Resting-state Functional Connectivity-based Parcellation of the Thalamus

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Target audience

Researchers interested in the thalamic connectivity, not only anatomical but also functional connectivity, and cortical or sub-cortical parcellation methods will pay attention to this study.

Purpose

The thalamus, which consists of multiple nuclei, plays an important role in brain function, acting as a relay between sub-cortical areas and cerebral cortex [1]. Dysfunctions of specific nuclei of the thalamus are crucial to pathophysiology of neurological and neuropsychiatric disorders [2, 3]. Previous studies [4, 5, 6] demonstrated parcellation of the thalamus based on functional or anatomical connectivity. However, intrinsic limitations appeared in these previous studies, especially the number of subdivisions couldn't be chosen freely. In the present study, we adopted and modified a novel resting-state functional connectivity-based approach [7] to parcellate the thalamus, by which we could choose the number of thalamic subdivisions. In addition, several evaluation indices were used to determine an optimal solution [7]. Furthermore, specific functional connectivity patterns of each functional subdivision were computed through partial correlation [5].

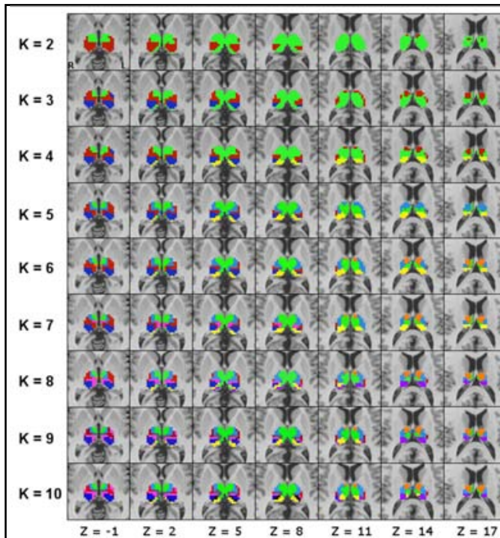

Fig. 1 Functional connectivity-based parcellation of the thalamus with different cluster solutions (K from 2 to 10).

Methods

The resting-state fMRI data, which were acquired at Beijing Normal University, are freely available on the 1000 Functional Connectomes Project website. Forty-two (20.86 ± 2.31 years old, 30 females) out of one hundred and ninety-eight right-handed healthy subjects from this dataset with whole brain coverage were selected. Standard rs-fMRI preprocessing steps were done in SPM8 and REST, during which global mean signal had been regressed. Functional connectivity coefficients between each thalamic voxel and every voxel of the whole brain were computed to form a connectivity matrix for each subject [7]. After then, average connectivity matrix was obtained across subjects. Eta^2 coefficient [8], acting as input in K-means algorithm, was computed to assess the similarity between resting-state connectivity patterns. Different cluster solutions (K from 2 to 10) were calculated. For each solution, Variation of information Index (VI), Symmetry Index (SI) and Hierarchy Index (HI) were computed to determine an optimal solution [7]. Partial correlation [5] was used to detect cortical areas which specifically functional connected to subdivisions of optimal solution.

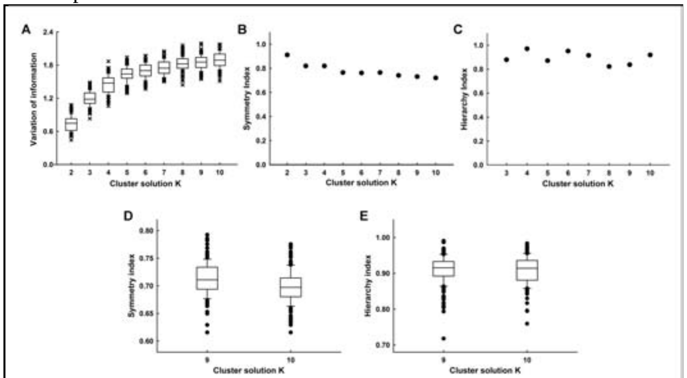

Fig. 2 Stability, symmetry and hierarchy indices of different cluster solutions. **A-C**, VI, SI and HI as a function of K, respectively. **D-E**, SI and HI of split-half procedure for K = 9 and K =10.

Results & Discussion

The parcellation results of different cluster solution were shown in Fig.1. The K = 4 and K = 5 solutions were resemble to results of previous studies [4, 5]. High symmetry and well hierarchy structure were revealed and quantified indices were shown in Fig.2. VI increases with larger K values except for K = 9 and K = 10 (p = 0.281 and 0.053, respectively). Thus solutions with K = 9 and K = 10 are stable. Focusing on solutions with K = 9 and K = 10, the K = 9 solution showed significantly higher SI value ($p < 0.00003$), while no significant differences were shown between HI of the two solutions ($p > 0.85$). K = 9 was determined as an optimal solution. The brain regions, which were significantly correlated with each one of nine subdivisions, were shown in Fig. 3. Correspondence between anatomical connectivity reported in previous studies and functional connectivity detected by the current study may reveal the validity of our parcellation approach.

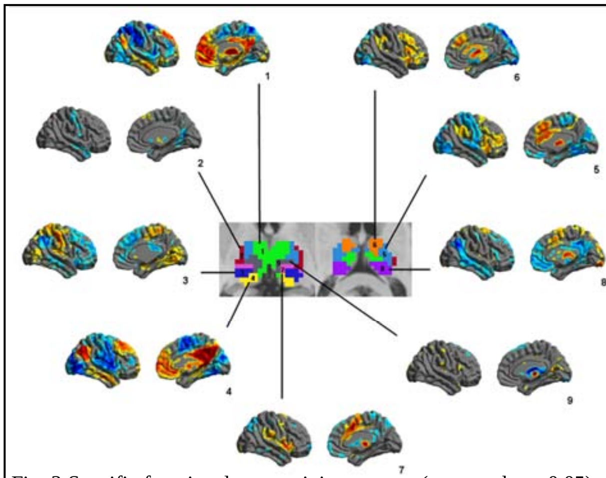

Fig. 3 Specific functional connectivity patterns (corrected $p < 0.05$) of each thalamic subdivision from K = 9 solution. Only the right hemisphere is shown.

Conclusion

An unsupervised parcellation approach based on resting-state functional connectivity profiles was used to parcellate the thalamus. We obtained robust and symmetrical thalamic parcellations. The detection of specific functional connectivity patterns of each subdivision proved validity of our approach.

Reference

[1] Sherman & Guillery, Philos Trans R Soc Lond B Biol Sci, 2002; [2] Welsh et al., Schizophr Bull, 2010; [3] Woodward et al., Am Journal of Psychiatry, 2012; [4] Behrens et al., Nat Neurosci, 2003; [5] Zhang et al., J Neurophysiol, 2008; [6] Zhang et al., Cerebral Cortex, 2010; [7] Kahnt et al., J Neurosci, 2012; [8] Cohen et al., Neuroimage, 2008;