Multi-Task Functional Connectivity And Flexible Hubs

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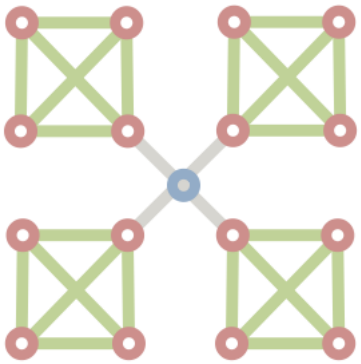
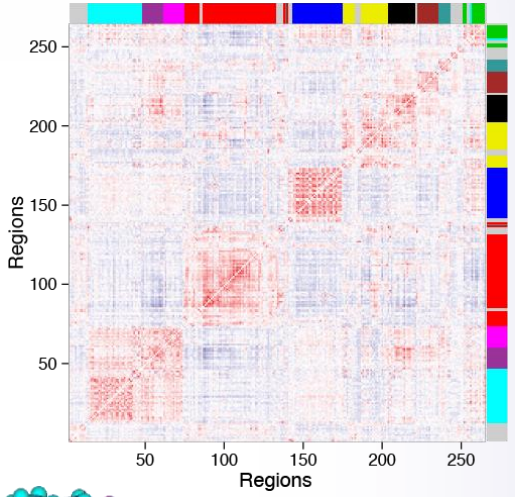
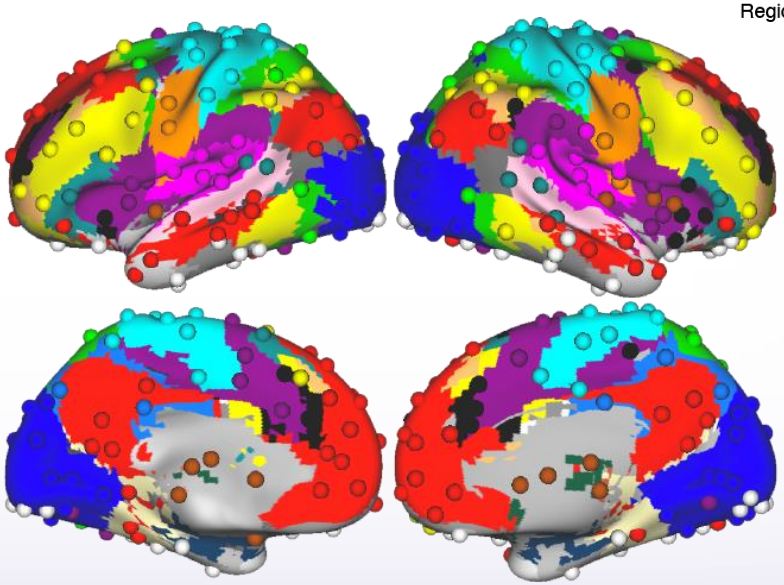
How is the brain's functional architecture organized?

- Systems as graph communities
  - Clusters of highly interconnected nodes
- 'Community detection' algorithms
- Applied to whole-brain resting-state graphs (Power et al., 2011)



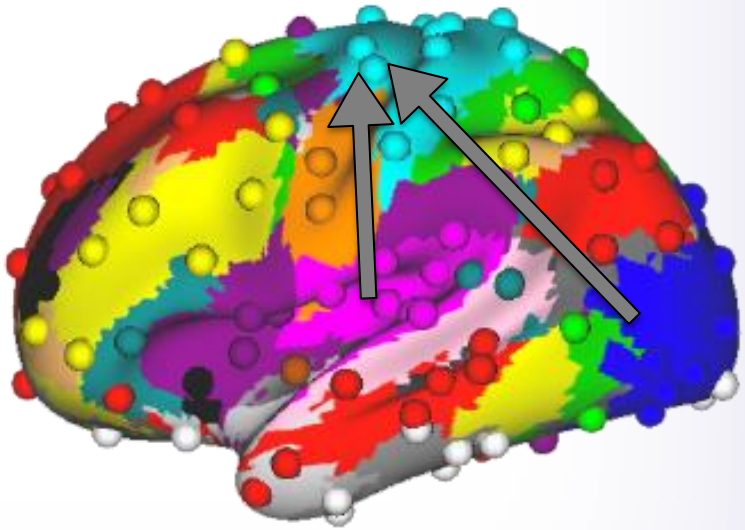




Networks
- CCN (cog. control)
- CON (cingulo-opercular)
- SAN (salience)
- DAN (dorsal attention)
- VAN (ventral attention)
- DMN (default-mode)
- Motor & somatosensory
- Auditory
- Visual
- Subcortical

Brain systems = brain's organization?

- Stable organization
  - Standard processing pathways
- Rapidly changing context?
- Task-evoked functional connectivity may be key
  - Coordinating global-scale activity flow



Overview

- Task FC updates build on a stable intrinsic network architecture
- Flexible hubs coordinate task FC updates to implement task goals
- Flexible hubs support mental health

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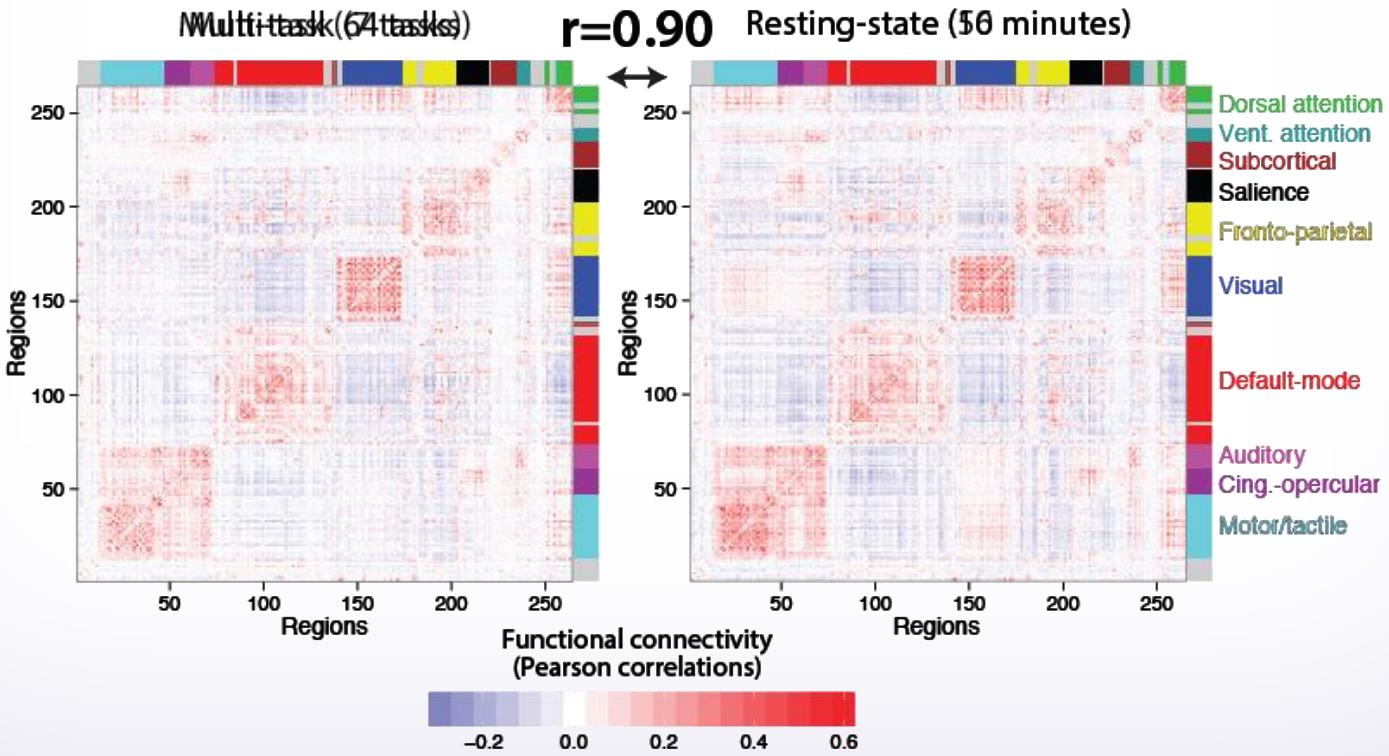
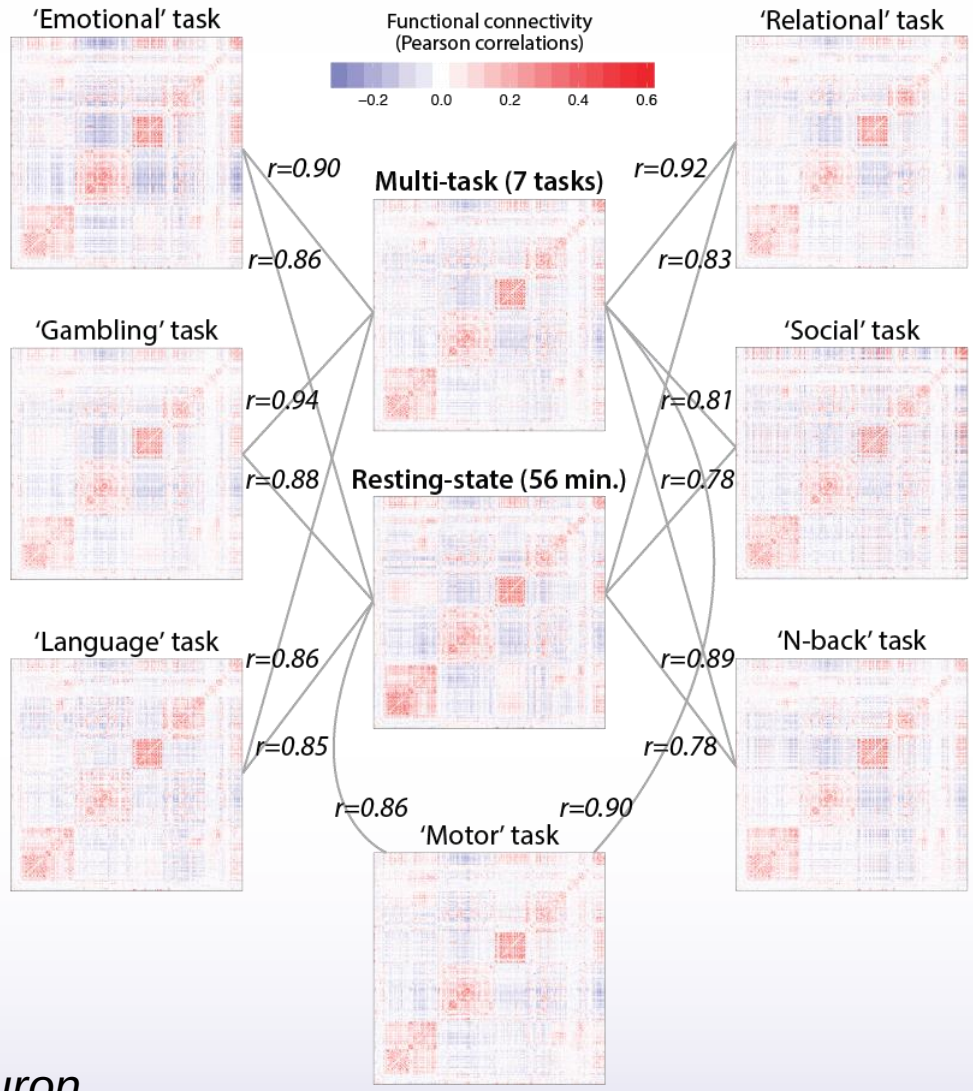
Is there a stable functional network architecture?

- Multi-task method: Remove inter-block rest, compute correlations across task time series



Cole et al., 2014; *Neuron.*

Does network architecture change across tasks?



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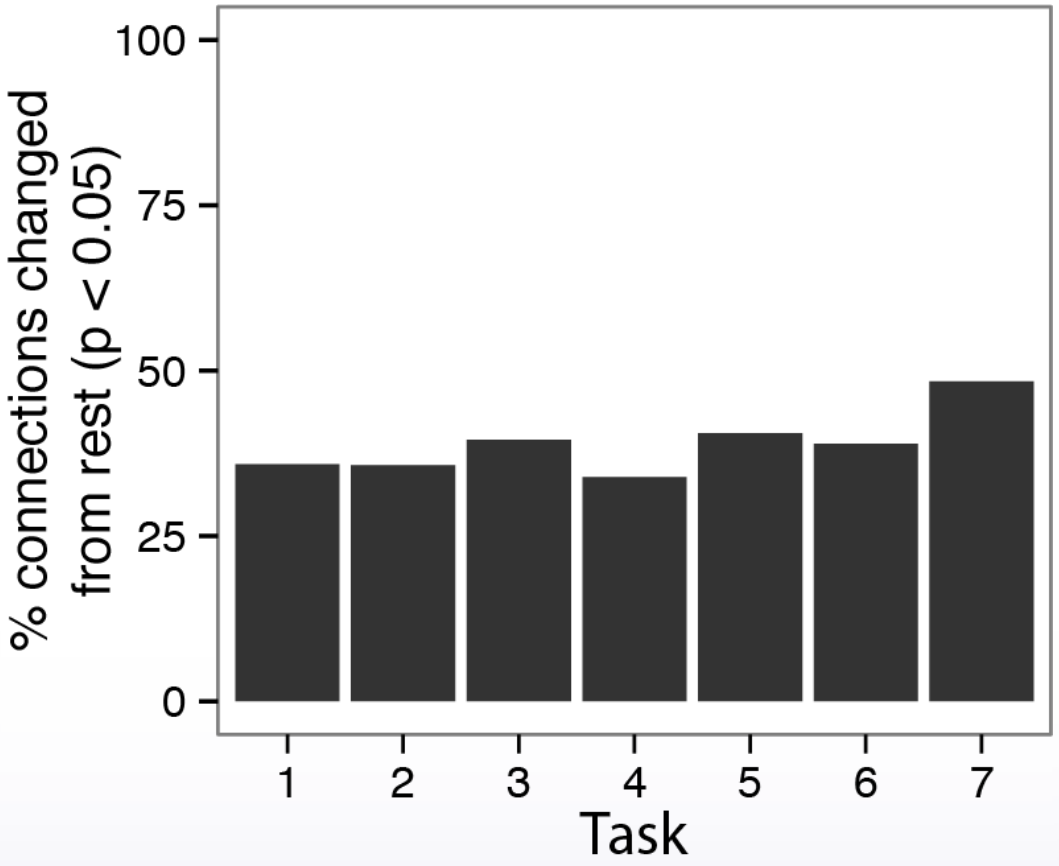
Significant FC changes from rest



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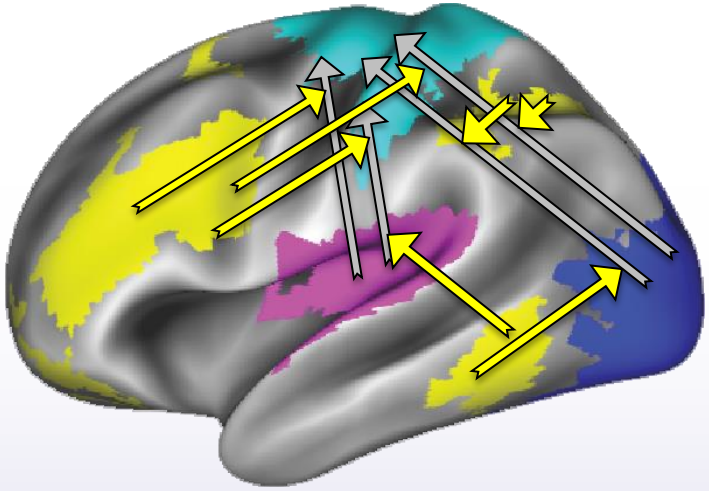
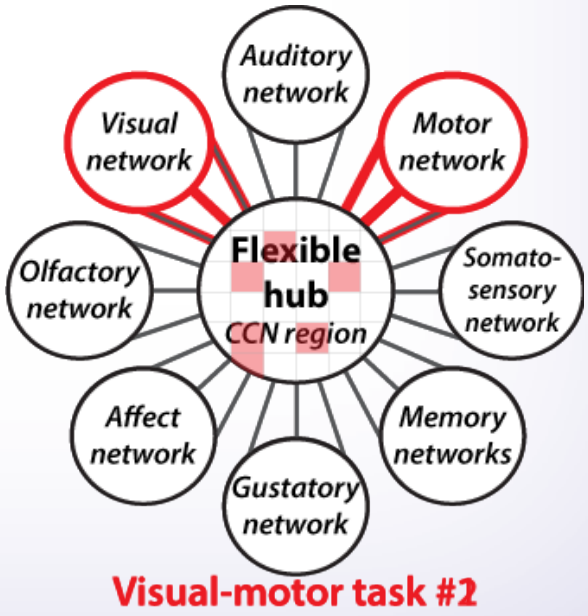
How are dynamic updates coordinated?

- Building on Desimone & Duncan (1995) and Miller & Cohen (2001)
  - Form of attentional selection
  - Like train track switching station



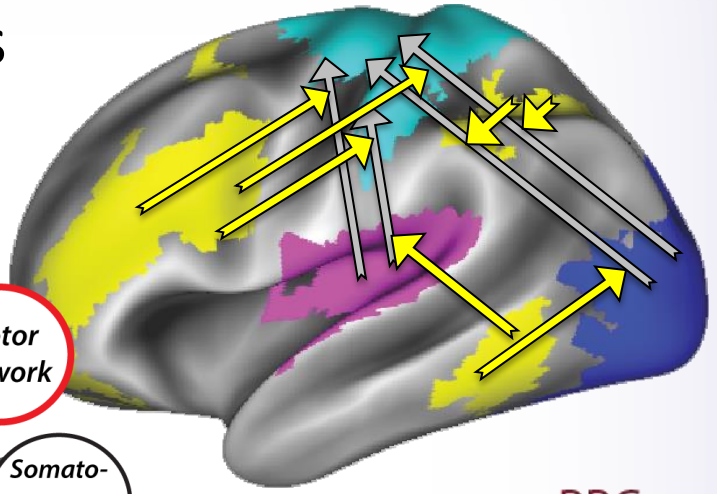
Flexible hub theory

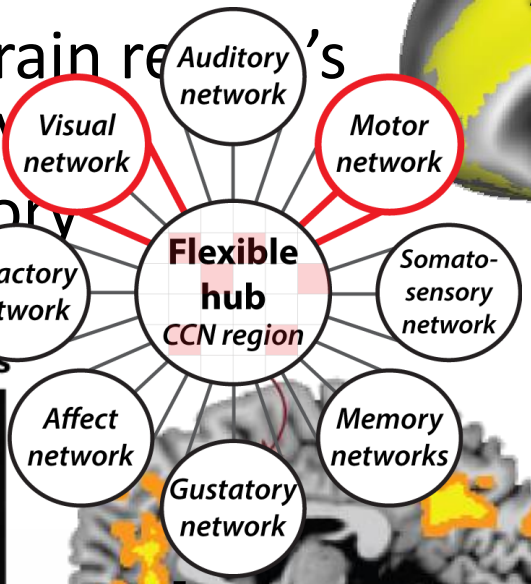
- Cognitive control network regions configure activity flow to implement task demands
- Two mechanisms:
  1. Global brain connectivity
  2. Flexible connectivity



Flexible control from global connectivity

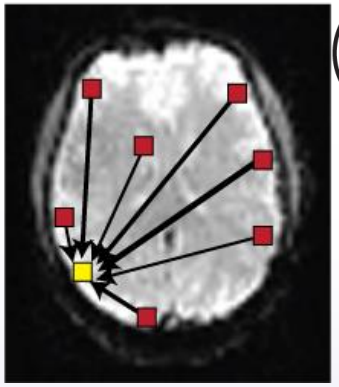
- *Hypothesis*: control network has high **global brain connectivity (GBC)**
- Summarize each brain re's overall connectivity
- Form of graph theory



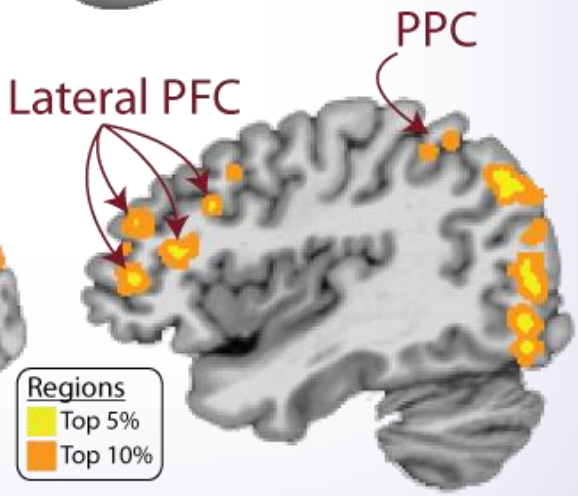


GBC Proced

Average Connections



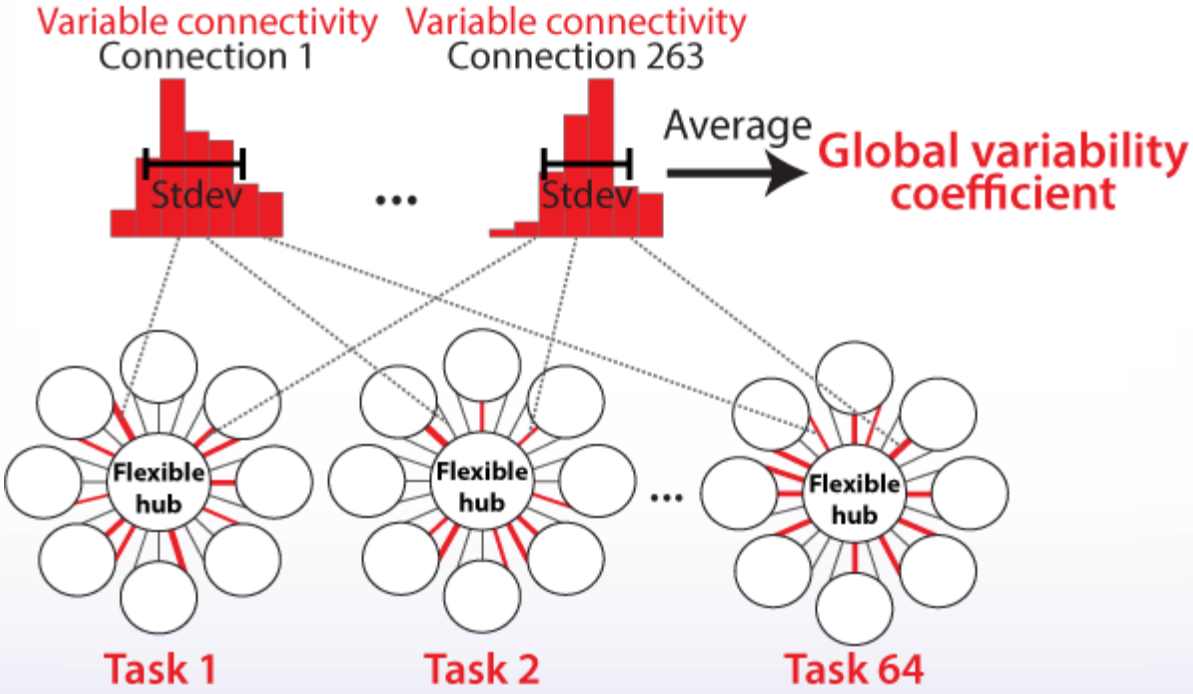
For each gray matter voxel:
1) Correlate with all other gray matter voxels
2) Average all correlations
3) Assign average to voxel



Cole, et al. (2010), *NeuroImage*; Also see Power et al., 2011

Testing for flexible connectivity

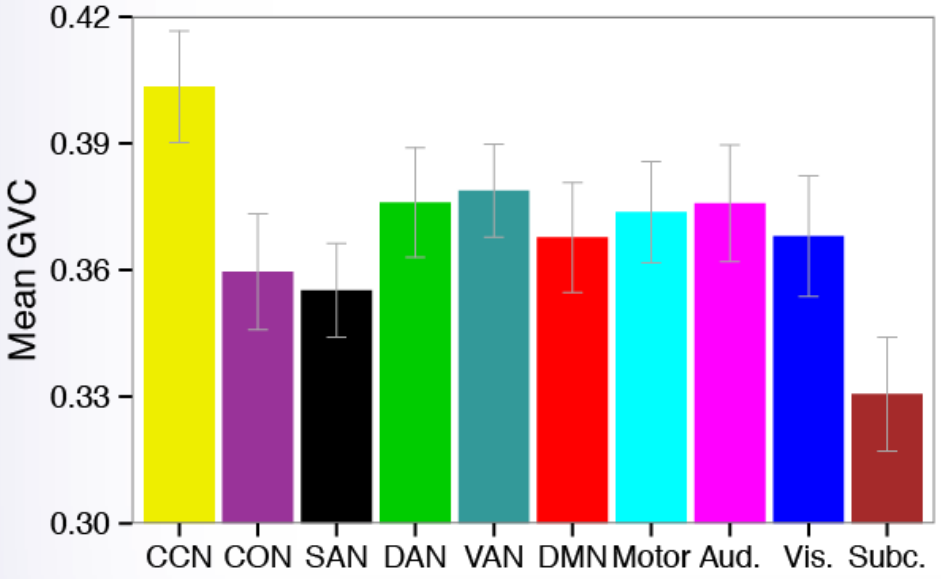
- **Hypothesis**: CCN has highly flexible (variable) connectivity
- *New measure*: **Global variability coefficient**



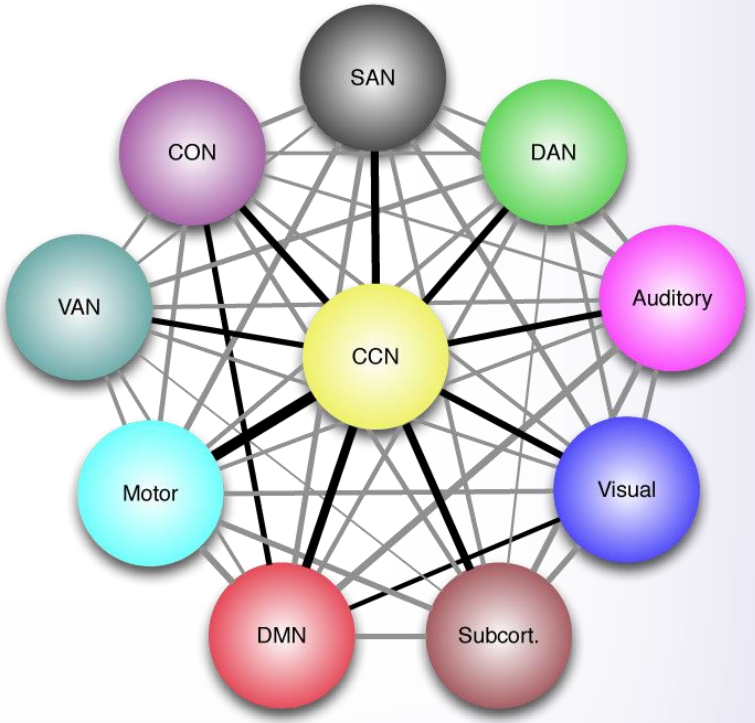
(Cole et al., 2013; *Nat Neuro*)

Testing for flexible connectivity

Global variability coefficient



Variable connectivity
across 64 task states



CCN shifts connectivity with the rest of the brain across a variety of tasks

(Cole et al., 2013; *Nat Neuro*)

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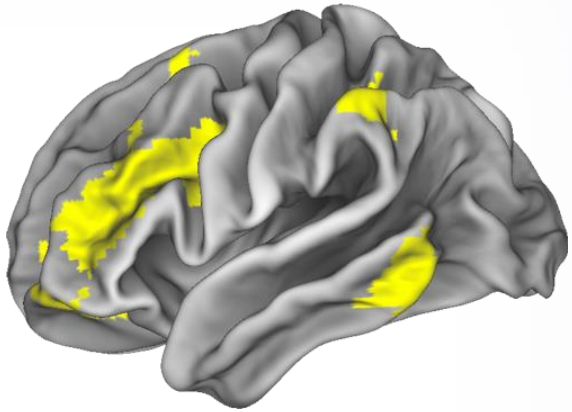
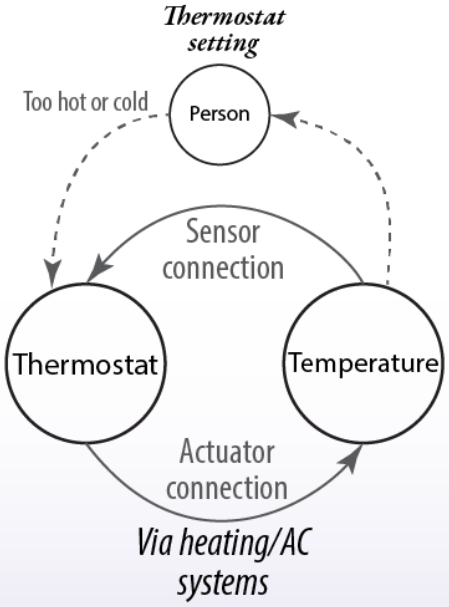
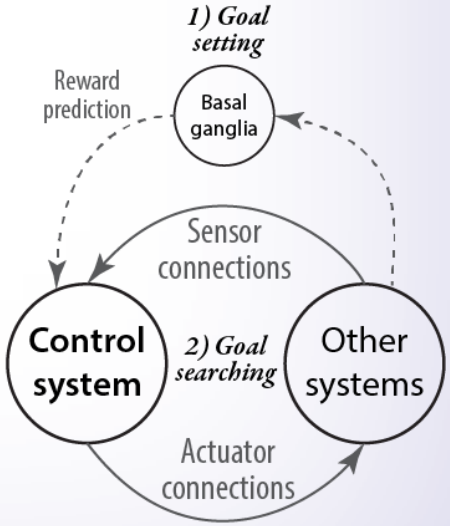
Flexible hub feedback control mechanism

- Frontoparietal system implements goal-directed cognition
  - Domain general (Chein & Schneider, 2005; Duncan, 2010)
- Likely a feedback loop + search mechanism







(Cole et al., In Press; *The Neuroscientist*)

Frontoparietal flexible hubs as immune system of the mind

- When reducing own symptoms is task goal
- When task-focused, suppresses irrelevant/unwanted mental processes (e.g., symptoms)
- When learning new tasks, following instructions (e.g., talk therapy, mental health strategies)

(Cole et al., In Press; *The Neuroscientist*)

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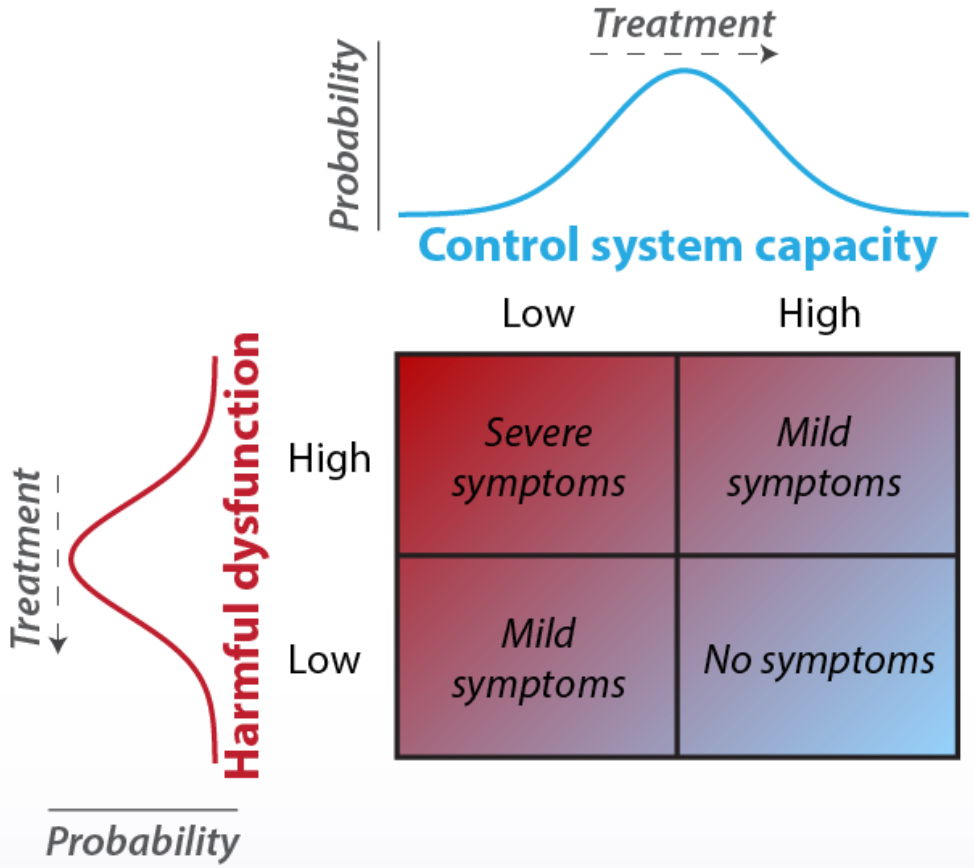

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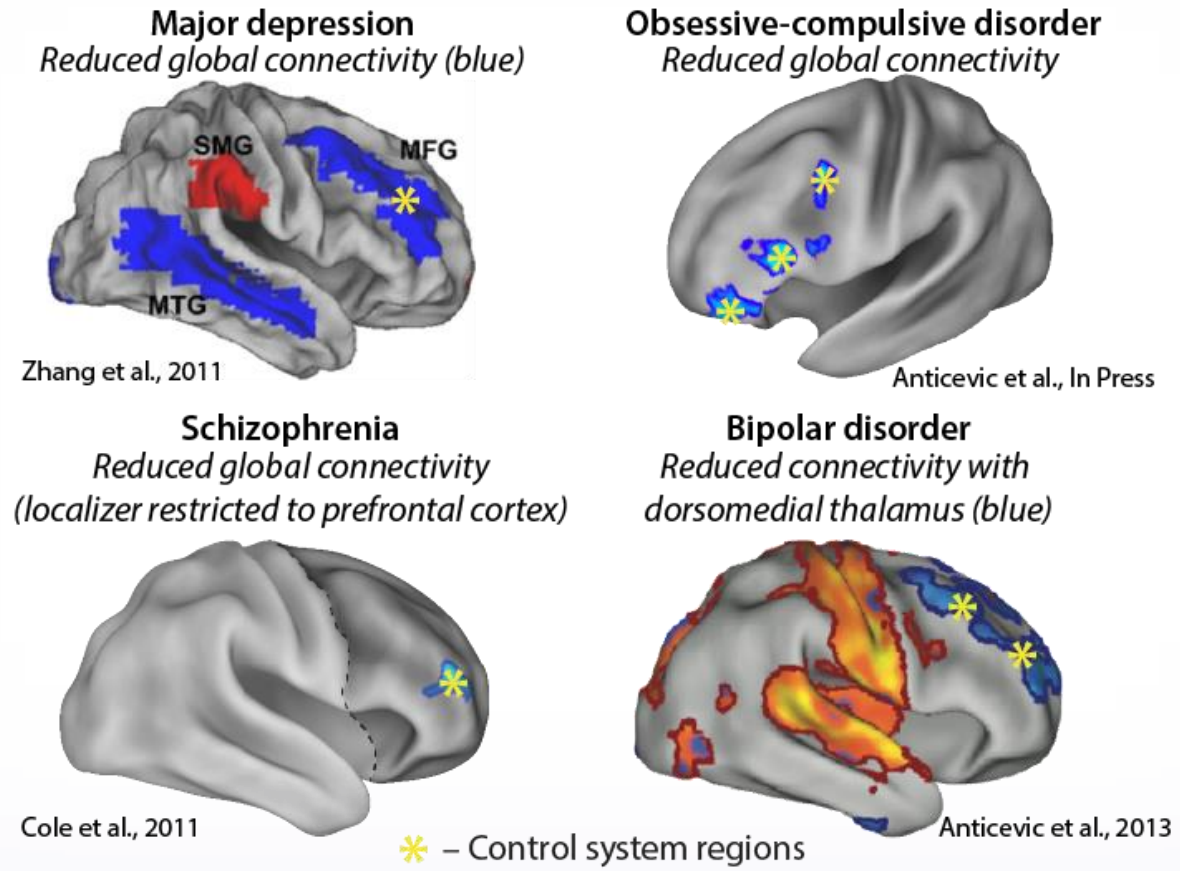

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Summary & Conclusions

- There is an intrinsic network architecture
  - Present across rest and many tasks
- Task-evoked network changes specify tasks
  - Coordinated by frontoparietal flexible hubs
- Frontoparietal flexible hubs promote mental health
  - Via global goal-directed coordination of brain activity

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More information: **www.colelab.org**