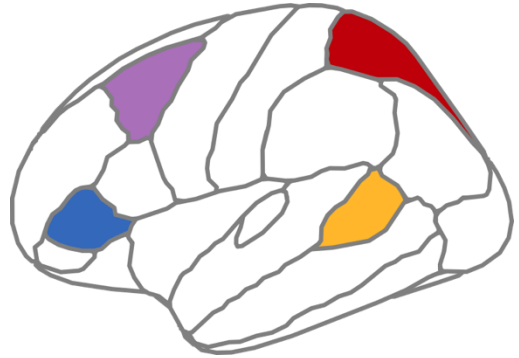


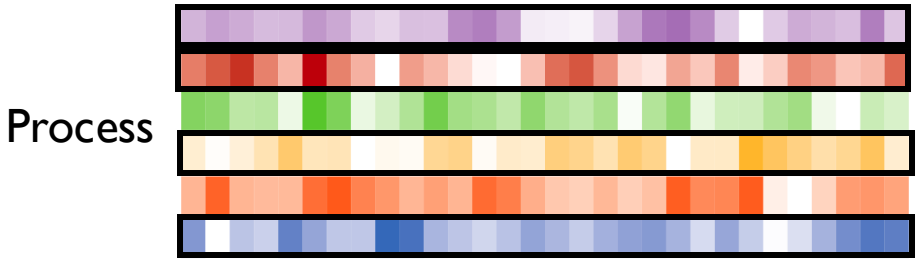




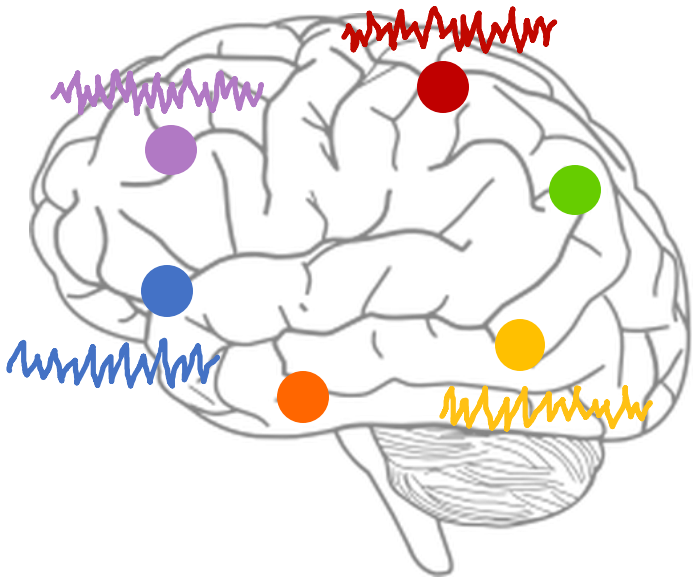




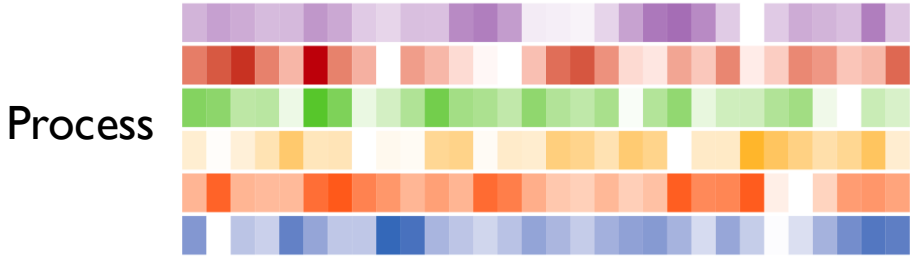
Multivariate time series (**MTS**) representation



Interdisciplinary complex systems comprise sets of **MTS**



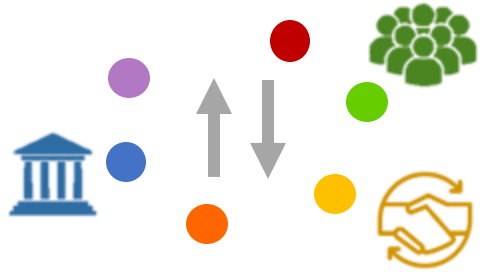
Multivariate time series (**MTS**)



City structure

City properties: density, traffic patterns, crime rates, culture

Economics



National economy: economic growth, recession

Physics

Fluid dynamics: vortices, turbulence

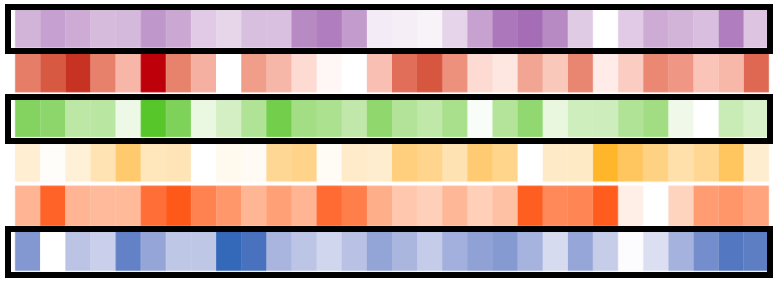
Social networks

Facebook friends: community formation

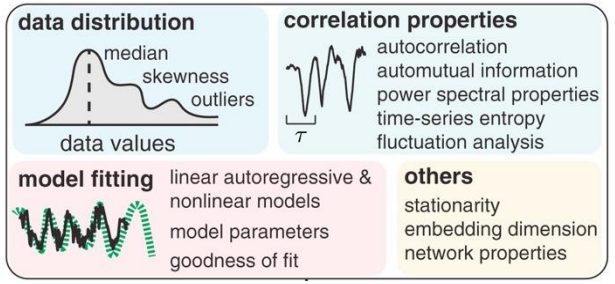
What does this **generalized representation** offer us?

Localized dynamics of one process

Multivariate time series (**MTS**)



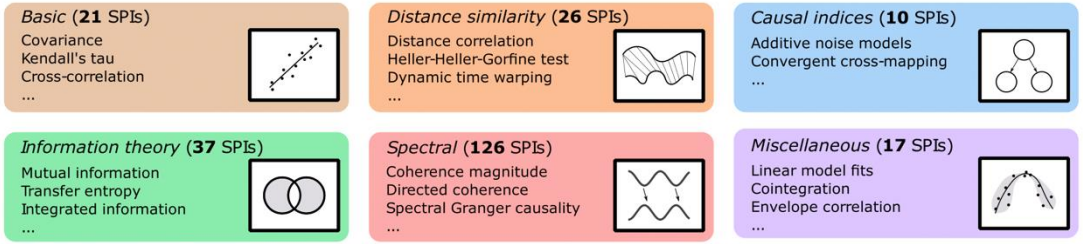
hctsa



catch22

Fulcher et al. *J R Soc* (2013), *Cell Systems* (2017)
Lubba et al. *Data Mining and Knowledge Discovery* (2019)

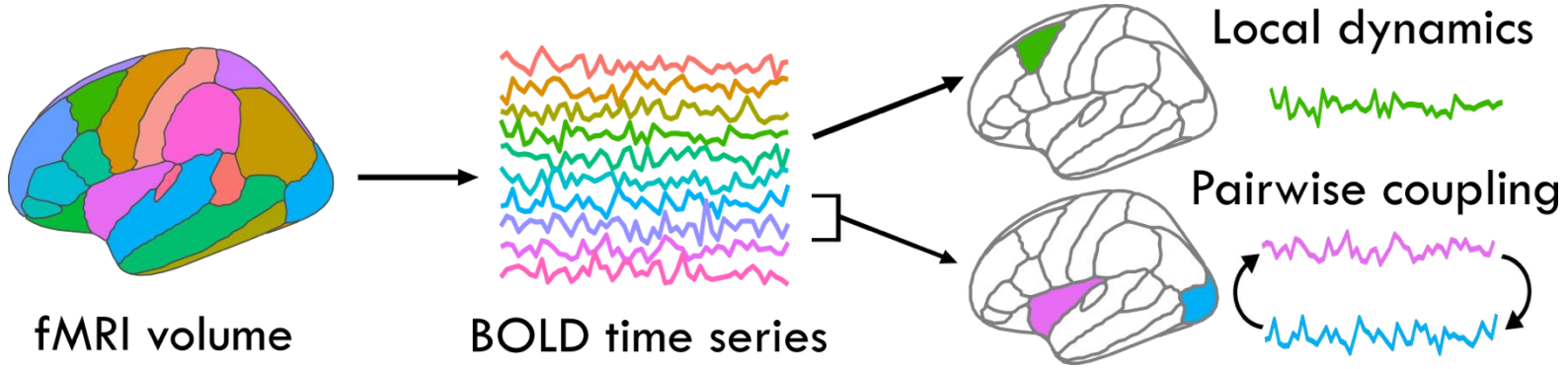
Statistical dependencies between **pairs** of processes



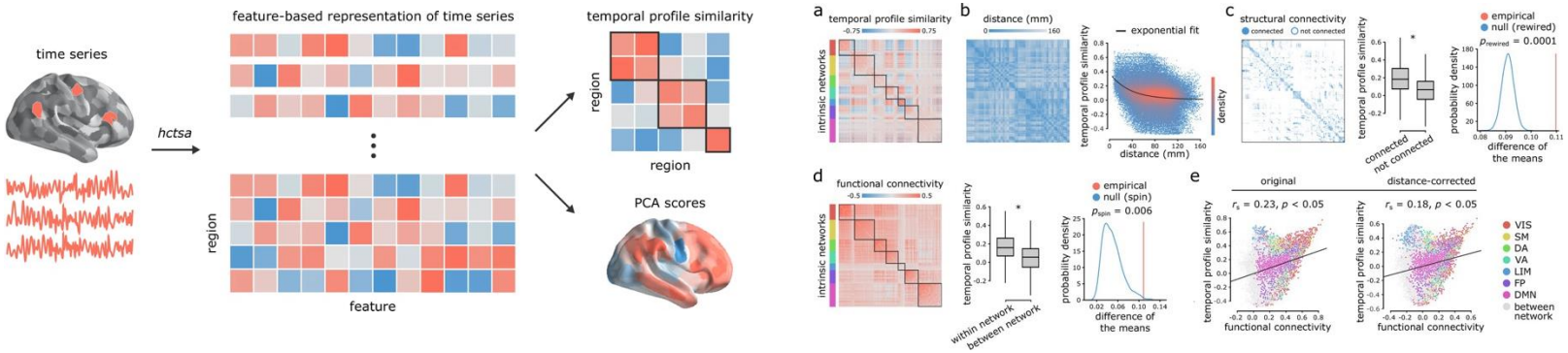
Cliff et al. *Nat Comp Sci* (2023)

annie.bryant@sydney.edu.au

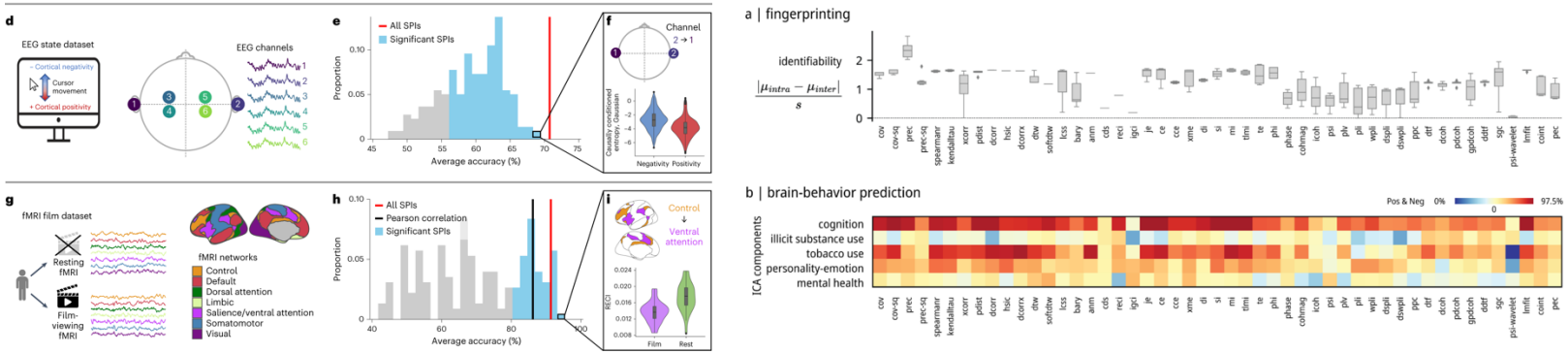
Analysing **brain dynamics** as a **complex system**



Shafiei et al. *eLife* 2020 (pictured),
Nat Comms 2023



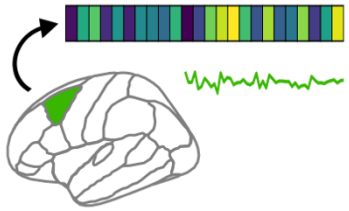
Cliff et al. *Nat Comp Sci* 2023 (left)
Liu et al. *bioRxiv* 2024 (right)



Case study: classifying **neuropsychiatric disorders**

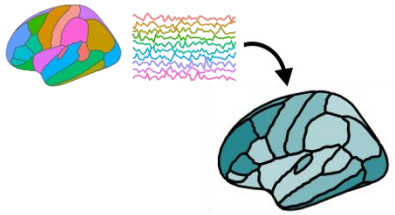
catch22

i. Local dynamics in an individual region



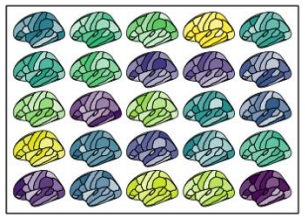
(A_{region})

ii. Whole-brain maps of an individual feature



$(A_{feature})$

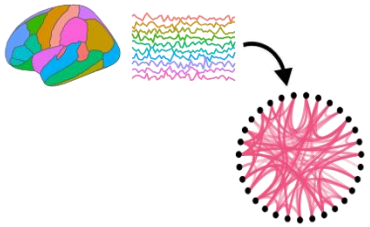
iii. Whole-brain maps of all features



(A_{uni_combo})

pyspi

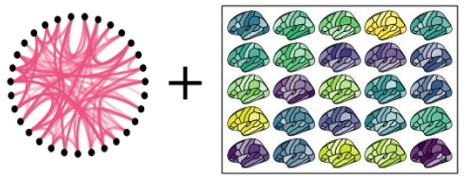
iv. FC across all region pairs with one SPI



(A_{FC})

catch22 + pyspi

v. FC across all region pairs by SPI plus all whole-brain maps of local dynamics



(A_{FC_combo})

SCZ
N=48
UCLA CNP

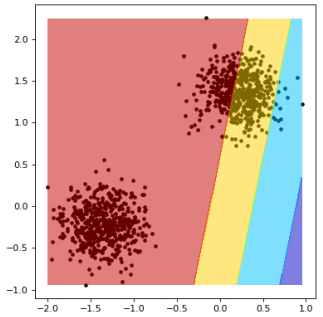
BP
N=49
UCLA CNP

ADHD
N=39
UCLA CNP

ASD
N=513
ABIDE

Controls

Cases



Source: scikit-learn

Linear support vector machine (SVM)

- Balanced accuracy
- Inverse probability weighting

× 10-fold CV

× 10 repeats

ABIDE

Data preprocessed by Traut et al. *NeuroImage* (2022)

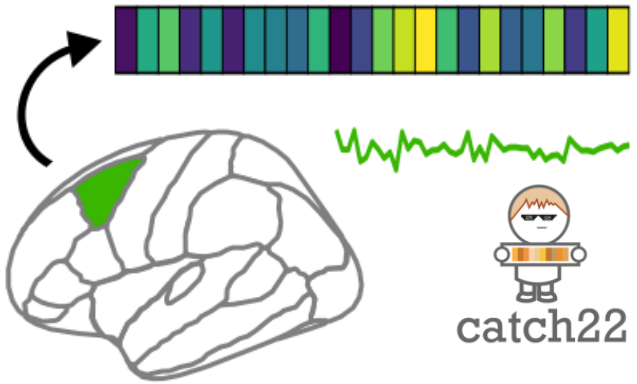
Ucla

Data preprocessed by Dr Kevin Aquino

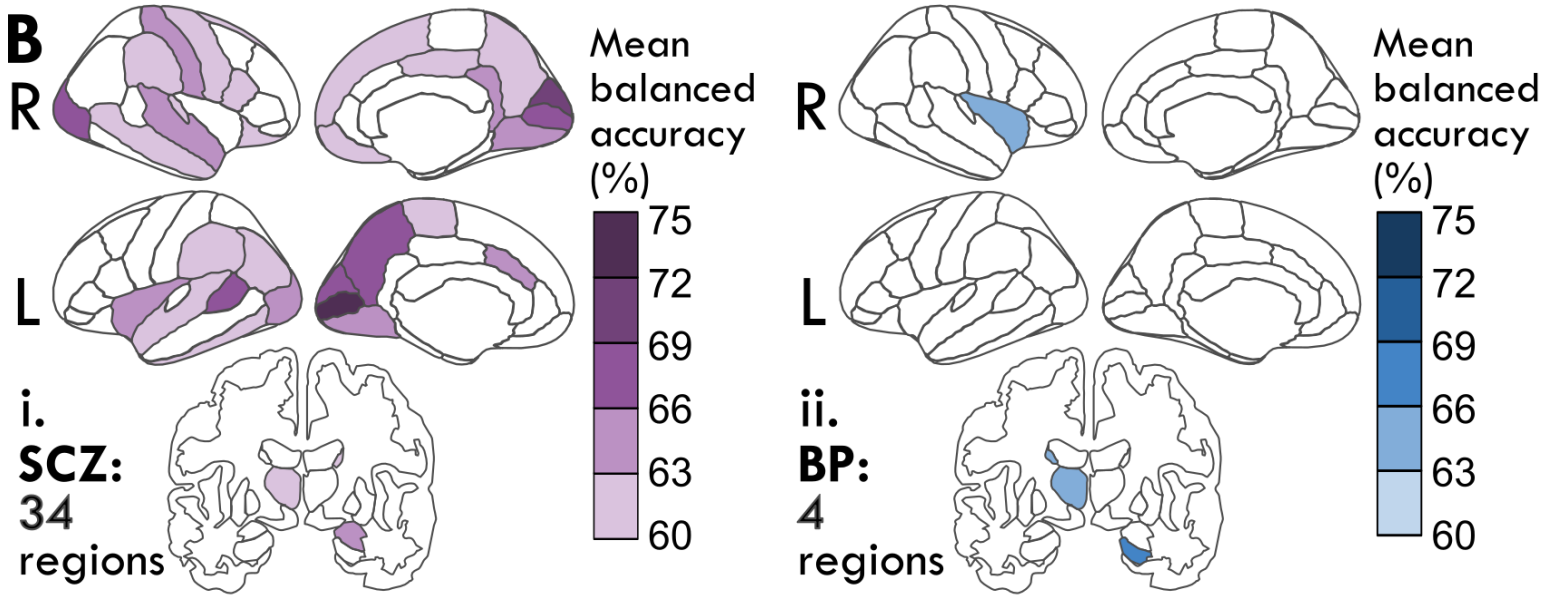
Bryant et al. *bioRxiv* (2024)

Interpretable **spatial maps** of **region-specific dysfunction**

Dynamical signatures of resting-state activity in **individual brain regions** can distinguish patients from controls in schizophrenia and bipolar disorder



aparc+aseg FreeSurfer atlas



Gene expression

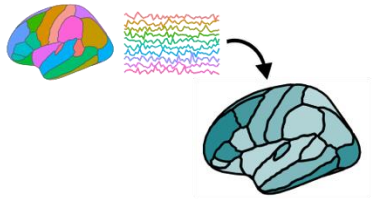
Anatomical changes

Stimulation analysis

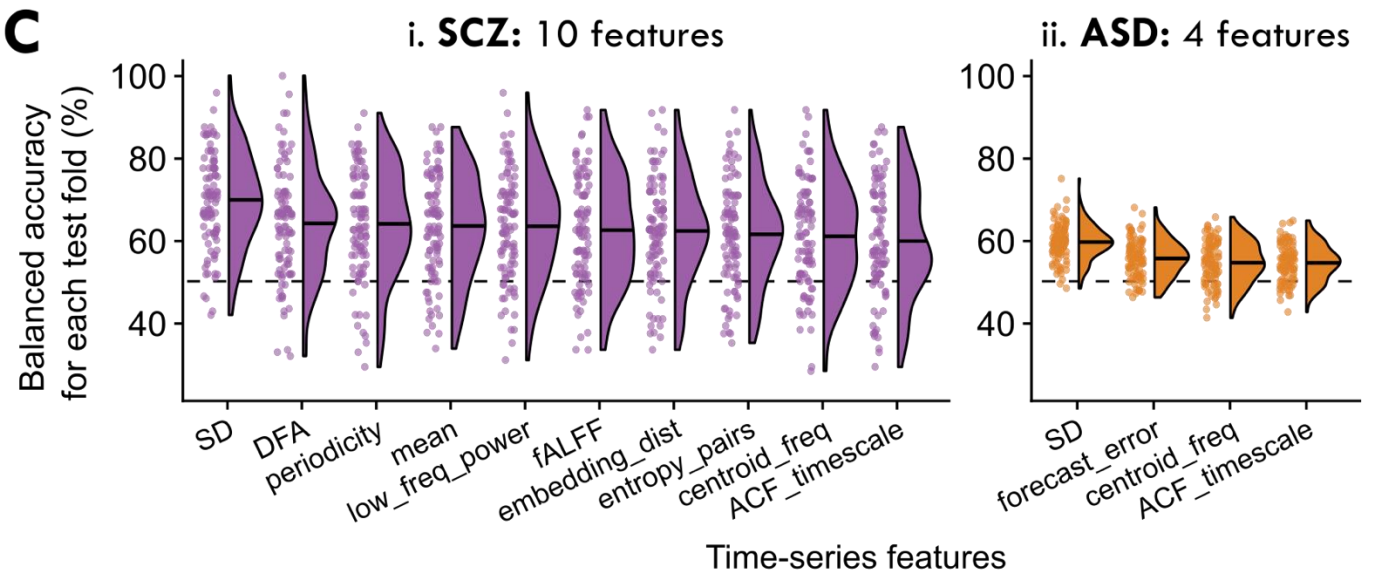
Bryant et al. *bioRxiv* (2024)

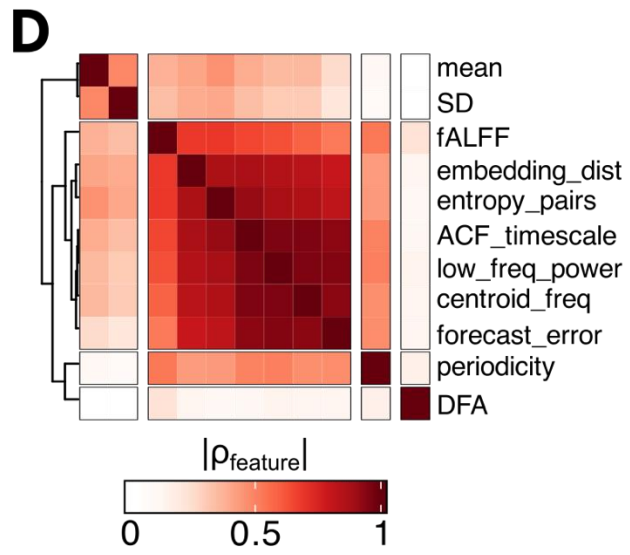
Highlighting **linear features** for **resting-state fMRI** analysis

ii. Whole-brain maps of an individual feature

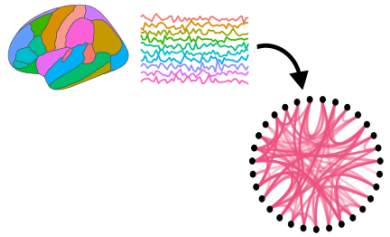


$(A_{feature})$

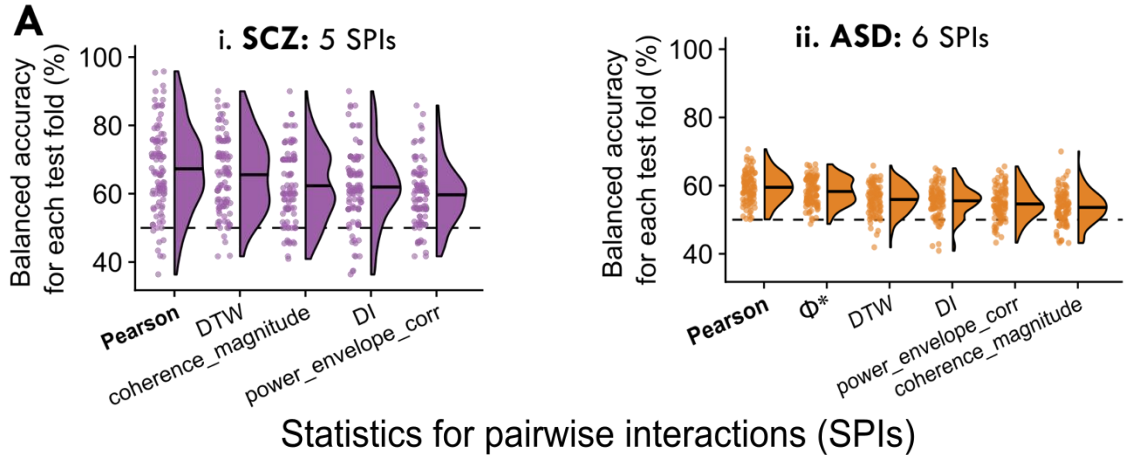


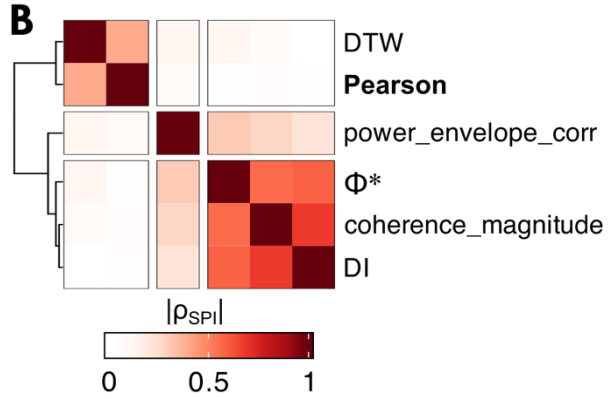


iv. FC across all region pairs with one SPI



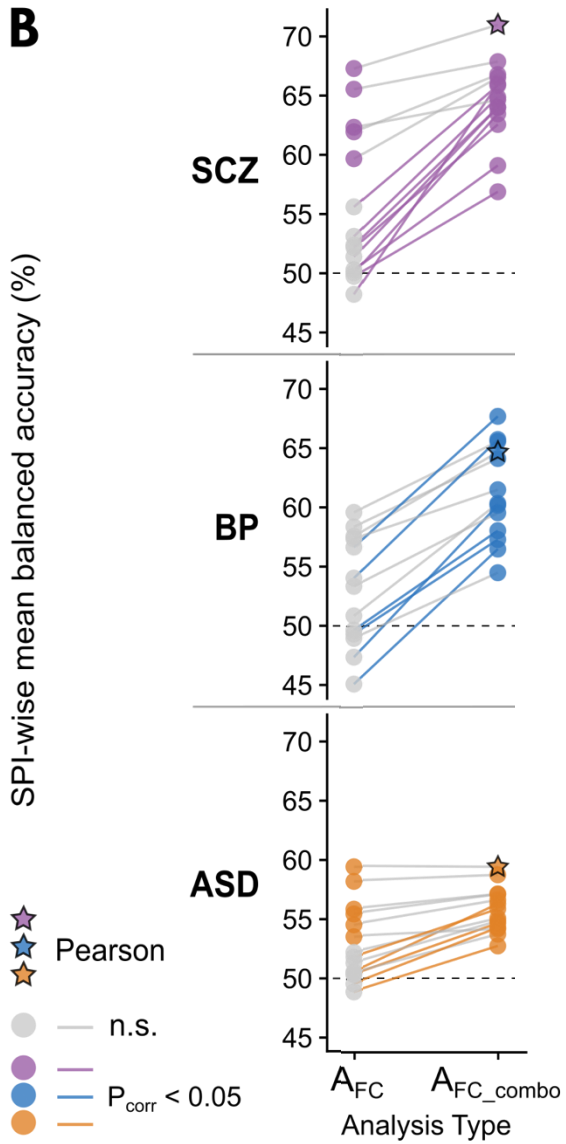
(A_{FC})





Bryant et al. *bioRxiv* (2024)

The benefit of **integrating** local dynamics **and** pairwise coupling



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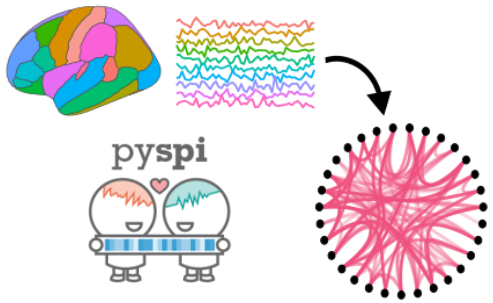
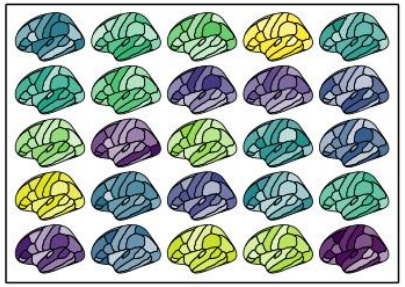


+

iii. Whole-brain maps of all features

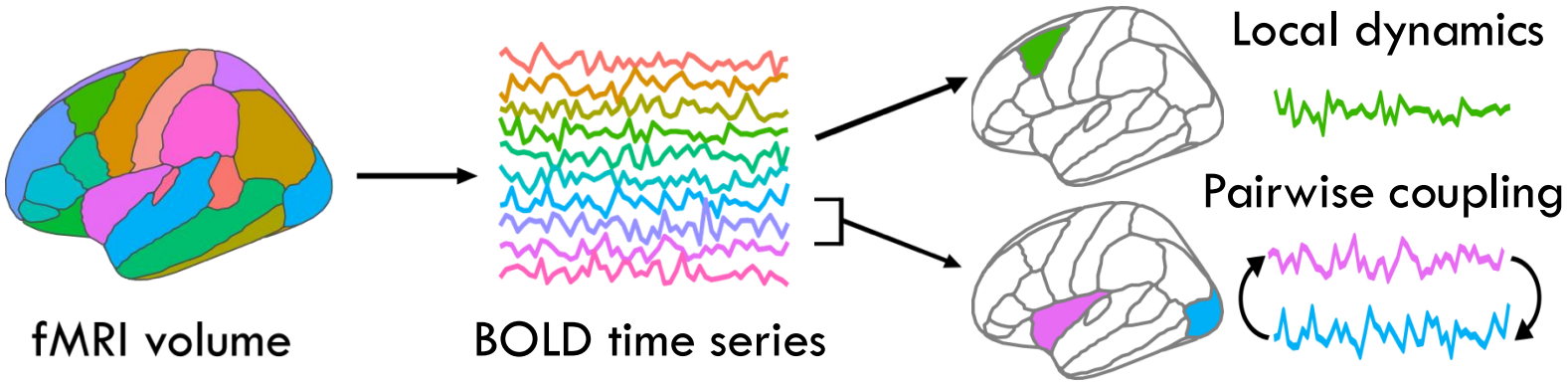


Most linear pairwise **functional connectivity** metrics are more informative with the inclusion of **brain-wide maps** of **local regional dynamics**

✨ synergy ✨

Bryant et al. *bioRxiv* (2024)

A **flexible, generalizable** framework for **neural** time-series data



Modality(s)
Timescales

catch22

pyspi

catch22 + pyspi

i. Local dynamics in an individual region

(A_{region})

ii. Whole-brain maps of an individual feature

$(A_{feature})$

iii. Whole-brain maps of all features

(A_{uni_combo})

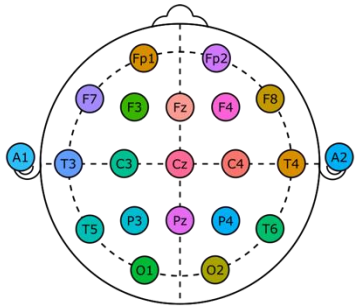
iv. FC across all region pairs with one SPI

(A_{FC})

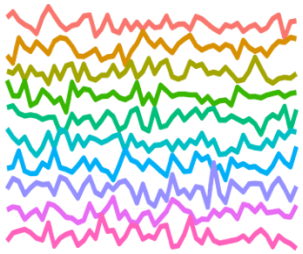
v. FC across all region pairs by SPI plus all whole-brain maps of local dynamics

(A_{FC_combo})

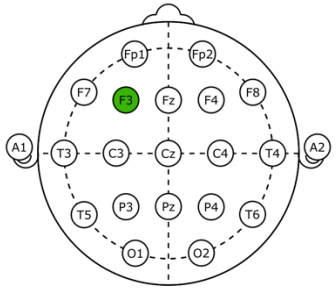
A **flexible, generalizable** framework for **neural** time-series data



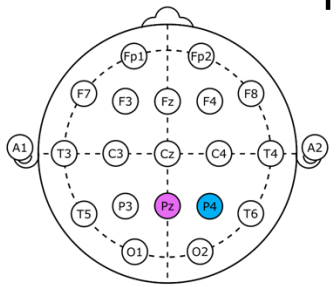
EEG electrodes



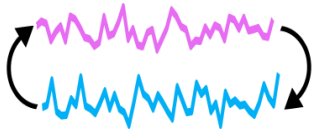
EEG time series



Local dynamics



Pairwise coupling



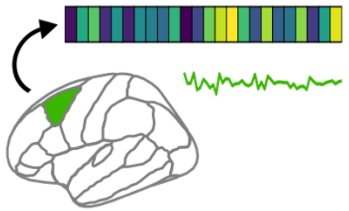
Modality(s)
Timescales

catch22

pyspi

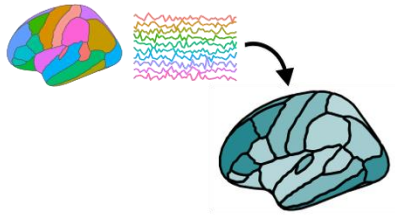
catch22 + pyspi

i. Local dynamics in an individual region



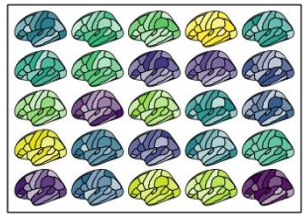
(A_{region})

ii. Whole-brain maps of an individual feature



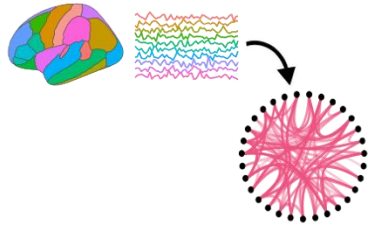
$(A_{feature})$

iii. Whole-brain maps of all features



(A_{uni_combo})

iv. FC across all region pairs with one SPI

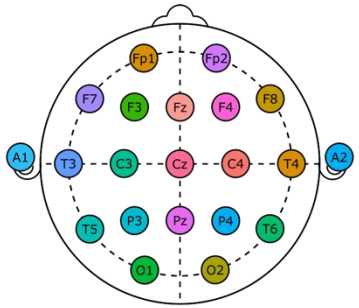


(A_{FC})

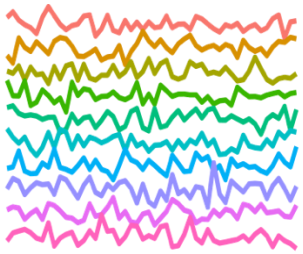
v. FC across all region pairs by SPI plus all whole-brain maps of local dynamics

(A_{FC_combo})

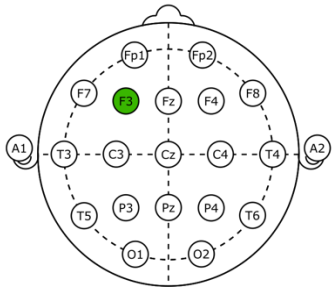
A **flexible, generalizable** framework for **neural** time-series data



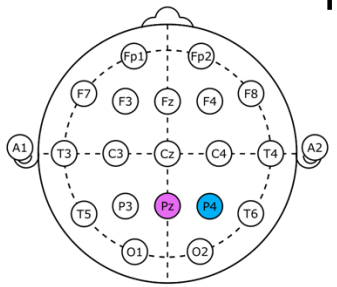
EEG electrodes



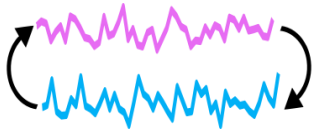
EEG time series



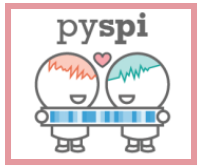
Local dynamics

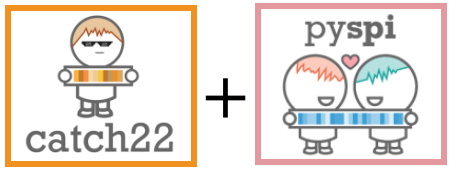


Pairwise coupling

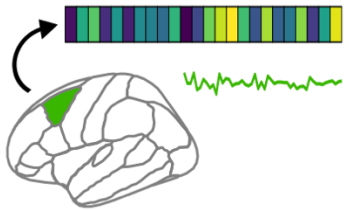


Modality(s)
Timescales
Time-series features



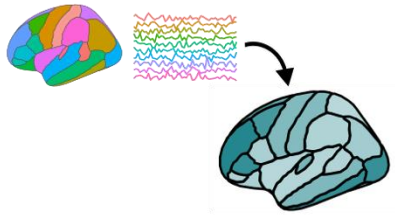


i. Local dynamics in an individual region



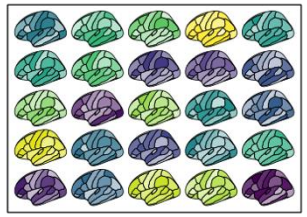
(A_{region})

ii. Whole-brain maps of an individual feature



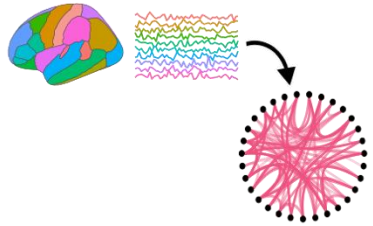
$(A_{feature})$

iii. Whole-brain maps of all features



(A_{uni_combo})

iv. FC across all region pairs with one SPI

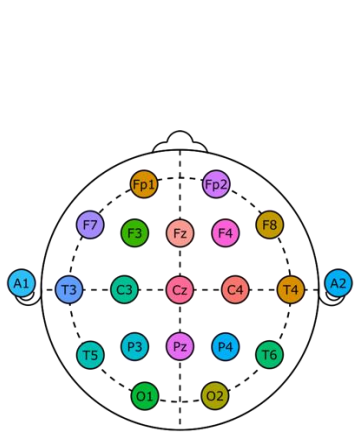


(A_{FC})

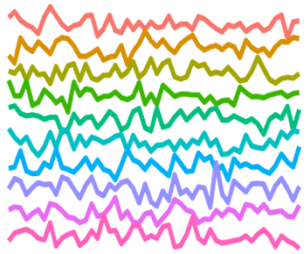
v. FC across all region pairs by SPI plus all whole-brain maps of local dynamics

(A_{FC_combo})

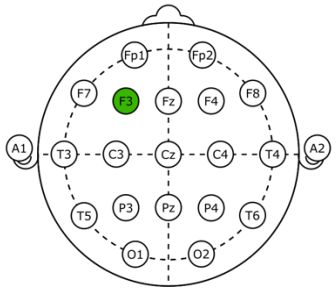
A **flexible, generalizable** framework for **neural** time-series data



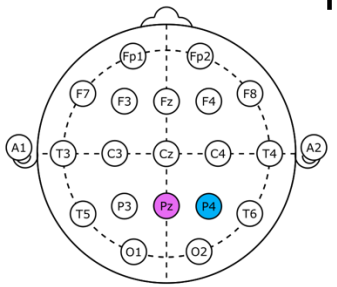
EEG electrodes



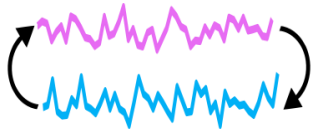
EEG time series



Local dynamics



Pairwise coupling

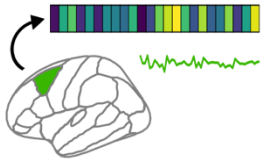


catch22

pyspi

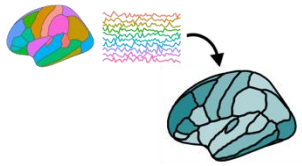
catch22 + pyspi

i. Local dynamics in an individual region



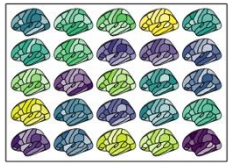
(A_{region})

ii. Whole-brain maps of an individual feature



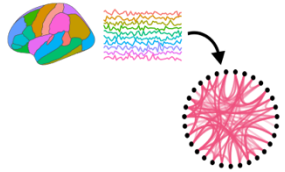
$(A_{feature})$

iii. Whole-brain maps of all features



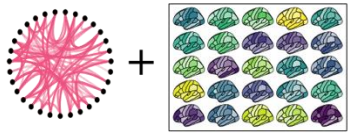
(A_{uni_combo})

iv. FC across all region pairs with one SPI



(A_{FC})

v. FC across all region pairs by SPI plus all whole-brain maps of local dynamics



(A_{FC_combo})

Modality(s)
Timescales
Time-series features
Clinical settings

Case-control

MRI fingerprinting

Stimulation studies

Thank you OHBM 2024 for the invitation & for your time 😊

Check out our preprint:

Find me at **Poster #1740** on **Wednesday and Thursday**

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