Large-scale oscillatory networks characterize cognitive states

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Summary

The temporal patterns in functional neuroimaging data are key for understanding whole-brain dynamics. This study used Independent Component Analysis (ICA) in the theta and alpha bands to unveil networks in MEG data from three visuospatial working memory (WM) tasks in the Human Connectome Project (HCP) and a second independent dataset. Four distinct networks, two in each band, were found and were input into a non-supervised clustering algorithm, which produced four states that may be related to different cognitive states. The posterior theta network was linked to an encoding state, while a dorsal alpha network was associated with maintenance of information in WM. This study highlights the reliability and validity of using electrophysiological networks, which showed a systematic switching between states throughout various task phases.

Methods

Datasets

- HCP (N=83): N-back task (Fig. 1)
- Data for intraindividual comparison (N=4): Subjects were scanned on seven occasions during two WM tasks(Fig 2).

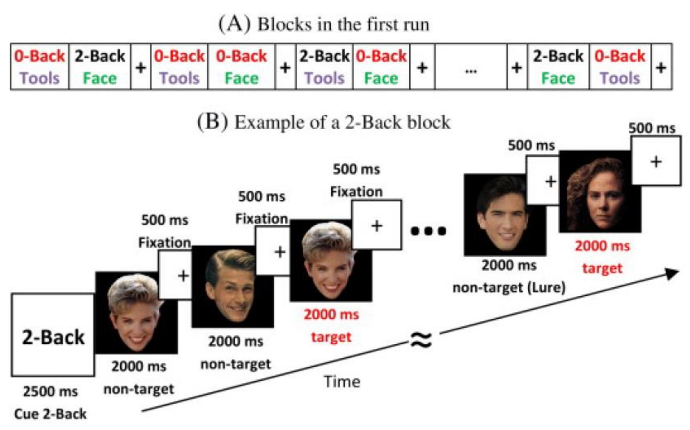

Fig. 1. N-back task in HCP

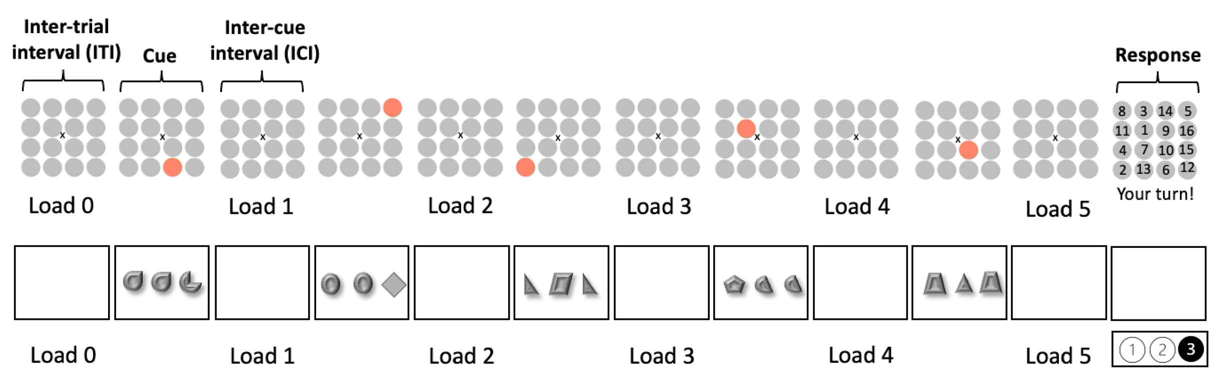

Fig. 2. Tasks in second dataset

Analysis steps

- Time-frequency decomposition in theta and alpha bands.
- Separation of sources with ICA.
- Unsupervised clustering (k-means).

Results

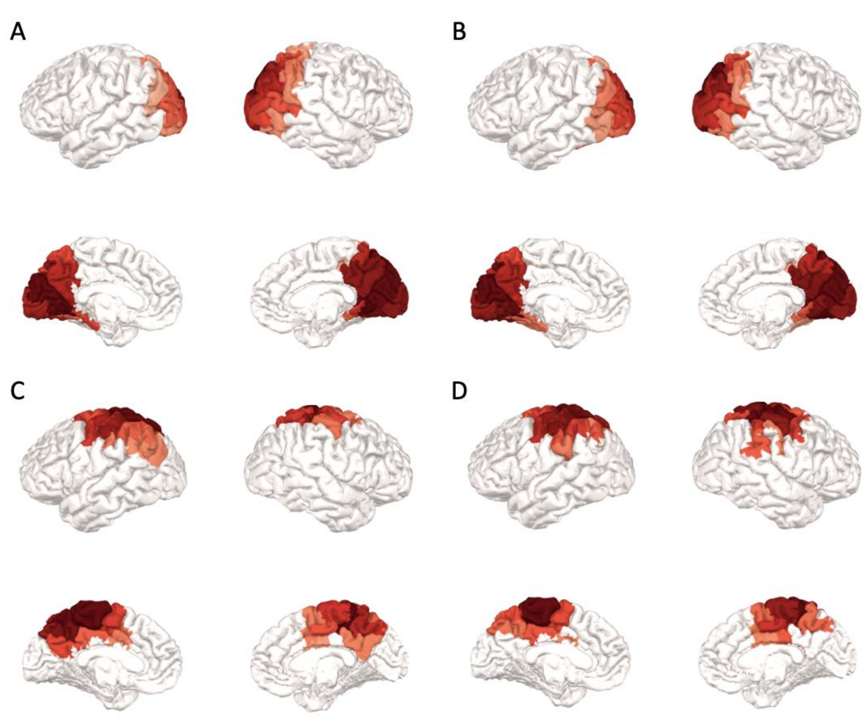

Fig. 3. Identified networks in HCP.

Four networks were identified in HCP: two posterior networks (theta, Fig. 3A; alpha, Fig. 3B) and two dorsal networks (theta, Fig. 3C; alpha, Fig. 3D).

The averaged individual time series of each network did not provide information on cognitive states (Fig. 4). However, subsequent clustering of the networks time series revealed four states (Fig. 5) and a systematic switching (Fig. 6).

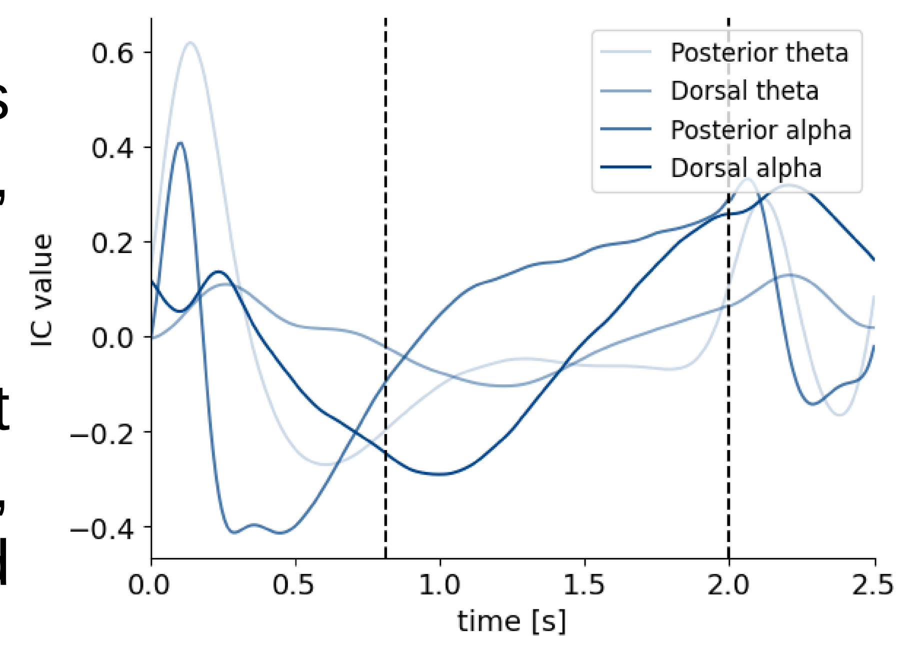

Fig. 4. Networks time series in HCP.

The same networks and similar states (Fig. 7) were found in the second dataset.

State dynamics during encoding and maintenance were assessed (Fig. 8). State 1, characterized by a positive influence of posterior theta, is active during encoding. Likewise, state 3, primarily influenced by dorsal alpha, increased during maintenance.

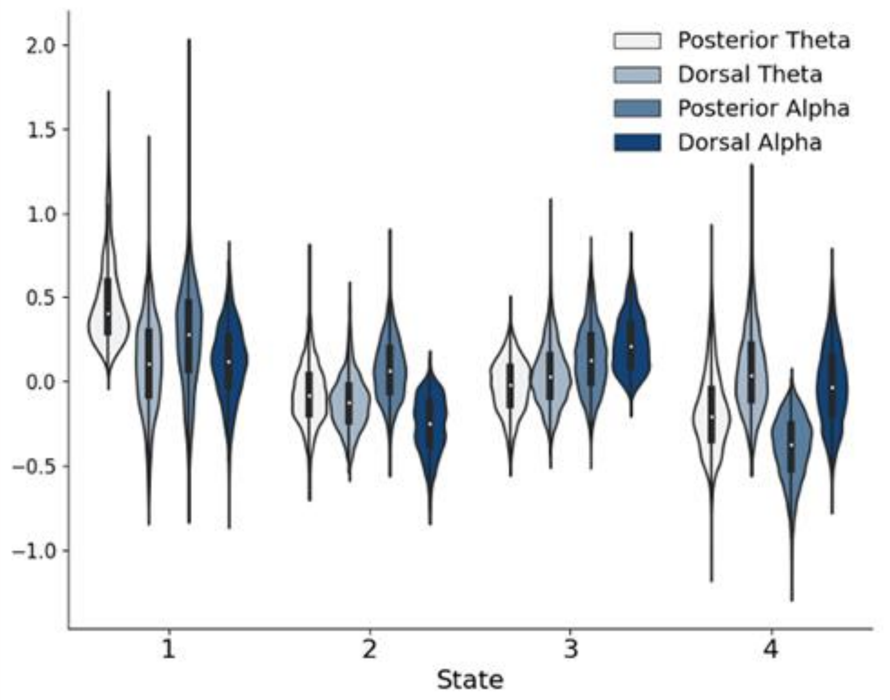

Fig. 5. Contribution of networks to each state in HCP.

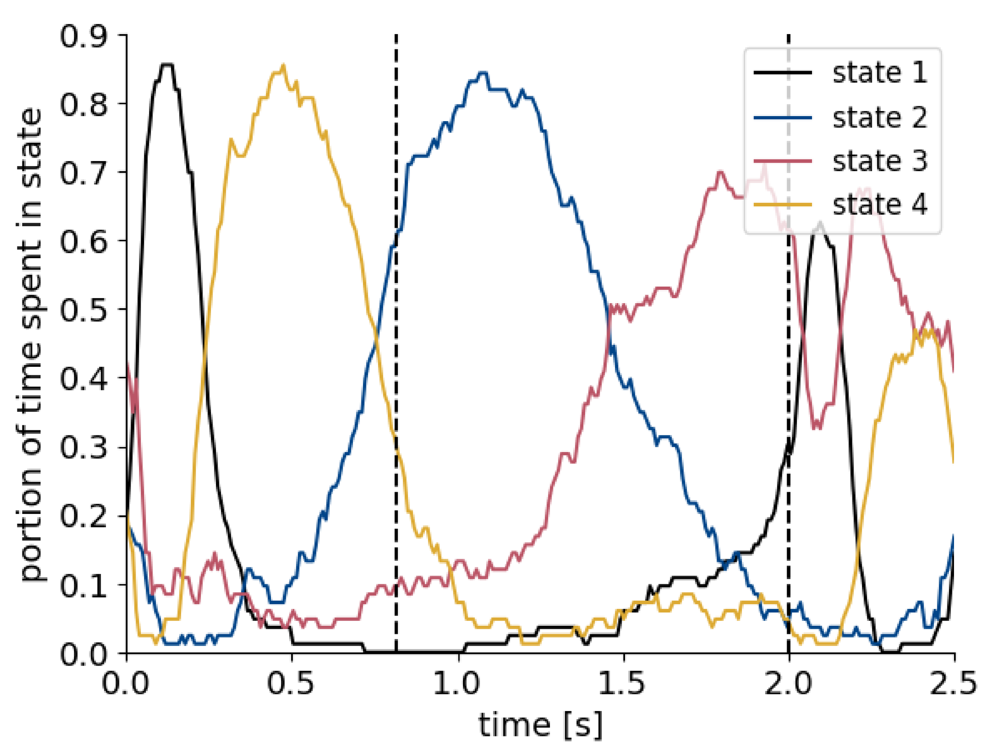

Fig 6. States time series during 2-back task. The first and second dashed lines represent the mean response time and the cue presentation end, repectively.

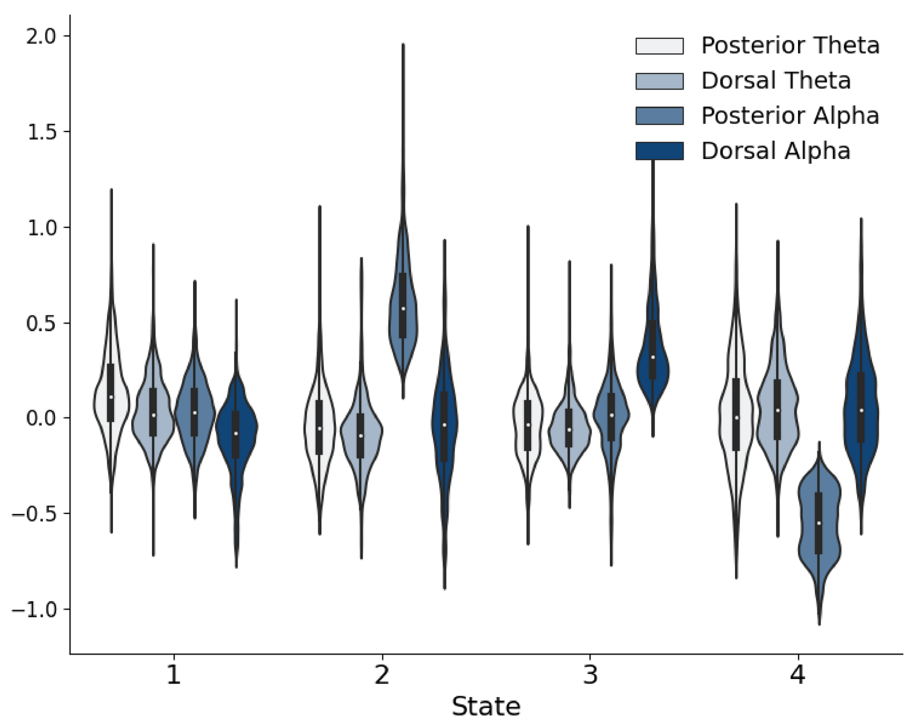

Fig. 7. Contribution of networks to each state in second dataset.

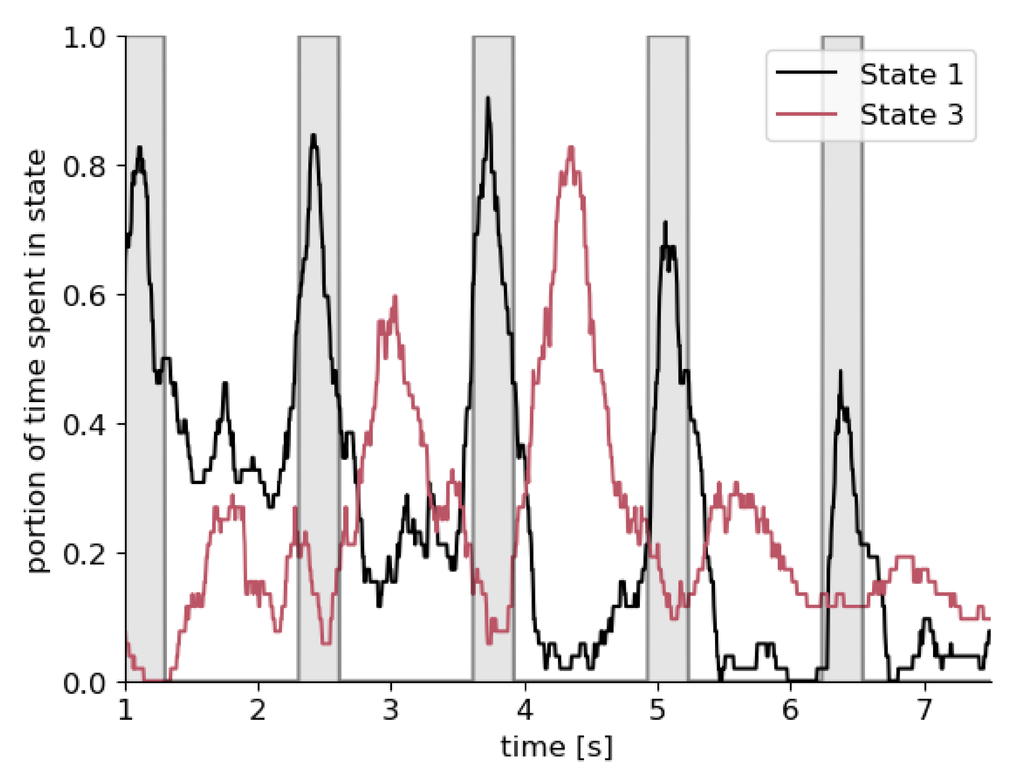

Fig. 8. Combined states time series of both tasks from second dataset. Shaded areas indicate cue presentation.

Conclusion

Activity of each state showed a systematic pattern across three different visuospatial working memory tasks in two independent datasets. These results were consistent within and among subjects over time. States 1 and 3 were described by the posterior theta and dorsal alpha networks and related to encoding and maintenance of WM information, respectively.

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