Comparison of Power Spectrum in Resting Brain Networks of Human and Rat using Seed Regions and Independent Component Analysis

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Introduction

At present, resting state functional MRI (rsfMRI) is increasingly used in human and rodent neuropathological research. Therefore, the purpose of this study was to find a stable and reliable analysis method of rsfMRI for human and rat, and to compare the region correlation and power spectrum in human and rat brain networks using seed regions and independent component analysis (ICA). By acquiring rsfMRI data with a comparable protocol (e.g. anesthesia for rat), scanning and analysis, in both humans and rats we were able to compare findings obtained in both species. The outcome of rsfMRI is different for humans and rats and depends strongly on the seed position in the seed regions functional connectivity analysis, and the applied number of components in the ICA. The most important difference was the power spectrum of several networks, such as visual, motor, default mode, amygdala, hippocampus and thalamus, in the rat shifted to lower frequency regime compared to human brain. Furthermore, a higher number of components was needed for the ICA analysis to separate different cortical regions in rats as compared to humans.

Materials and Methods

Whole human (n = 18, 31 runs) and rat brain (n = 5, 10 runs) images were acquired by 1.5T Siemens SONATA MRI and 7T Bruker MRI, respectively. For human brain scan, the images were acquired by echo planar imaging (EPI) with the following parameters: repetition time/echo time (TR/TE) = 2000ms /30 ms, image resolution = 3.9 x 3.9 x 4 mm^3, slice number = 34, number of repetition = 180, and the scan time = 6 min. In rat preparation, each rat was anesthetized with 3.5% isoflurance mixed with 300ml/min air. Before MRI experiments a short-acting tranquilizer and synthetic medicine, Domitor, of 0.1 c.c. / 100 mg was injected. During experiments, the temperature was maintained at ~37 ^oC using hot pad. The images were acquired by EPI with the following parameters: TR/TE = 1200ms /24 ms, image resolution = 0.3 x 0.3 x 1 mm^3, slice number = 10, number of repetition = 200, and the scan time = 4 min.

In data analysis, the human and rat brain data were first coregistered using Statistical Parametric Mapping (SPM) and FMRIB Software Library (FSL), respectively, and detrend, high-pass filter as well as smoothing were then performed. The independent component analysis (ICA) was used for objective analysis with FSL, and seed regions functional connectivity analysis with alphasim correction was used for subjective analysis by Resting State fMRI Data Analysis Toolkit (REST), respectively. Specifically, ICA, MNI seed region analysis, and task-based seed region analysis were used in the human brain data; ICA and manual seed region analysis were used in the rat brain data, respectively. The functional connectivity between brain regions and the power spectrum were obtained in these various analyses. The advantages of different analyses and the differences between the human and the rat brain networks were compared and discussed.

Results and Discussions

In human brain, the result of the task-based seed region analysis (not shown) was used as the gold standard and it was compared with MNI seed region analysis (Fig. 1b). We found there was no significant difference between these two analyses. Therefore, we believed the MNI seed region analysis was reliable to be performed in large numbers of clinical research. The result of ICA (Fig. 1a) was more objective, but it could be affected by other functional brain regions classified into the interesting brain networks. Although MNI seed region was more subjective than ICA, the information of the correlations between the brain sub-regions could be obtained. The result found in the rat brain (Fig. 2) was consistent with the human brain. The most important difference between human and rat brain was the power spectrum of several networks, e.g. visual, motor, default mode, amygdala, hippocampus and thalamus, in the rat shifted to lower frequency regime compared to human brain (Fig. 3). It may be due to the different physiological mechanisms, such as heart rate, respiratory rate and blood pressure, in human and rat, as well as the anesthesia used for rat [1-3]. Furthermore, a higher number of components was needed for the ICA analysis to separate different cortical regions in rats (components # = 50) as compared to humans (components # = 25).

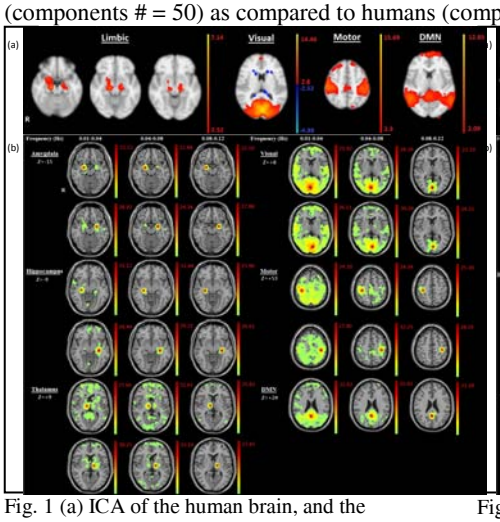

Fig. 1 (a) ICA of the human brain, and the probabilities = 0.5. (b) MNI seed region analysis of the human brain, and the p-value = 0.0001 after alphasim correction and the minimal t-score of the color bar is 4.48.

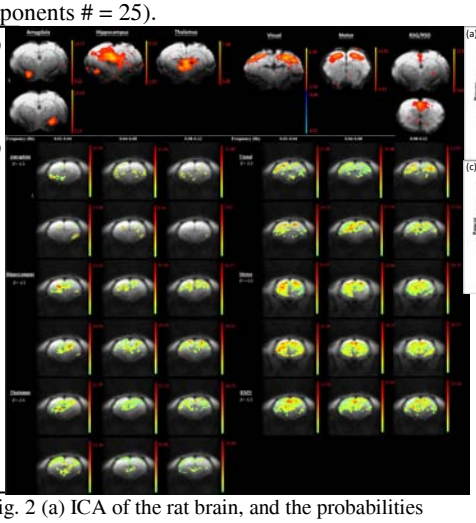

Fig. 2 (a) ICA of the rat brain, and the probabilities = 0.5. (b) Manual seed region analysis of the rat brain, and the p-value = 0.0005 after alphasim correction and the minimal t-score of the color bar is 4.78.

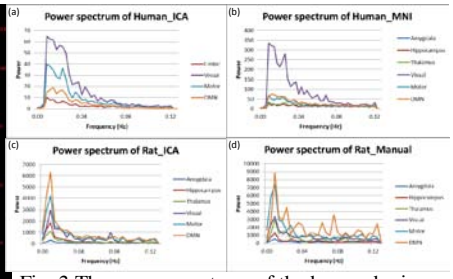

Fig. 3 The power spectrum of the human brain using (a) ICA and (b) MNI seed region analysis. The power spectrum of the rat brain using (c) ICA and (d) manual seed region analysis.

Conclusions

Our results showed the most important difference between human and rat brain was the power spectrum of several brain networks in the rat shifted to lower frequency regime compared to human brain. We also discussed the advantages and disadvantages in the different rsfMRI analyses. We suggested ICA could be first used to find the alteration in unknown brain network. For specific brain network, seed regions analysis could be performed further. Appropriate image analysis methods in resting state fMRI were expected to be widely used in human and rodent neuropathological research.

References

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