Characteristic brain connectivity patterns during consciousness and unconsciousness

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Background: The dynamics underlying brain’s functional connectivity patterns at anesthetic-induced unconsciousness (AIU) remain elusive. Specifically, the roles of different brain connectivity states in sustaining and modulating brain’s activity in consciousness and unconsciousness are unclear.

Methods: Resting-state fMRI data of 25 Long-Evans rats were acquired at awake state and five anesthetic depths induced by increasing concentrations of isoflurane (0.5, 1.0, 1.5, 2.0 and 3.0%). The fMRI data were pre-processed using conventional methods. For each scan, the regionally averaged BOLD signals of 134 unilateral ROIs were segmented using the sliding window method (window length = 60s, step size = 5s, TR = 1s). 5 brain connectivity states across all anesthetized conditions were found using k-means clustering (k=5, Manhattan distance), and then ranked by their spatial similarity to the structural map, which was assessed from the Allen Mouse Brain. For each brain state, its occurrence rate at each condition was assessed. The state transition sequences were determined from the clustering results, and different transition pathways between state 1 and 5 were assessed.

Results: The five brain connectivity states exhibited distinct spatial patterns and occurrence rate at different conditions. Specifically, state 5, which was most similar to the structural map, was dominant at 3.0% isoflurane, indicating that this connectivity state was dictated by the brain’s anatomical connection at a deeply unconscious state. In comparison, state 1, which was the most different from the structural map, was dominant at awake state and 0.5% isoflurane, suggesting that this connectivity state was characteristic of conscious states. Two principle transition pathways between state 1 and 5 were found: direct transition and through state 3 which was dominant at 1.5% isoflurane.

Conclusions: These findings support that brain connectivity states 1 and 5 are characteristic for both consciousness and unconsciousness, respectively.

Fig. 1. A. 5 Brain connectivity states. B. Structural map. C. Occurrence rate of each brain state at each condition. D. Three transition pathways between state 1 and 5.