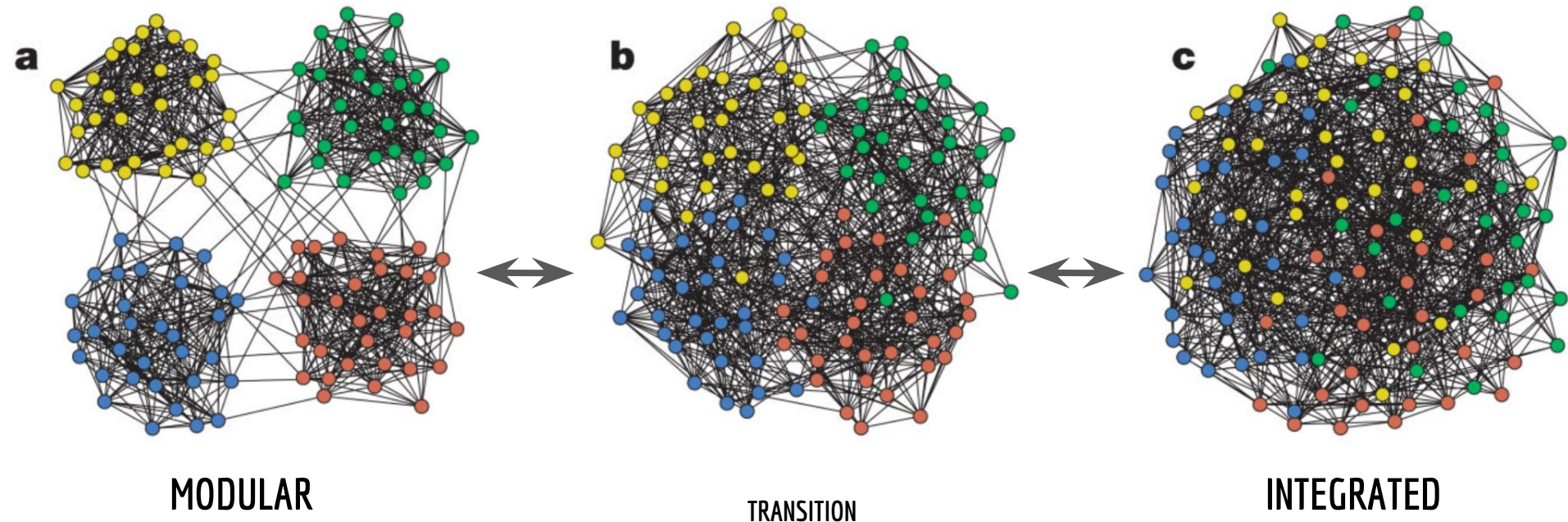


Opposing engagement of cerebellar and basal ganglia networks with shifts of cortical network topology

Kimberly Nestor
PI: Timothy Verstynen, PhD
Carnegie Mellon University



Network connectivity is mutable and can change from modular to integrated

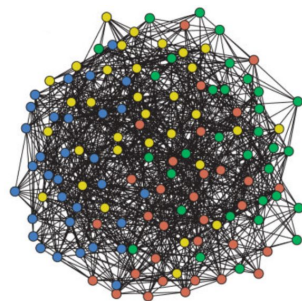
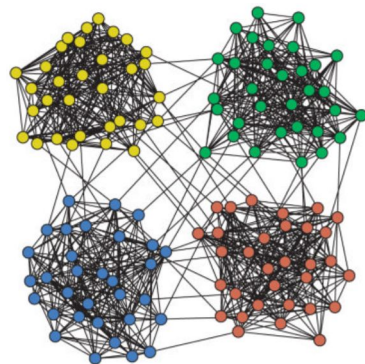


How does the brain adapt to an ever changing landscape?

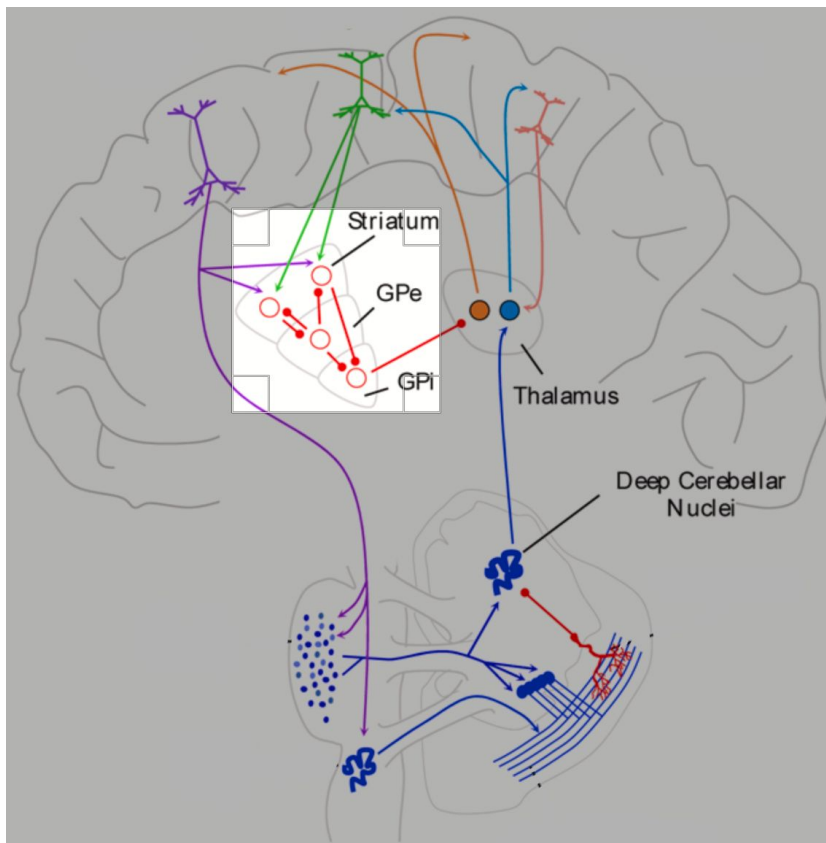
Reorganization occurs on a fast and slow timescale
(Zhou et al., 2019)

Cortical topology is linked to task cognitive complexity
(Owen et al., 2021)

Cortical topology can indicate richness of memory recall
(Geib et al., 2017)



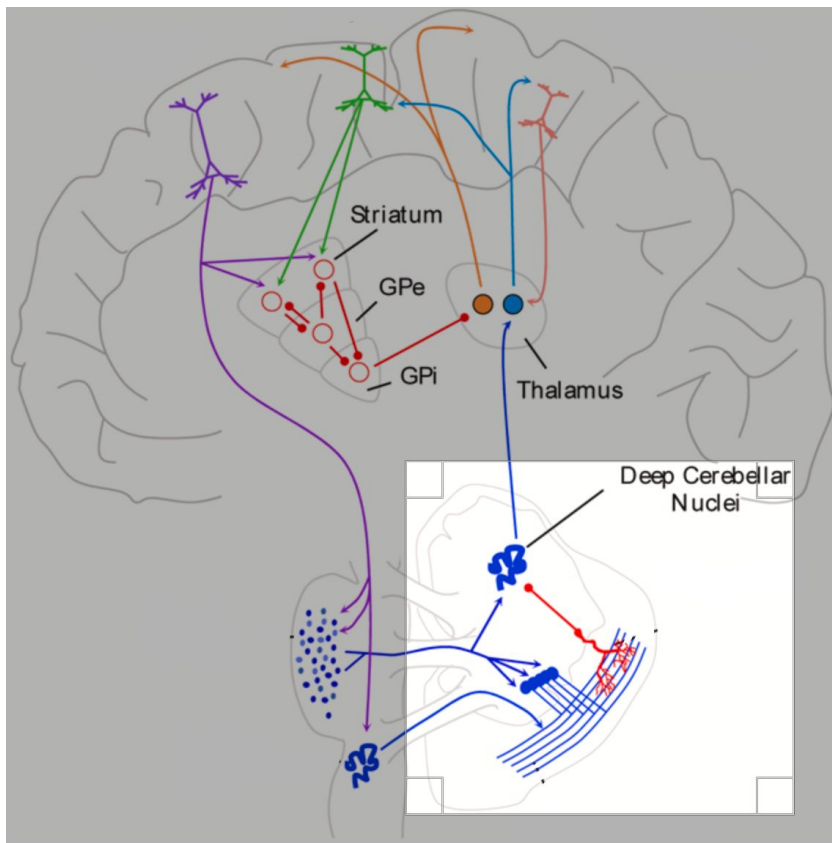
Subcortical regions are highly connected with cortical regions



Integration

- Basal ganglia projects to matrix thalamus from globus pallidus interna (GPi).
- Matrix thalamus projects diffusely to cortical regions

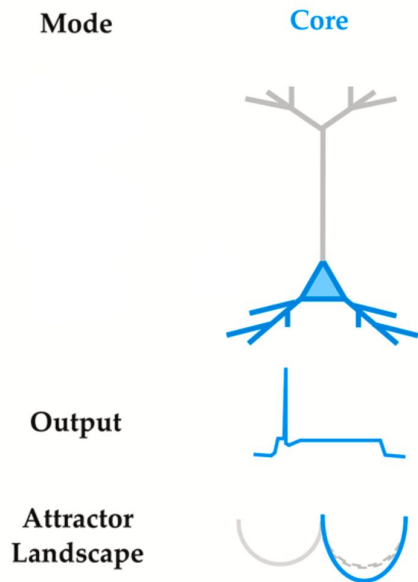
Subcortical regions are highly connected with cortical regions



Segregation

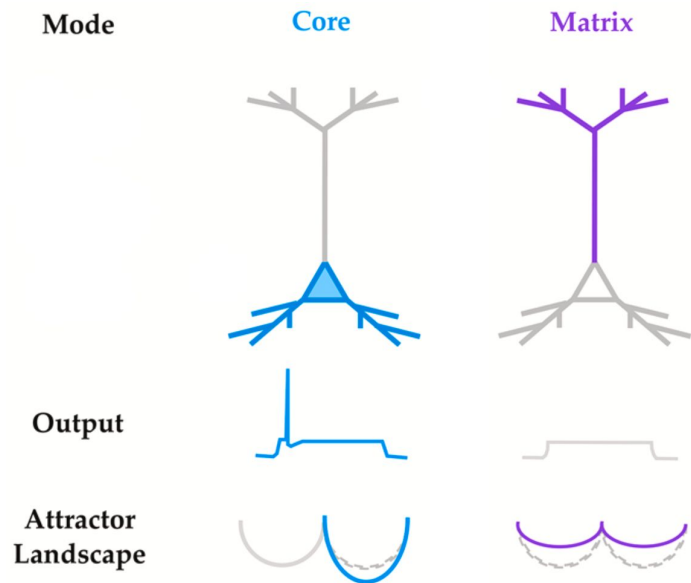
- Cerebellum projects to core thalamus from the deep cerebellar nuclei
 - Core thalamus projects focally to cortical hubs

Cellular activation input to the thalamus drive changes in the attractor landscape



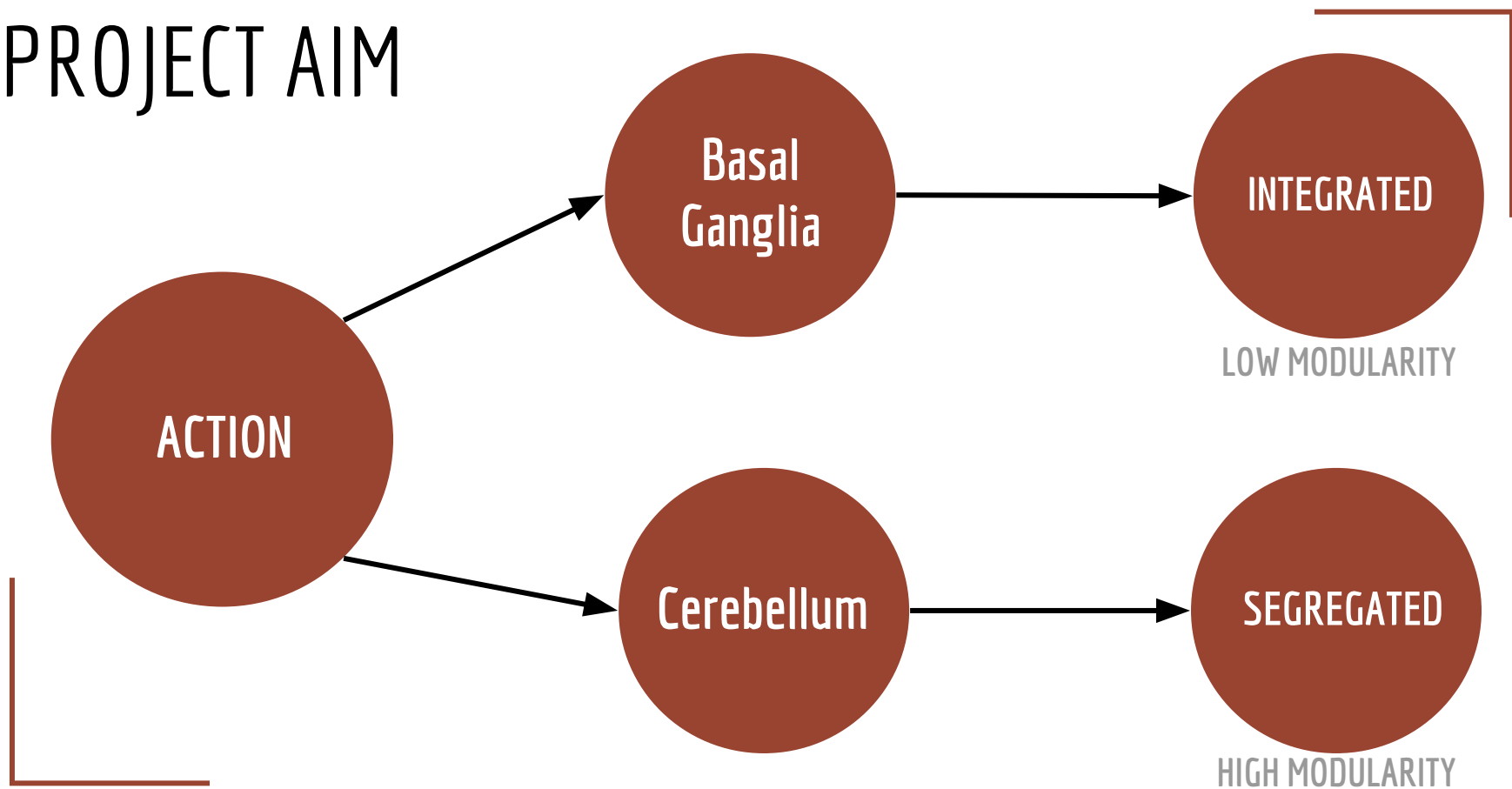
- Segregation leads to deepening of the wells
 - Greater stores of energy to select regions
 - Excitatory, glutamatergic input from the deep cerebellar nuclei to core thalamus (Shine, 2021).

Cellular activation input to the thalamus drive changes in the attractor landscape



- Segregation leads to deepening of the wells
 - Greater stores of energy to select regions
 - Excitatory, glutamatergic input from the deep cerebellar nuclei to core thalamus (Shine, 2021).
- Shallowing of wells and global integration
 - Less energy stored in regions, but spread across landscape
 - Inhibitory GABAergic cells of the GPi to matrix thalamus cause tonic inhibition causing cortical activation (Shine, 2021).

PROJECT AIM



METHODS

Participants - total n=242

Female=119, Male=123

Mean age=40 ± 6 years, min=30, max=51

Scanner - Siemens 3T Trio

12-channel head coil

fMRI = T2*-weighted; 3mm isotropic; RT = 2s; ET = 28ms; Flip = 90°

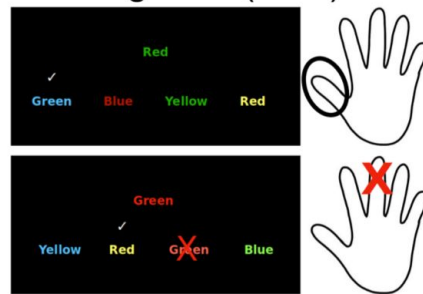
Task Acquisition - Stroop Task and Multi-Source Interference Task (MSIT)

Adaptive dependent on participant accuracy only in incongruent blocks

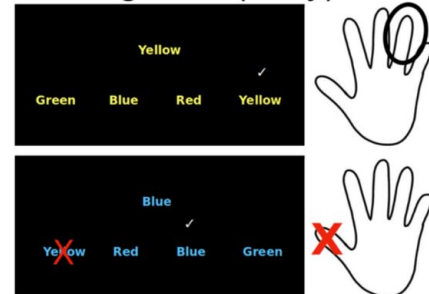
Interleaved, four congruent and four incongruent blocks (60s), rest (10s)

Color-Word Stroop Task

A Incongruent (hard) trial



B Congruent (easy) trial



METHODS

Data analysis

Shen functional atlas parcellation - determines clusters of brain areas, where $k=268$

Edge time series - fMRI analysis method, allows examination of network across entire timescale

Modularity index

Estimate value Q , for modularity across a network

Automatically determines segmented communities

Eigenvector centrality

Recursively determines centrality for children of target node

Cross correlation

Determines time lagged relationships between Bg, Cb and cortex

Shen, 2021

Zamani Esfahlani et al., 2021

Shine et al., 2016

Newman, 2010

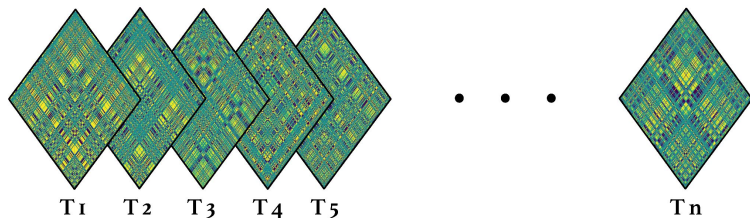
METHODS: Detailed

Edge time series

$$z_i = \frac{x_i - \mu_i}{\sigma_i}$$

Let $c_{ij} = [z_i(1) \cdot z_j(1), \dots, z_i(T) \cdot z_j(T)]$

and $c_{uv} = [z_u(1) \cdot z_v(1), \dots, z_u(T) \cdot z_v(T)]$



Modularity index

$$B = A - P$$

Modularity
matrix

Observed

Expected

$$Q^{signed} = \sum_{ij} [B_{ij}^+ - B_{ij}^-] \delta(\sigma_i, \sigma_j)$$

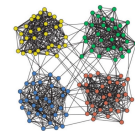
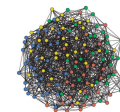
Kronecker
function



SEGREGATED

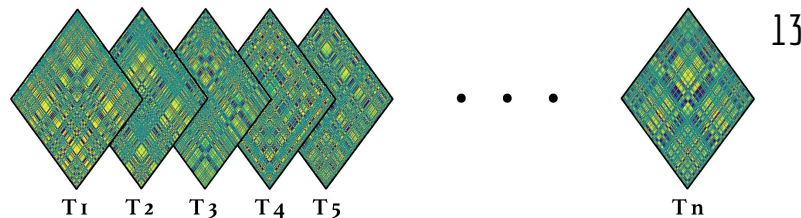


INTEGRATED

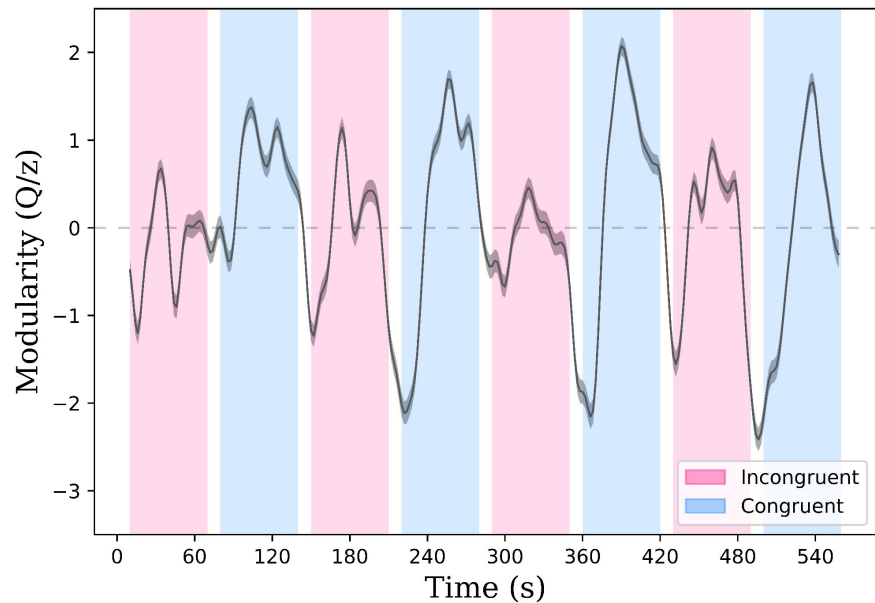


RESULTS: AIM 1

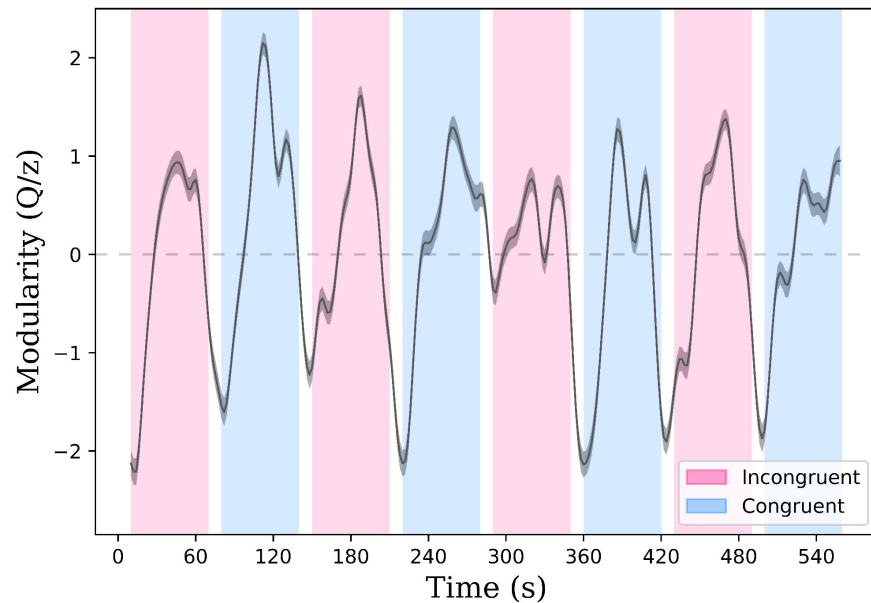
Modularity Index



STROOP

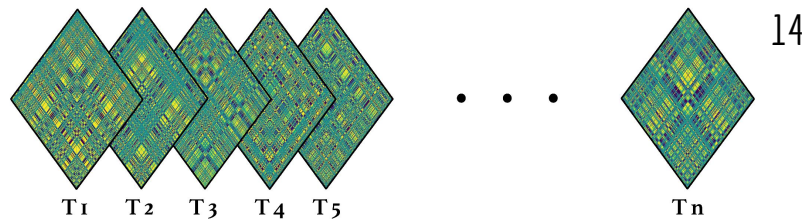


MSIT

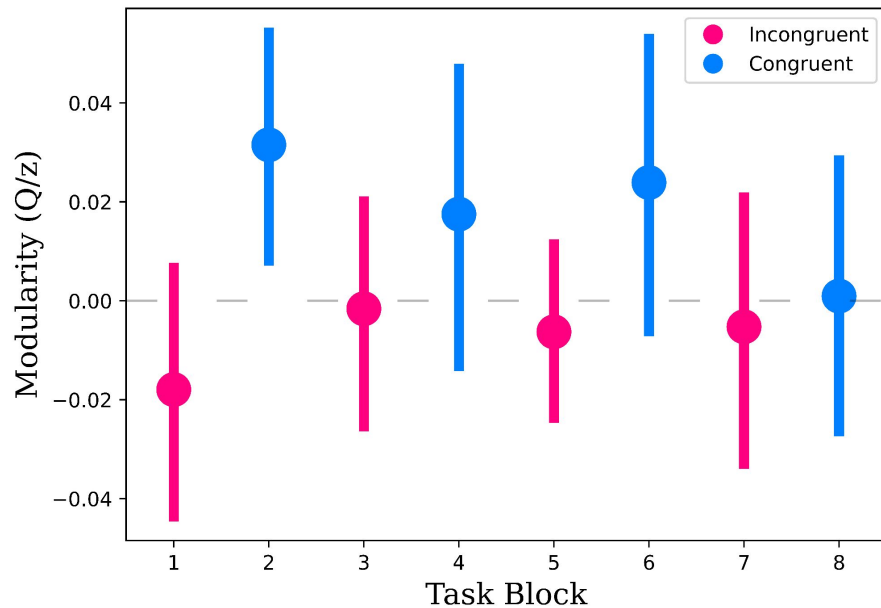


RESULTS: AIM 1

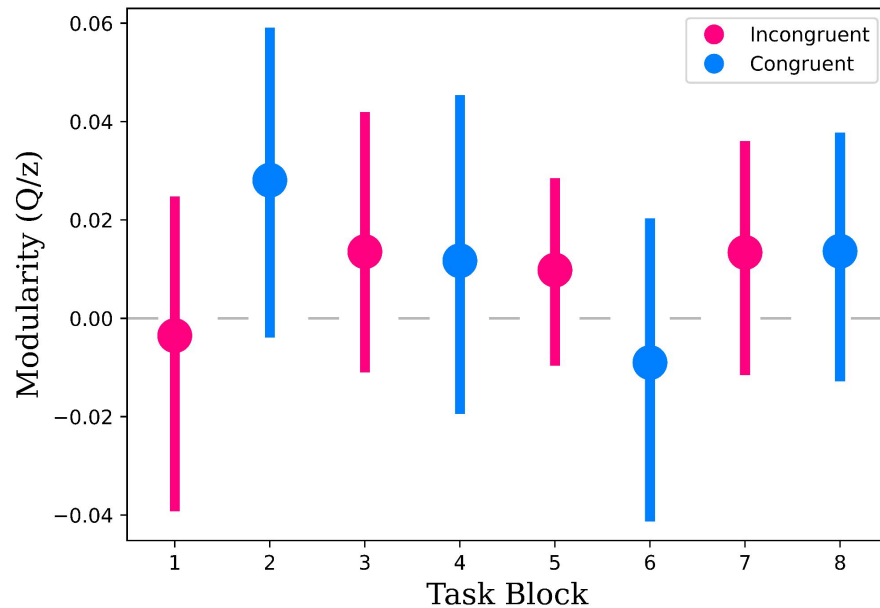
Modularity Index



STROOP



MSIT



METHODS: Detailed

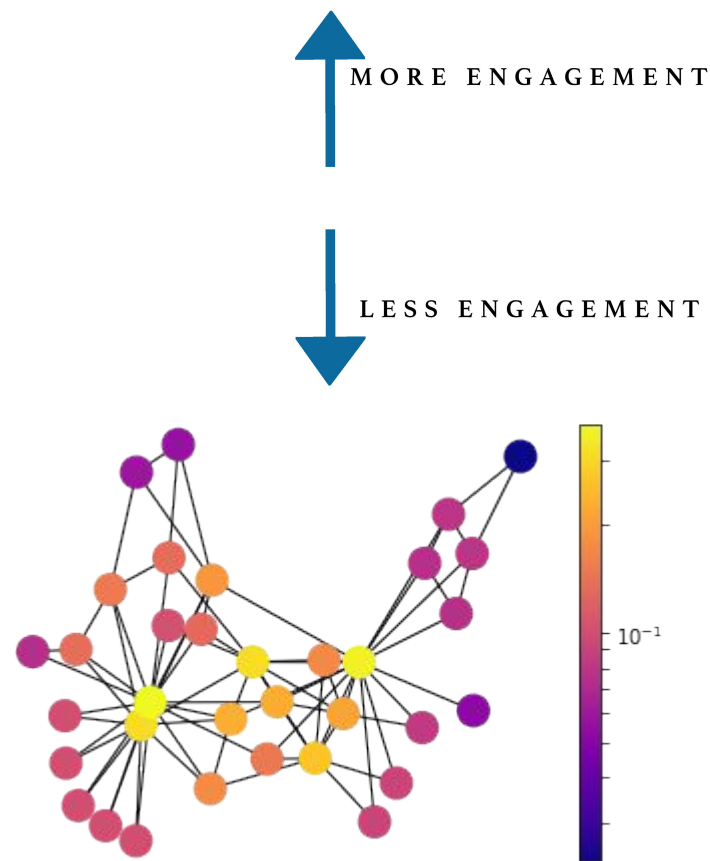
Eigenvector centrality

$$x_i = K_1^{-1} \sum_j A_{ij} x_j$$

Maximum
eigenvalue

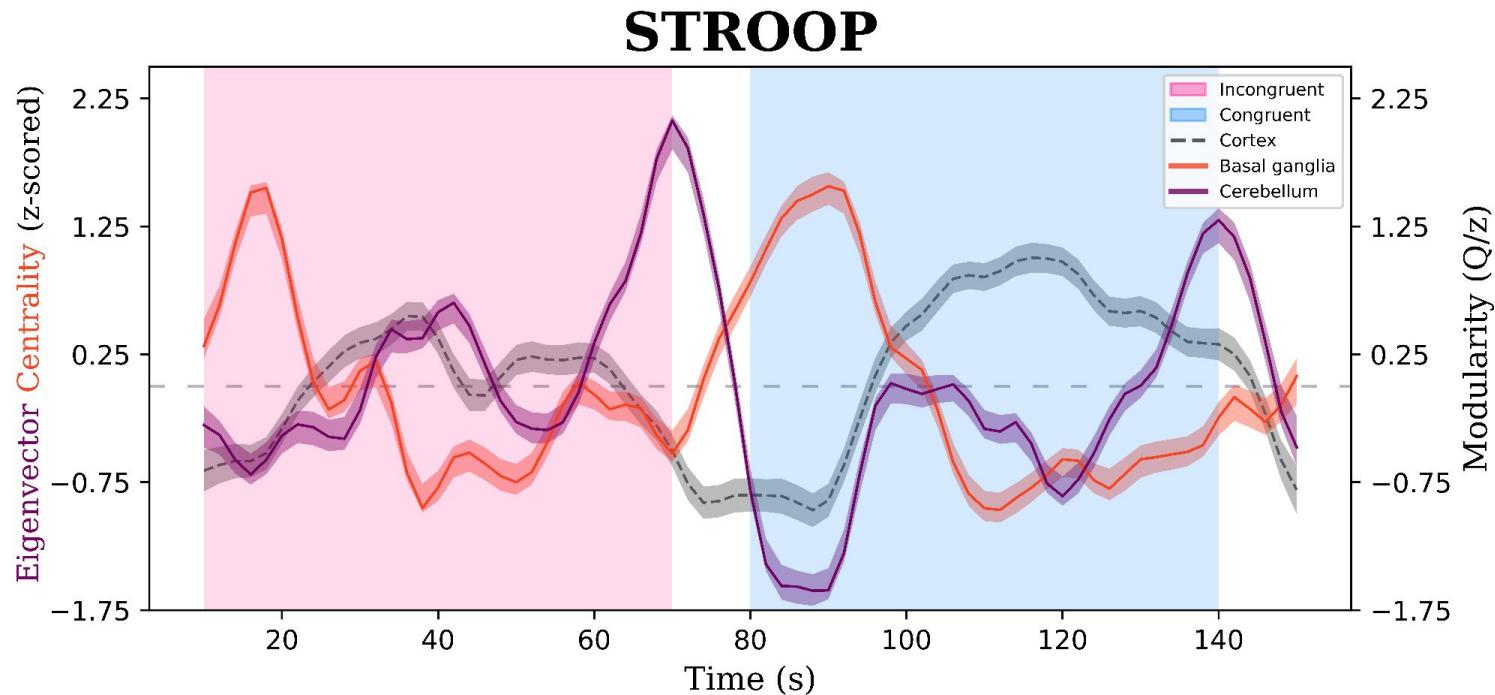
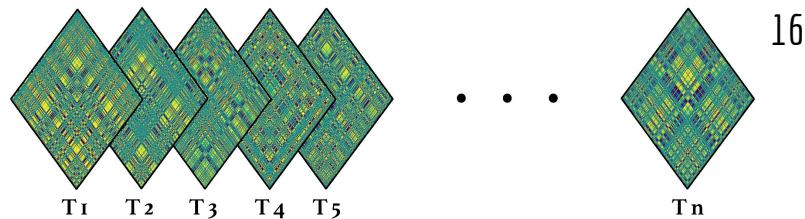
Adjacency
matrix

Child node
eigenvector



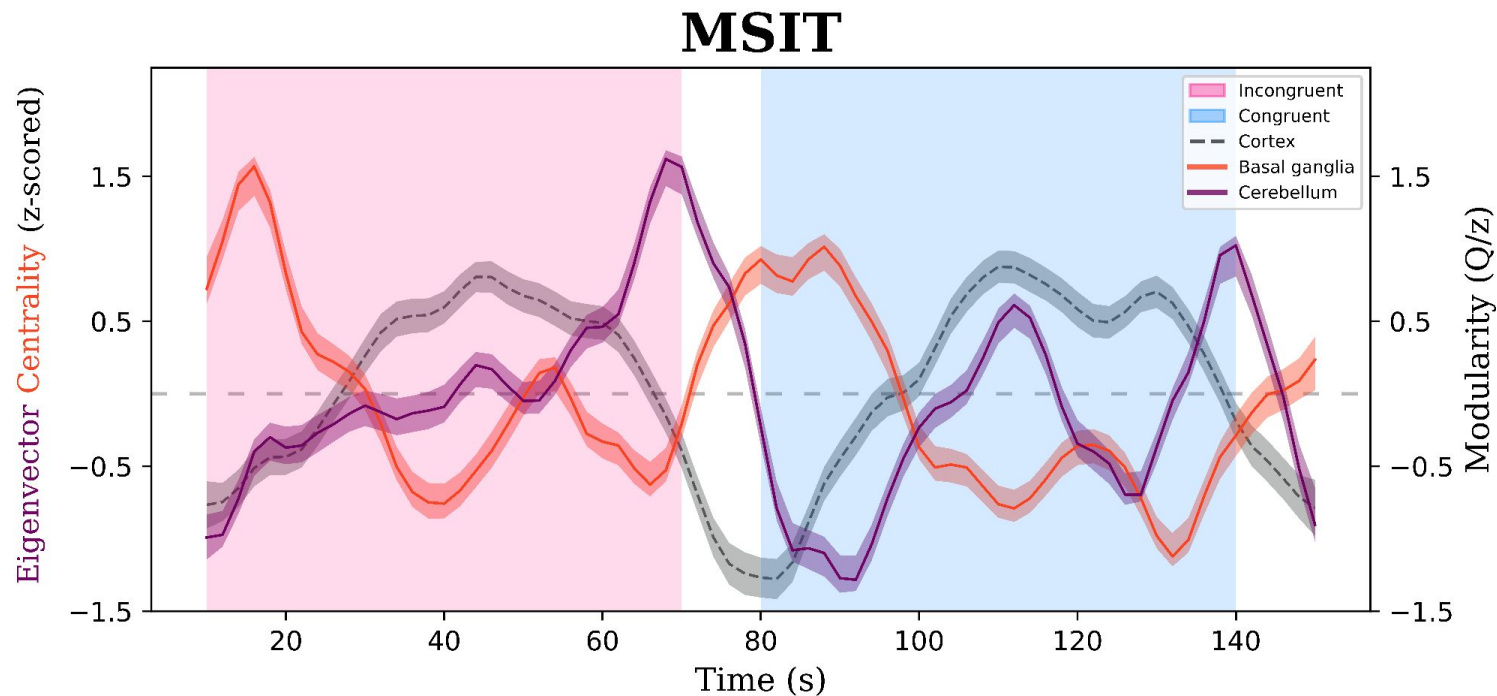
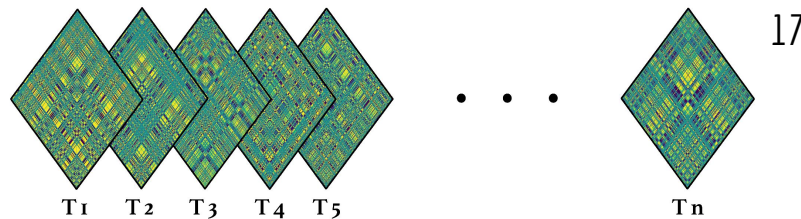
RESULTS: AIM 2

Eigenvector Centrality



RESULTS: AIM 2

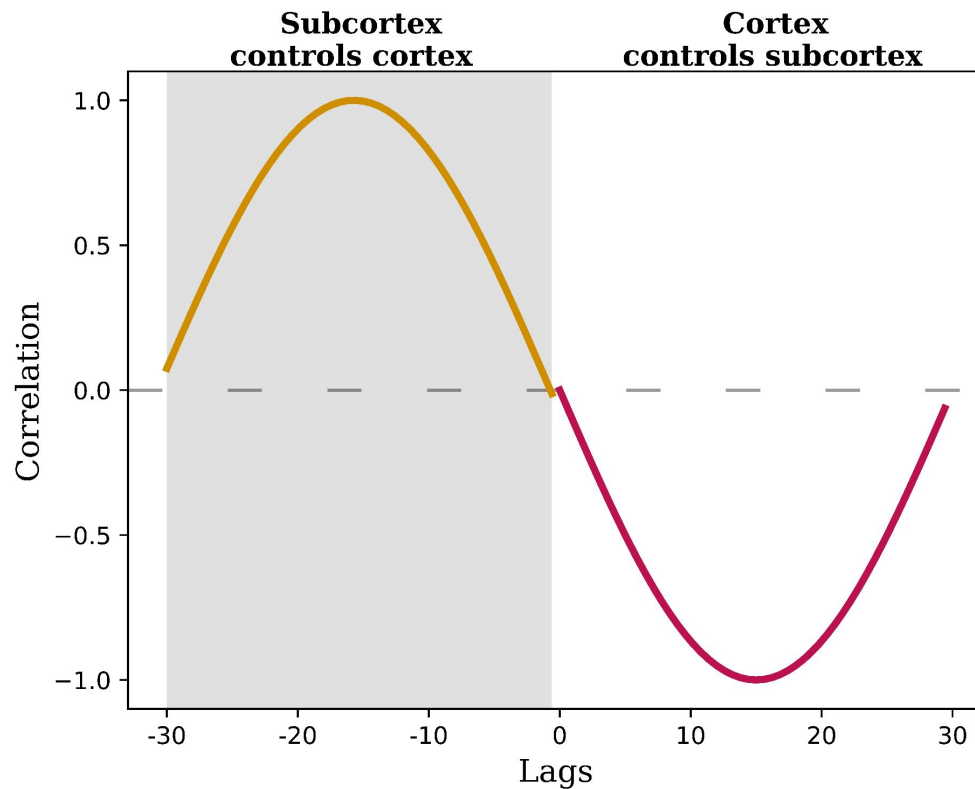
Eigenvector Centrality



CROSS CORRELATION

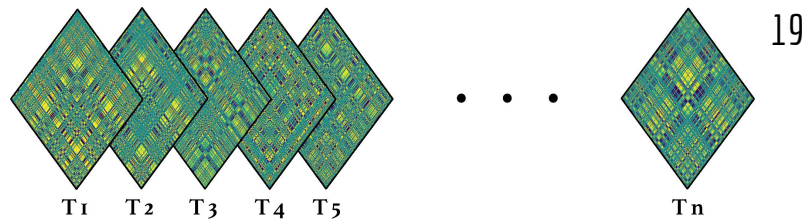
INTERPRETATION

18

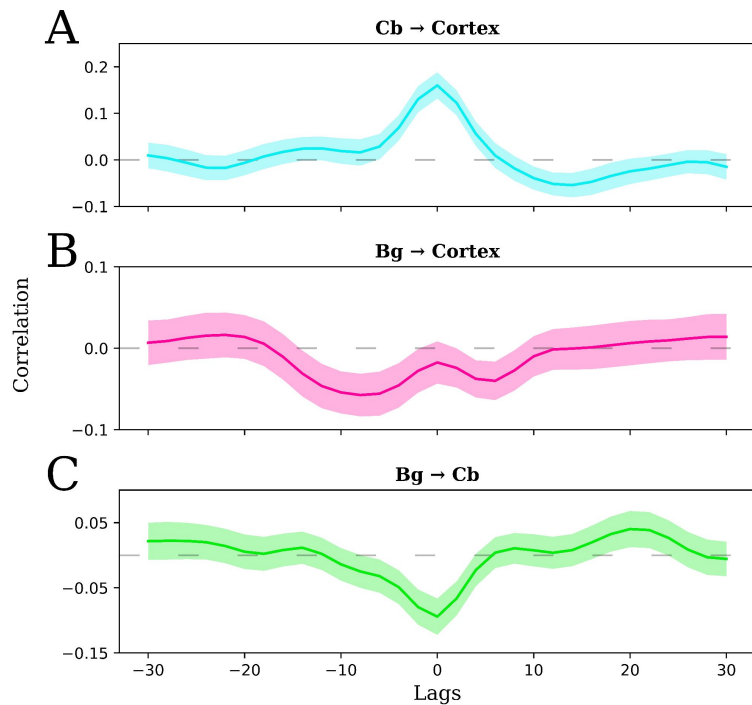


RESULTS: AIM 2

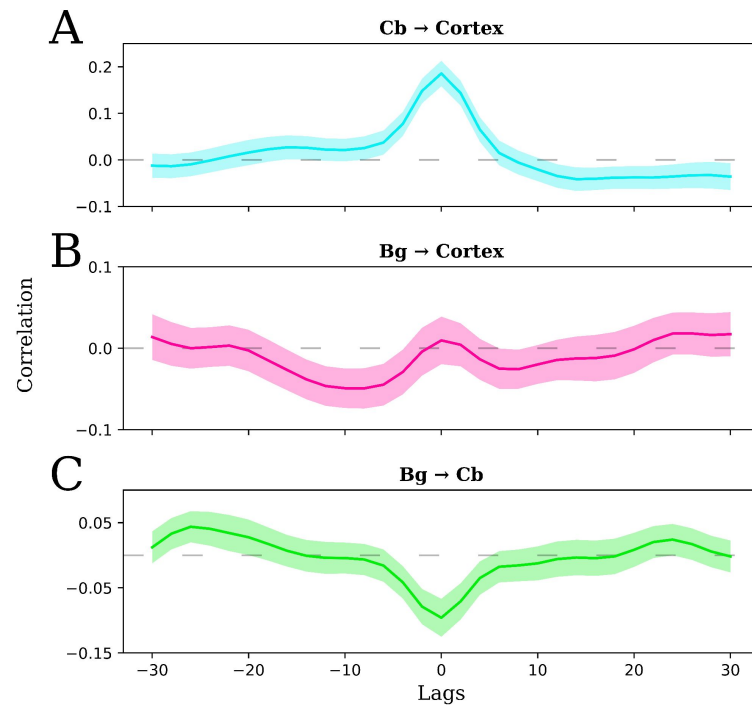
Cross Correlation



STROOP



MSIT



CONCLUSION

- Cortical network topologies are highly flexible.
- Basal ganglia engagement peaks at the beginning of task blocks, while cerebellum at the end.
- Evidence for basal ganglia as a control mechanism for cortical network topology, but not cerebellum

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THANK YOU !!

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QUESTIONS ?