FRamework for
Information
Theoretical analysis of
Electrophysiological data and
Statistics

Etienne Combrisson

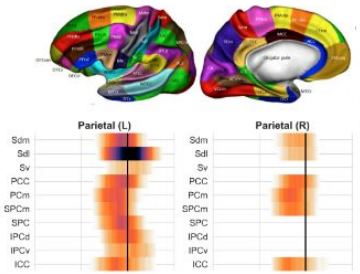
https://github.com/brainets/frites

https://brainets.github.io/frites/

Neurophysiological data

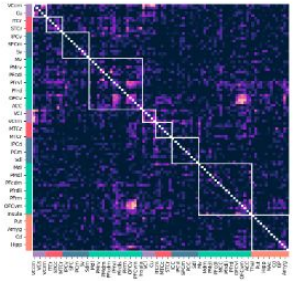
↓

IT Framework

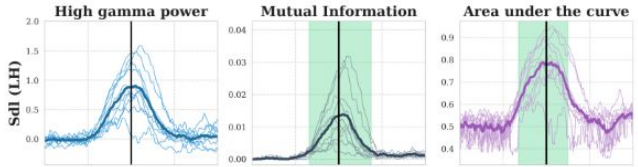


Local task-related brain activity

Task-related functional (un)directed connectivity

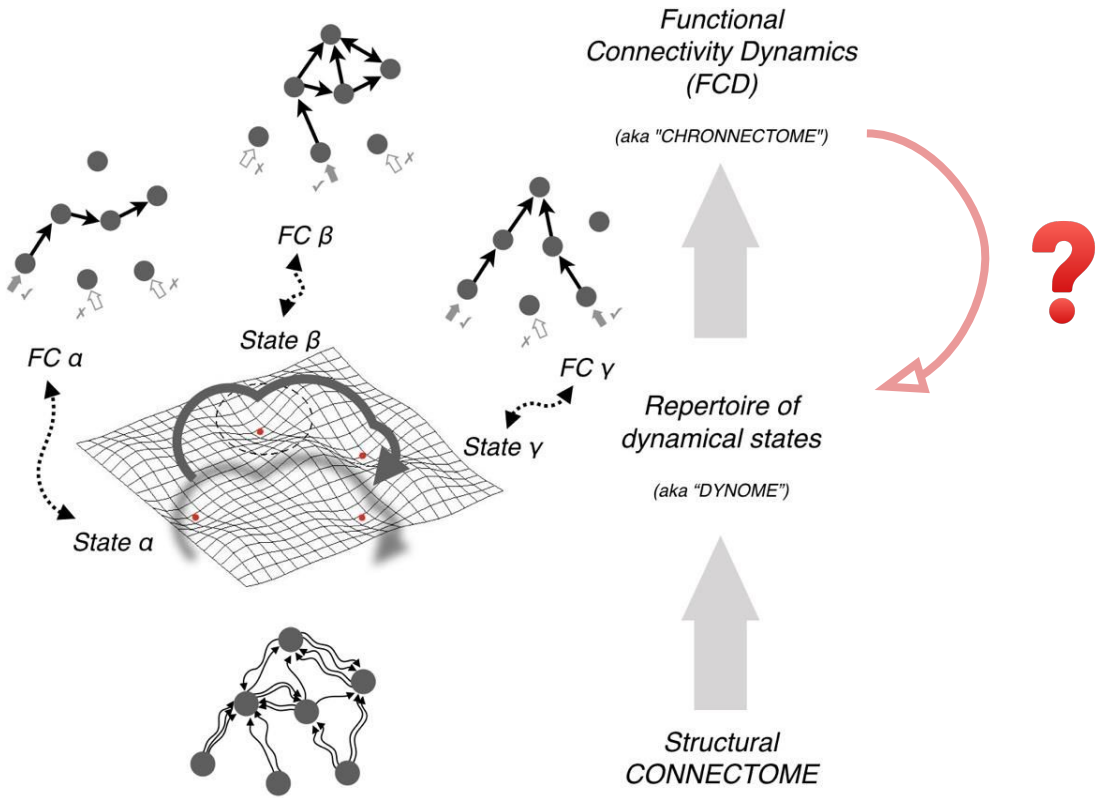


Group-level statistical inferences



Combrisson E, Allegra M, Basanisi R, Ince RAA, Giordano B, Bastin J, Brovelli A (2021). Group-level inferences of information-based measures for the analyses of cognitive brain networks. *biorxiv*

From Functional Connectivity to Neuronal Dynamics



Battaglia D, Brovelli A (2020) *The Cognitive Neurosciences, Sixth Edition*

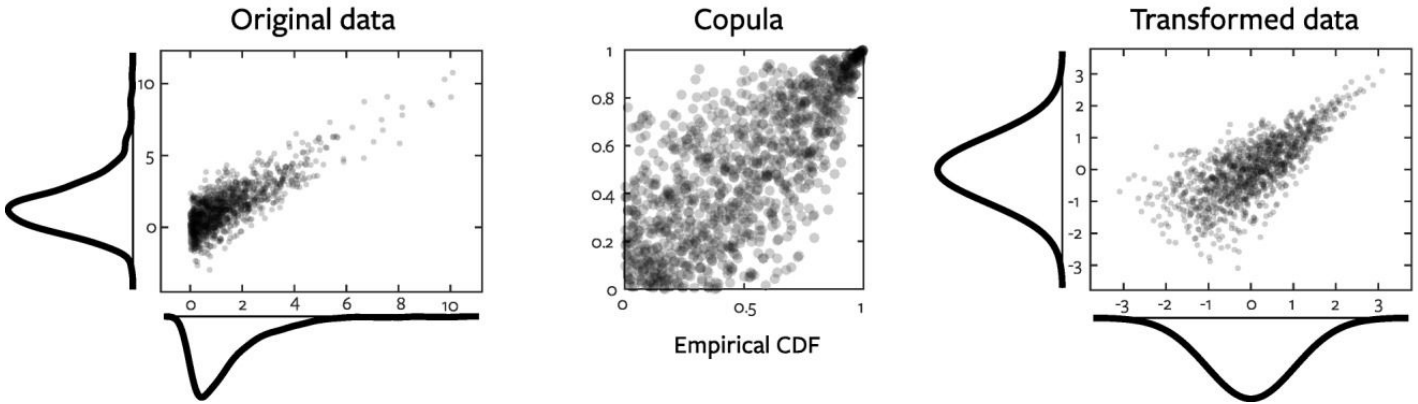
Information Theory

TABLE I. Relation between information theoretic quantities and other statistical approaches

Information theoretic quantity	Other statistical approaches
MI (discrete; discrete)	Chi-square test of independence Fishers exact test
MI (univariate continuous; discrete)	2 classes: t test, KS test, Mann–Whitney U test ANOVA
MI (multivariate continuous; discrete)	2 classes: Hoteling T^2 test Decoding (cross-validated classifier)
MI (univariate continuous; univariate continuous)	Pearson correlation Spearman rank correlation Kendall rank correlation
MI (multivariate continuous; univariate continuous)	Generalized Linear Model framework Decoding (cross-validated regression)
MI (multivariate continuous; multivariate continuous)	Canonical correlation analysis Distance correlation
Conditional mutual information	Partial correlation (continuous variables and linear effects only)
Directed information (transfer entropy)	Granger causality
Directed feature information	Dynamic Causal Modeling Psychophysiological interactions
Interaction information	Representational similarity analysis (redundancy only) Cross-classification decoding (redundancy only) Mediation analysis

Ince RAA et al (2016) A statistical framework for neuroimaging data analysis based on mutual information estimated via a Gaussian copula. *Human Brain Mapping*

Gaussian Copula MI and CMI



$$I(R;S) = H(S) - H(S|R)$$
$$= H(R) - H(R|S)$$
$$= H(R) + H(S) - H(R,S)$$

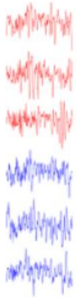
Gaussian Copula →

$$I(X;Y) = \frac{1}{2\ln 2} \ln \left[\frac{|\Sigma_X||\Sigma_Y|}{|\Sigma_{XY}|} \right]$$

Ince RAA et al (2016) A statistical framework for neuroimaging data analysis based on mutual information estimated via a Gaussian copula. *Human Brain Mapping*

Local analysis

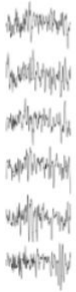
[Discrete case] contrasting the brain data coming from multiple conditions

$$I = \left(\text{  } \; ; \begin{bmatrix} 0 \\ 0 \\ 0 \\ 1 \\ 1 \\ 1 \end{bmatrix} \right)$$

[Continuous case] “correlates” brain data with a continuous variable

$$I = \left(\text{  } \; ; \begin{bmatrix} 0.9 \\ 0.7 \\ 0.6 \\ 0.5 \\ 0.4 \\ 0.3 \end{bmatrix} \right)$$

[Conditional case] “correlates” brain data with a continuous variable conditioned by a discret variable

$$I = \left(\text{  } \; ; \begin{bmatrix} 0.9 \\ 0.7 \\ 0.6 \\ 0.5 \\ 0.4 \\ 0.3 \end{bmatrix} \mid \begin{bmatrix} 0 \\ 0 \\ 0 \\ 1 \\ 1 \\ 1 \end{bmatrix} \right)$$

Core Functions

master ▾ frites / frites / core /

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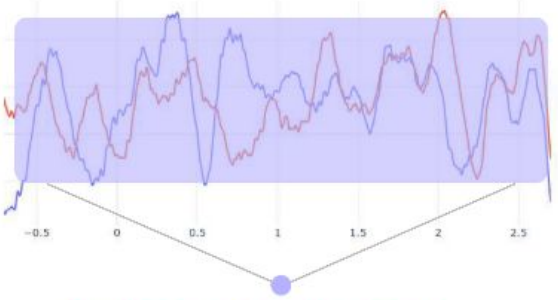
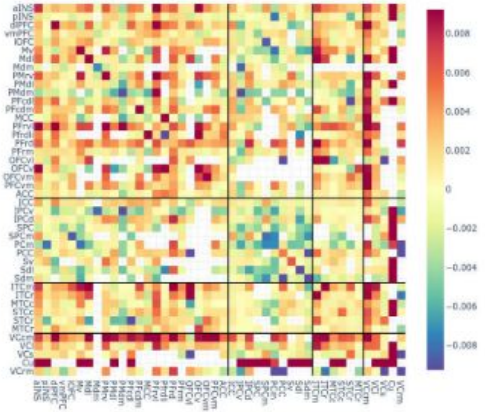
EtienneCmb Still fixing warnings — 0d1a122 on 26 Jul — History

..		
tests	Fix flake8	6 months ago
__init__.py	Remove gcmi ephy related files	10 months ago
copnorm.py	Still fixing warnings	4 months ago
gcmi_1d.py	Fix gcmi_1d types for Numpy warnings	4 months ago
gcmi_nd.py	Fix np.float and np.int types for Numpy warnings	4 months ago
mi_bin_ephy.py	Add binning MI estimator	10 months ago
mi_stats.py	core functions support conn	2 years ago

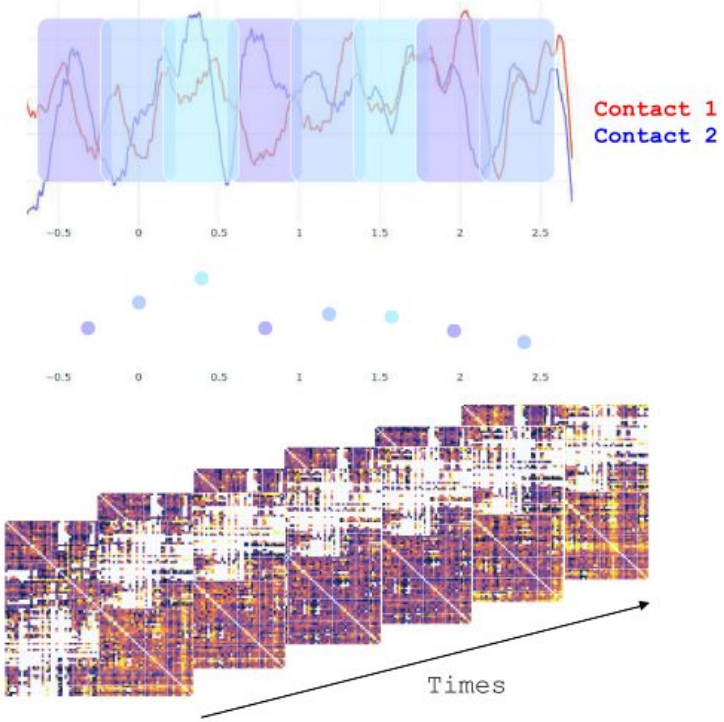
Functional Connectivity

Static functional connectivity

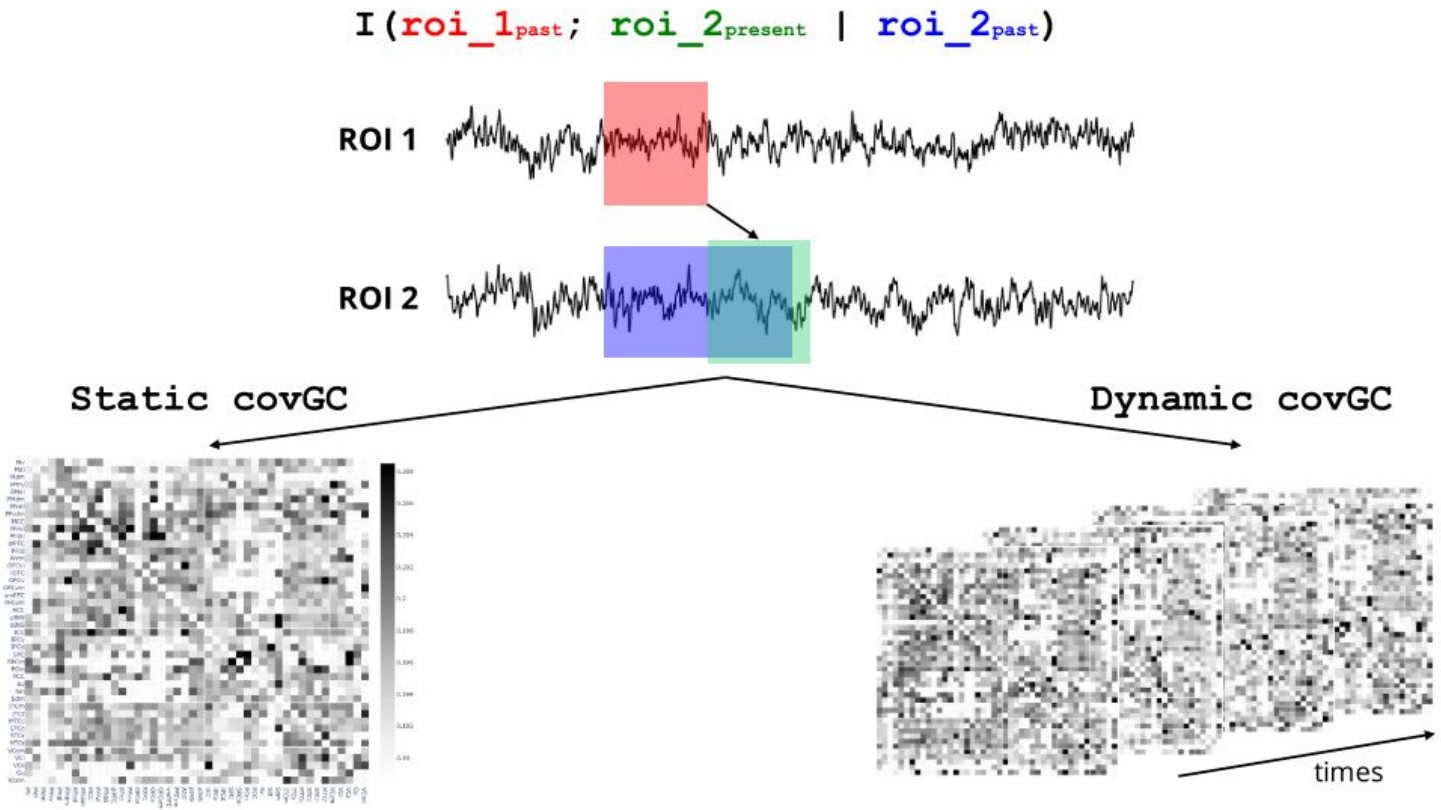




Dynamic functional connectivity



Granger Causality



Connectivity Measures

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EtienneCmb Improve WfMi message about copnorm — 11bc06d 6 days ago — History

..

tests	Improve temporal dimension of the ccf	last month
__init__.py	Implementation + test of the cross-correlation function	last month
conn_ccf.py	Fix attribute conversion in conn related functions	last month
conn_covgc.py	Fix attribute conversion in conn related functions	last month
conn_dfc.py	Fix attribute conversion in conn related functions	last month
conn_fcd_corr.py	Improve WfMi message about copnorm	6 days ago
conn_io.py	Reset to frequencies in samples	last month
conn_sliding_windows.py	Fix flake8	6 months ago
conn_transfer_entropy.py	Fix np.float and np.int types for Numpy warnings	4 months ago
conn_utils.py	Still fixing warnings	4 months ago

Estimators

master ▾ **frites** / frites / **estimator** /

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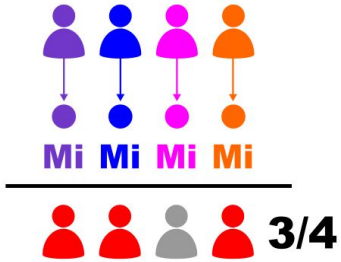
EtienneCmb Improve CustomEstimator documentation — 5584654 on 11 Aug — **History**

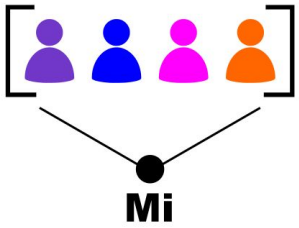
..		
tests	Add CustomEstimator	3 months ago
__init__.py	Add CustomEstimator	3 months ago
est_bin.py	Improve documentation	3 months ago
est_corr.py	Improve documentation	3 months ago
est_custom.py	Improve CustomEstimator documentation	3 months ago
est_dcorr.py	Improve documentation	3 months ago
est_gcmi.py	Improve documentation	3 months ago
est_mi_base.py	Estimators cleaning	6 months ago
est_resampling.py	Improve documentation	3 months ago

Statistical analysis

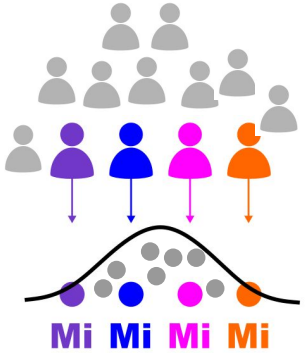
Single-subject



Fixed Effect (FFX)



Random Effect (RFX)



+

Permutation-based statistics and Multiple Comparison Correction

Stats functions

master ▾ frites / frites / **stats** /

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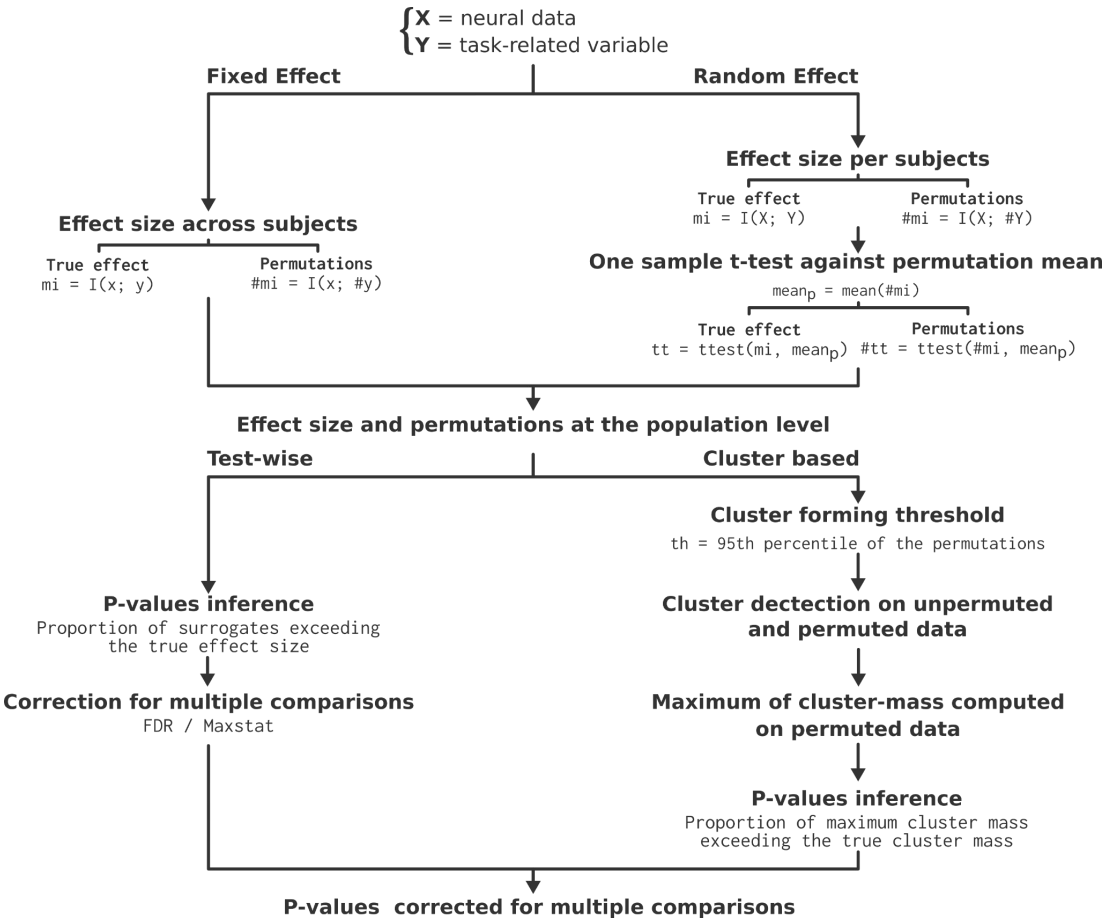
EtienneCmb Fix flake8 — ✕ 27578ca on 15 May — History

..		
tests	Fix flake8	6 months ago
__init__.py	Doc API improvements + code reorganization	12 months ago
stats_mcp.py	Fix flake8	6 months ago
stats_param.py	Method for computing the pop_mean_surr with les RAM requirements	13 months ago

Workflows


X = neural data
Y = task-related variable
Fixed Effect
Random Effect
Effect size across subjects
True effect
mi = I(x; y)
Permutations
#mi = I(x; #y)
Effect size per subjects
True effect
mi = I(X; Y)
Permutations
#mi = I(X; #Y)
One sample t-test against permutation mean
mean_p = mean(#mi)
True effect
tt = ttest(mi, mean_p)
Permutations
#tt = ttest(#mi, mean_p)
Effect size and permutations at the population level
Test-wise
Cluster based
P-values inference
Proportion of surrogates exceeding the true effect size
Correction for multiple comparisons
FDR / Maxstat
Cluster forming threshold
th = 95th percentile of the permutations
Cluster dectection on unpermuted and permuted data
Maximum of cluster-mass computed on permuted data
P-values inference
Proportion of maximum cluster mass exceeding the true cluster mass
P-values corrected for multiple comparisons

Workflows

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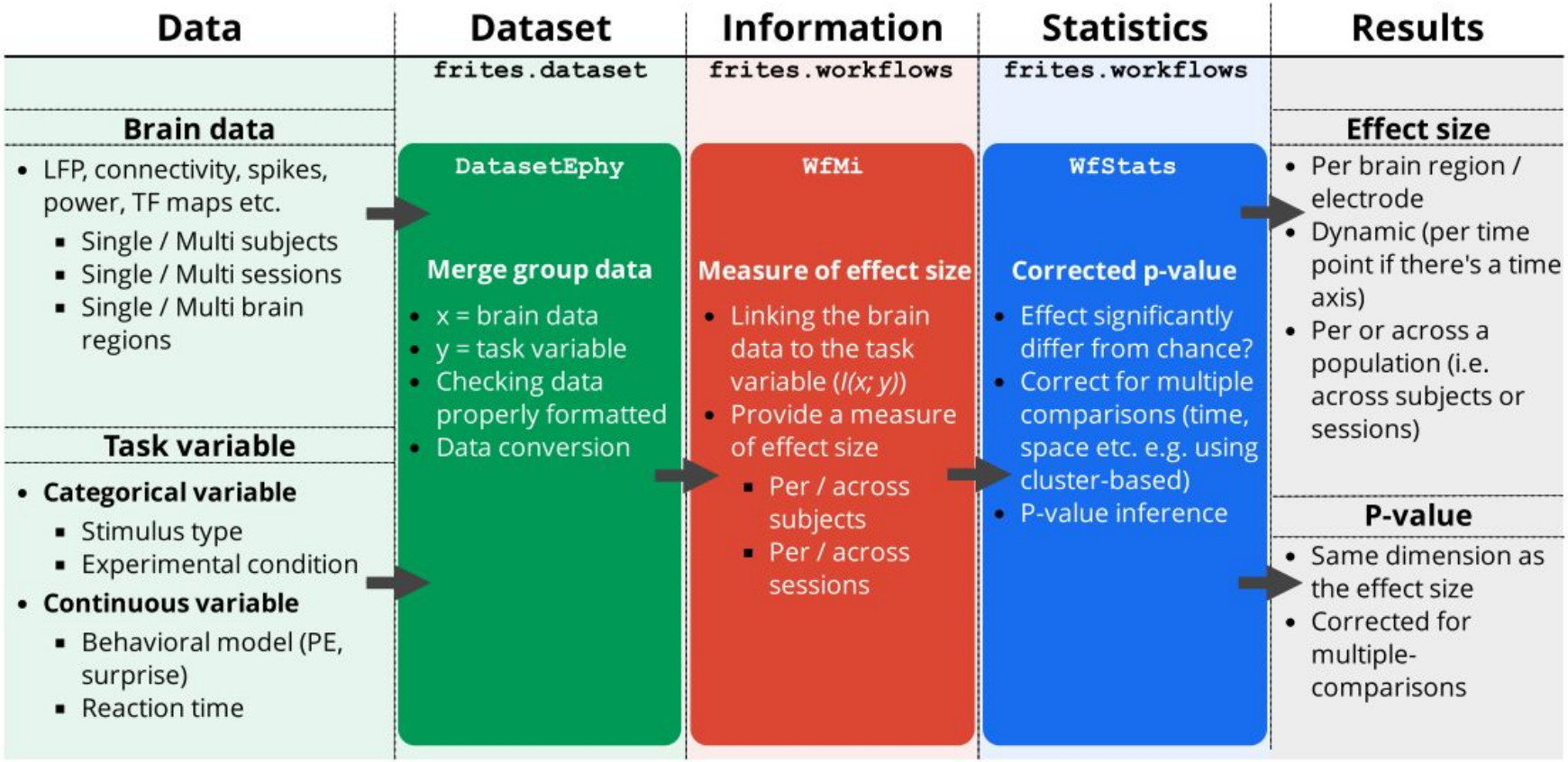
EtienneCmb Improve WfMi message about copnorm — 11bc06d 6 days ago — History

..		
tests	Fix code quality	4 months ago
__init__.py	Add example for combining WfMi	4 months ago
wf_base.py	Fix flake8	6 months ago
wf_conn_comod.py	Fix flake8	6 months ago
wf_mi.py	Improve WfMi message about copnorm	6 days ago
wf_mi_combine.py	Move doc (stupid mistake !)	4 months ago
wf_stats.py	Fix flake8	6 months ago

Typical Pipeline



https://brainets.github.io/frites/

Frites

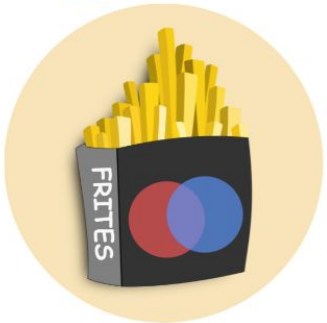
Overview Installation API Reference Examples

Version 0.4.0

- Examples
- Changelog
- Get help

Frites

Test and deploy passing | Code quality passing | build passing | codecov 84% | pypi package 0.4.0 | downloads 15k



FRamework for
Information
Theoretical analysis of
Electrophysiological data and
Statistics

On this page

Description
Highlights

Description

Frites is a Python toolbox for assessing information-based measures on human and animal neurophysiological data (M/EEG, Intracranial). The toolbox also includes directed and undirected connectivity metrics such as group-level statistics on measures of information (information-theory, machine-learning and measures of distance).

Examples

Search the docs ...

Estimate the Dynamic Functional Connectivity
Statistical analysis of a stimulus-specific network
Define an electrophysiological dataset using MNE-Python structures
Build an electrophysiological dataset
Define an electrophysiological dataset using Xarray
MI between two continuous variables conditioned by a discret one
MI between a continuous and a discret variables
Compute MI across time and frequencies
MI between two continuous variables
Investigate relation of order
Compute a conjunction analysis on mutual-information
Mutual-information at the contact level
Trial-resampling: correcting for unbalanced designs
Defining a custom estimator
Estimator comparison
Estimate dynamic functional connectivity
Estimate comodulations between brain areas
Lag estimation between delayed times-series using the cross-correlation

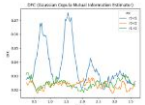
Examples

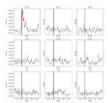
Illustration of the main functions.

Contents

Tutorials

Frites' tutorials





On this page

Tutorials
Multi-subjects dataset
Group-level statistics on measures of information
Information-based estimators
Connectivity and Information Transfer
Autoregressive model
Utility
Statistics
Simulations
Xarray

FRamework for
Information
Theoretical analysis of
Electrophysiological data and
Statistics


Etienne Combrisson


Vinicius Lima


Andrea Brovelli

1. **ROI-based** and **Network-based** analysis in the same framework
2. **Single-trial and dynamic (time-resolved) Functional Connectivity** measures for neurophysiology (MI, Granger causality, etc)
3. **Atlas**-based or **channel**-level (e.g., **MNI coords**) FC analysis
4. **Whole-brain** (MEG, EEG) and **sparse** (SEEG, LFP, MUA) data
5. **Single**-participant and **group**-level statistical inference
6. Frites is on **EBRAINS**
7. **Integration** with Siibra, IntrAnat, NeO and Elephant
8. Testing on **SEEG localisers** (JP Lachaux) and **SEEG CCEPs** (O David)

EBRAINS

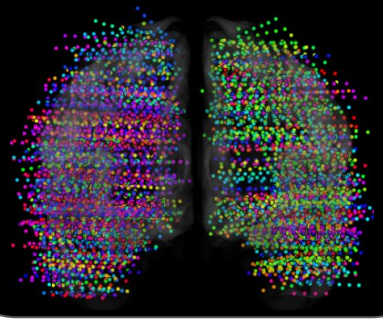
Application to sEEG data - Visual search

TASK

Where is the letter “T” among visual distractors?

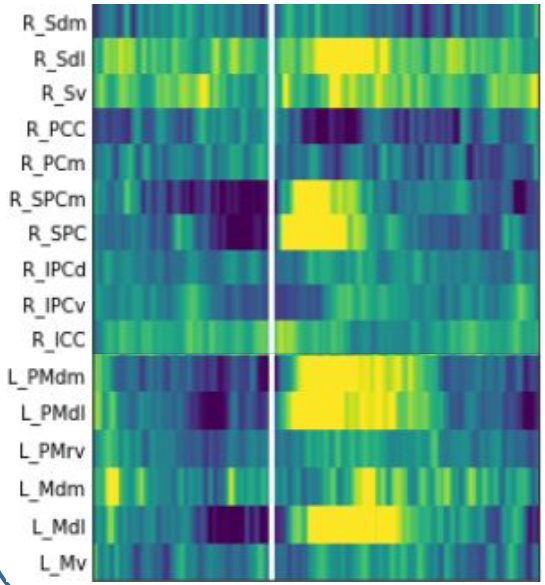
DATA

62 SEEG subjects



NEURAL CORRELATE

HGA activity in motor (L), premotor (L) and parietal (R) regions



Task-related FC on HGA amplitude

Pairwise links modulated according to reaction time (p<0.05)