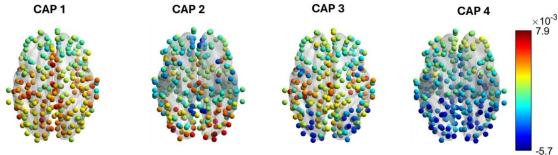


Dynamic Brain States During Reasoning: A Co-activation Pattern (CAP) Analysis

Fatemeh Hasanzadeh, Christian Habeck, Yaakov Stern*

Cognitive Neuroscience Division, Department of Neurology, Columbia University Medical Center, New York, NY, 10032, US.

Reasoning performance is supported not simply by which brain networks are active, but by how long the brain remains in task-relevant dynamic states. Aging is associated with reduced stability of these states and greater engagement of less efficient configurations.

INTRODUCTION	METHODS	RESULTS	RESULTS
Background: - Brain activity is highly dynamic, yet conventional fMRI analyses typically focus on time-averaged activation or connectivity. - Co-Activation Pattern (CAP) analysis identifies recurring whole-brain states at the level of individual fMRI volumes. - CAP methods have primarily been applied to resting-state data and clinical populations. The role of dynamic brain states during higher-order cognition, particularly fluid reasoning, remains poorly understood. Objective: Characterize dynamic brain states during reasoning and rest, examining how their temporal dynamics relate to task performance and individual differences like aging	Participants: 303 adults (Mean age 53.19 ± 16.65 years, 53% female). Reasoning Tasks: - Matrix Reasoning - Letter Sets - Paper Folding Performance: Proportion of correct responses. CAP Analysis Pipeline: Data Preparation Concatenate Task & Resting-State fMRI Data across participants (Power Atlas :264 ROIs) K-means Clustering Select the optimal number of clusters using the elbow method CAP States Averaged data within each cluster to create final CAPs Temporal Metrics Fraction Occupancy Dwelling Time Appearance Rate Statistical Analyses Network overlap analysis with resting-state networks Partial correlations with demographic Linear regressions predicting task performance	Four Dynamic Brain States Identified  Figure 1. Four whole-brain co-activation patterns (CAP1–CAP4) were identified across reasoning tasks and rest. Functional Characterization of CAPs CAP1: Predominant resting-state, baseline-like brain state. CAP2: Overlap with the visual network. CAP3: Engages DMN and sensorimotor networks, supporting higher-order reasoning. CAP4: Widespread network suppression, suggesting a transitional state	

Four Dynamic Brain States Identified

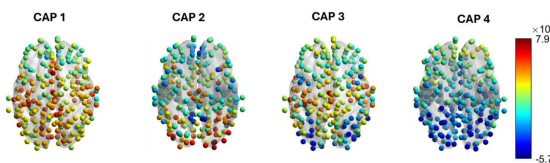


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Functional Characterization of CAPs

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CAP2: Overlap with the visual network.

CAP3: Engages DMN and sensorimotor networks, supporting higher-order reasoning.

CAP4: Widespread network suppression, suggesting a transitional state

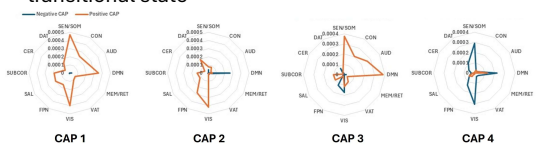


Figure 2. Similarity between CAPs and RS networks

CAP Dynamics Predict Reasoning Performance

- Longer dwelling time in CAP2 and CAP3 predicted better reasoning performance.
- Greater fractional occupancy of CAP2 was associated with higher accuracy across reasoning tasks.
- CAP1 engagement was linked to poorer Paper Folding performance.

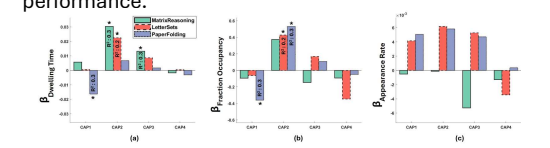


Figure 3. Beta coefficients of three regression models examining (a) dwelling time, (b) fraction occupancy, and (c) appearance rate (Controlled for age, sex, cortical volume, and education).

 Aging Alters Brain-State Dynamics - Older adults spent more time in CAP1, a brain state primarily associated with rest. - Engagement of task-relevant states (CAP2 and CAP3) decreased with age. **CONCLUSION** - Four distinct brain states characterize reasoning-related brain dynamics. - Stable engagement of CAP2/CAP3 supports better reasoning performance. - Aging shifts brain activity toward baseline-like states and away from task-relevant states. - CAP analysis offers a powerful framework for studying cognitive aging and brain-state dynamics. |