Functional Connectivity Profiles Predict Trial-by-Trial Success in a Navigation Task

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BACKGROUND

- Functional connectivity patterns between brain regions reveal network properties that reflect cognitive differences
- Connectome-based Predictive Modeling (CPM) can be used to predict brain states, age groups, and task type (Vergun et al., 2013; Wang et al., 2019)
- Recent findings suggest tangent-based connectivity is more effective for CPM compared to other connectivity metrics (Dadi et al., 2019)
- CPM has not yet been used to analyze task performance, especially at the trial level
- The goal of this study is to use CPM to predict performance

METHODS

Experiment

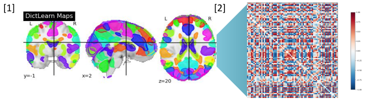
- **42** healthy young adults scanned via functional Magnetic Resonance Imaging **(fMRI)**
- Maze navigation, split into **explore** and **test** phase.
- Test phase accuracy: Range: **12.5% - 100%** | Mean: **58%**

Models

- **Four** Linear Support Vector Machines (SVM), each trained on **covariance**, **correlation**, **partial correlation**, or **tangent** based functional connectomes.

Training & Test Data

- [1]Dictionary Learning (DL) probabilistic atlas of **80** regions computed from rest-fMRI data. (Dadi et al., 2019)
- fMRI time series during **test** phase extracted into DL atlas, binned into **trial-by-trial time windows** (mean 35 s)
- [2]Functional Connectomes computed for each time window



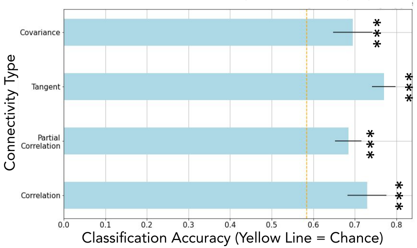
- The SVM classifiers were trained using a stratified shuffle split method (**30% test split**) on the resulting **1,976** connectomes for **each connectivity type**

HYPOTHESIS

Provided a rich time frame per trial, Linear Support Vector Machine **classifiers can predict trial-by-trial accuracy** when trained on **tangent-based functional connectivity patterns** computed from trial fMRI data obtained during a maze navigation task.

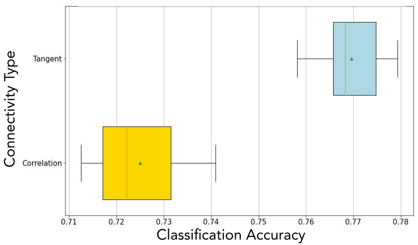
CONNECTOME MODEL PERFORMANCE

Model Performance by Connectivity Type



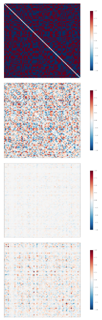
- **Linear SVM models predict individual trial accuracy** at levels above chance when trained on four types of **functional connectivity profiles** (Permutation tests, n = 1000, $p < 0.001$)

Comparison of Best Performing Models

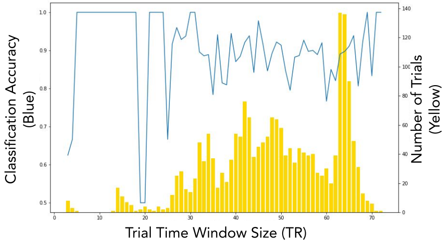


- Conducting a 5 x 2 Cross-Validation split, **tangent-based models** perform significantly **better than correlation-based**. (Paired Corrected Resampled T-Test, T = 5.303, $p < 0.001$)

Type	Description
Covariance	A simple measure of similarity between pairwise regions of interest
Correlation	Covariance between pairwise time-series, but where time-series are normalised. AKA Normalized or Full Correlation
Partial Correlation	Correlation (Full) between pairwise time-series, but where all other time-series have been regressed out
Tangent	Covariance, but where each time-series is transformed into its deviation from a group averaged covariance



Model Performance as a Function of Trial Duration



- The **tangent-based model** (79% test set accuracy, 89% overall) suggests **stable model performance** across trial time window sizes (Pearson R: -0.014, p-value: 0.537). TR = 720 ms.

DISCUSSION

- The SVM performed better than chance for predicting accuracy during a trial across all functional connectivity metrics.
- Notably, tangent space functional connectivity outperformed other functional connectivity metrics, in line with previous connectome model studies.
- We find that CPM is a promising tool for investigating trial-by-trial connectome contributions to task performance.
- These findings suggest that functional network communication during test can be used as a marker for success.
- The relationship between trial time window size and model performance requires further examination, given the low number of trials with small time-window sizes

Future Directions

- Train SVM models on trial time windows with ~ 25 or more TRs
- Examine average performance of CPM as a function of trial time window size
- Examine contributions of dynamic functional connectivity networks during the exploration phase to navigation task performance

REFERENCES & ACKNOWLEDGEMENTS

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