# ICA Network State Analysis

## Methods

Data Extraction

Metrics

Comparisons

It was decided to compare the conditions on three bases: overall information content per dataset, information content per assembly, and similarity of activation time courses per assembly. In addition, correlation matrices for the overall memberships and activation time courses of each assembly were generated.

In addition, it was determined to run these tests with three potential representations of the functional connectivity. First, a standard BOLD activation correlation analysis would be performed. Rather than detecting neural assemblies, ROI BOLD activation time courses were utilized. The second representation converted the BOLD time courses to *z*-scores, then utilized the Lopes-dos-Santos method to detect neural assemblies in the data. Finally, the time-varying phase angles of the BOLD time courses were computed and the Lopes-dos-Santos procedure utilized to detect the assemblies in the tensor of time-varying phase angles. It was hoped that running all three analyses simultaneously would serve as a method comparison. In this way, the relative sensitivity and reliability of each method could be established..

## 21.02.2019

Findings: Synchrony Data (LEiDA)

Analyses were first run only on the leading eigenvector of the functional connectivity matrix. This served to reduce the dimensionality of the data, and thus the computing power necessary to compute the results, by several orders of magnitude. This version of the analysis thus not only provided results rapidly, but also served as a useful method for debugging the pipeline, as errors became evident in minutes rather than hours.

* Figure 1: Total Entropy per Condition
  + Per Assembly
    - Highly significant differences were found between conditions when comparing assembly entropies. This held for all three tested data representations.
  + Per Subject
    - No significant differences were found between conditions when comparing subject entropies. This held for all data representations tested.
* Figure 2: Individual Assembly Entropy per Condition
  + BOLD Time Courses:
    - No ROI BOLD time courses displayed significantly different activation courses between conditions at the 0.05 significance level.
  + Z-Scored Assembly Activations:
    - Assemblies 1, 8, and 9 displayed significantly different activation courses between conditions at the 0.05 significance level. However, multiple-comparison correction nullified these differences.
  + Phase Synchrony Assembly Activations:
    - Assemblies 1, 4, 5, 6, 8, 10, 15, 16, 17, and 18 displayed significantly different activation courses between conditions at the 0.05 significance level.
    - Multiple-comparison correction demonstrated the robustness of significance of Assemblies 1, 4, 5, 6, 15, 17, and 18.
* Figure 3: Overall Assembly Membership and Activation Correlation
  + This analysis was restricted to those assemblies which displayed significantly different activation trajectories between conditions. As only the phase synchrony representation displayed more than one such assembly, only this representation was tested.
  + These assemblies displayed some overlap in membership, but this overlap was restricted to less than 20% of member nodes for virtually all assemblies.
  + The selected assemblies displayed virtually no overlap in activation time courses, suggesting that the algorithms have selected maximally independent assemblies.
* Figure 4: Assembly Activation Correlation between Conditions
  + Assemblies generally displayed limited activation correlation between conditions. Only one assembly displayed a correlation coefficient of magnitude greater than 0.10, and only one other displayed a CC of magnitude greater than 0.06. A majority of assemblies display a cross-condition correlation on the order of 0.05. In addition, the majority of cross-condition correlations are negative.
  + The seven assemblies showing significant differences between conditions [1, 4, 5, 6, 15, 17, 18] unsurprisingly displayed limited to no correlation in the activation time courses between conditions. No assembly displayed a cross-condition correlation with magnitude greater than 0.04.

## 22.02.2019

Findings: Synchrony Data (no LEiDA)

After leading connectivity eigenvector analysis confirmed code functionality, the analysis was rerun using the full functional connectivity tensor. The findings of this analysis are reported below.

* Figure 1: Total Entropy per Condition
  + Per Assembly
    - Both BOLD time courses and *z*-scored assembly activations display highly significant differences in total assembly entropies between conditions.
    - The phase representation, possibly due to the large number of assemblies detected, did not display a significant difference between conditions.
  + Per Subject
    - No significant differences were found between conditions when comparing subject entropies. This held for all data representations tested.
* Figure 2: Individual Assembly Entropy per Condition
  + BOLD Time Courses:
    - No ROI BOLD time courses displayed significantly different activation courses between conditions at the 0.05 significance level.
  + Z-Scored Assembly Activations:
    - Assemblies 7, 9, and 15 displayed significantly different activation courses between conditions at the 0.05 significance level. However, multiple-comparison correction nullified these differences.
  + Phase Synchrony Assembly Activations:
    - Assemblies 450 and 533 displayed significantly different activation courses between conditions at the 0.05 significance level. However, multiple-comparison correction nullified these differences.

One immediately obvious difference between the LEiDA analysis and full connectivity matrix is the number of functional assemblies detected in the phase synchrony representation of the data. Whereas 18 phase-locked functional assemblies were detected in the leading eigenvector analysis, the full connectivity matrix displayed 538 such assemblies. This high number of assemblies, and the correspondingly harsh multiple comparison correction necessary, may be the reason that no significant difference was found between conditions in either total or assembly-wise entropy using the phase synchrony representation.

Next steps:

~~Run KS test / divergence on distribution~~ (we do this in entroSigTest function)

~~Eliminate cerebellum timeseries (46-58, 104-116)~~

~~Plot significant assemblies in matrix form~~

Plot significant assemblies in cortical map form (color code)

Send network maps to Cabral