MAPPING DISTINCT TIMESCALES OF FUNCTIONAL INTERACTIONS AMONG BRAIN NETWORKS

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At a Glance

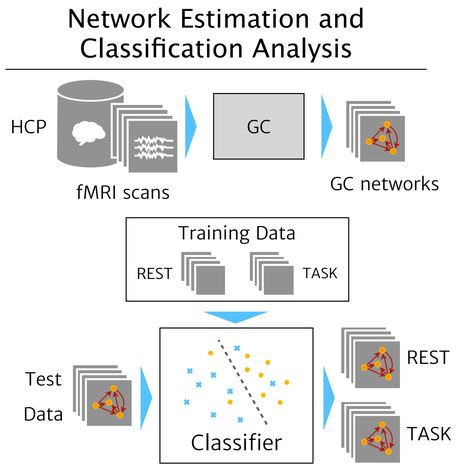
- Brain processes occur at diverse timescales, ranging from milliseconds to minutes.
- Understanding functional interactions at these different timescales is key to understanding how brain produces behavior.
- **Granger–Geweke Causality (GC)** is a powerful technique used to identify functional dependences among different timeseries.
- We use GC-measures on **functional Magnetic Resonance Imaging** data to discover functional networks that operate at different timescales and differ reliably across cognitive states.
- Our results address widely-held criticisms about the applicability of GC to fMRI data.

Data Analysis

- fMRI scans from **Human Connectome Project (HCP)** were used.
- 4000 scans from 500 subjects and eight cognitive conditions – **Rest** and seven **Tasks**.

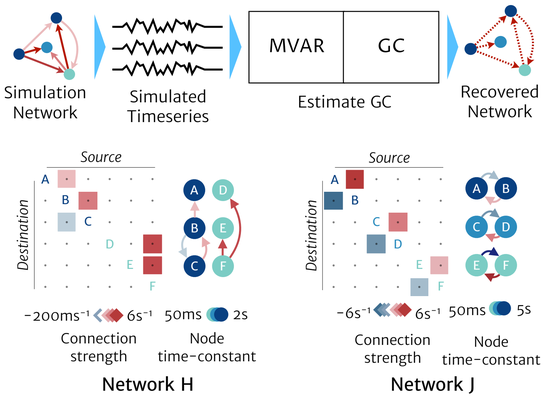
Analysis Framework

- Functional connectivity networks were identified using iGC and dGC.
- A linear classifier was trained to classify **Rest** from **Task** datasets.



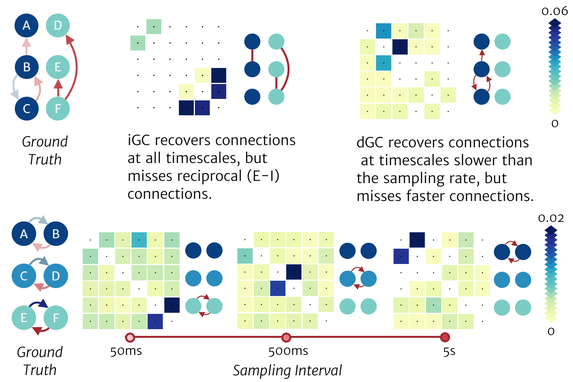
Simulations

Simulation Framework



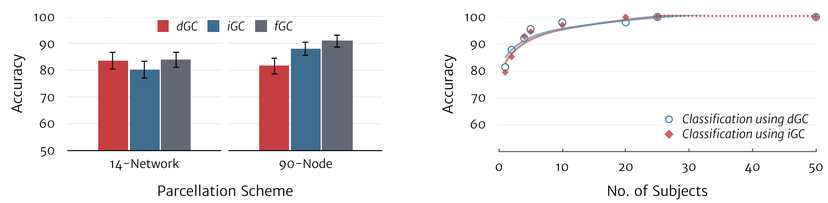
Results

- Networks recovered by iGC and dGC are complementary.
- dGC recovers connections at distinct timescales depending on sampling-rate.



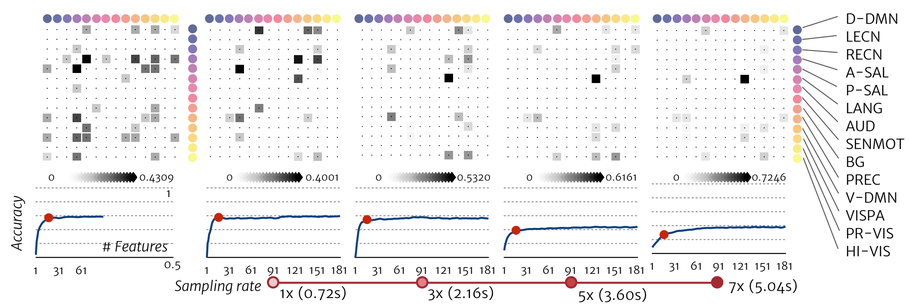
Distinguishing Task from Rest with GC Connectivity Networks

- GC networks can robustly discriminate between **Rest** and **Task** (Language) conditions.
- Discriminability improves (>95%) on averaging multiple (~5) single-subject GC matrices.



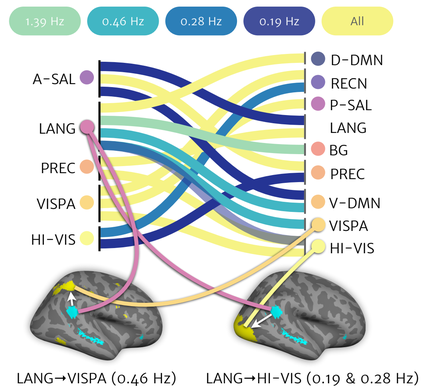
Identifying Maximally-Discriminative Connections

- The connections most relevant for discriminating **Task** from **Rest** were identified using **Recursive Feature Elimination (RFE).**
- dGC recovered partly distinct networks depending on the sampling-rate.



Distinct Timescales of Functional Interactions

- Discriminative connections identified by dGC, exclusively at different sampling intervals.



References

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Glossary

functional Magnetic Resonance Imaging

- fMRI is an imaging technique that measures brain activity indirectly by measuring changes in **blood–oxygenation.**
- fMRI has good **spatial resolution** (1-3mm), but limited **temporal resolution** (1-2s).

Functional Connectivity

- **Functional Connectivity** refers to functional interactions among different regions of the brain.
- Functional networks are discovered from recordings of fMRI activity using **statistical relationships** among the timeseries.

Granger Causality

- GC is a technique used to discover **directed** functional connectivity.
- GC measures dependence between two timeseries based on how much the knowledge about the past of one timeseries improves the prediction of the future of the other.
- **Total Dependence (fGC).** The total linear dependence between two timeseries is composed of:
  - **Instantaneous GC (iGC).** A symmetric measure of instantaneous dependence, based on zero-lag correlations.
  - **Lagged/directed GC (dGC).** A directed measure of dependence, based on lagged correlations.

$$\text{fGC} = \text{iGC} + \text{dGC}$$

- GC is estimated by modeling the timeseries data using a **Multivariate Autoregressive (MVAR) model.**

$$\mathbf{x}(t) = \sum_{i=1}^{p} A_i \mathbf{x}(t-i) + \mathbf{e}(t)$$

$$\mathcal{F}_{x \to y} = \log \frac{\Sigma_{\text{reduced}}}{\Sigma_{\text{full}}}$$

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