

Resting Functional Noise of fMRI

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Background

A characteristic tripod pattern of resting rhythm has been detected by 3T fMRI studies. Temporally synchronized BOLD signals involved bilateral occipital, precuneus, posterior cingulate, inferior parietal lobule, and medial prefrontal cortices (Yeh et al, 2002). In this fMRI study of a cognitive Chinese covert naming task (CCNT) in a 1.5T MR system, the characteristic resting activity co-existed with central correlates of CCNT (Kuo et al, 2003 and 2004) as demonstrated by independent component analysis (ICA). With verification by removal the resting signals from raw data, the resting rhythm showed significantly interference with the statistical evaluation of fMRI results.

Specific Aims

1. Detection of the characteristic resting tripod rhythms during task performance (e.g. Chinese covert naming task)
2. Verification of the statistical effect of resting rhythms in the fMRI analysis

Materials and Methods

(1) Theory of Back-Projection

With independent component analysis (ICA), the mixing matrix was $M = WX$, X was the original BOLD signals in matrix of T (repetition number) by V (voxels), W was C (components) by T (times), and M was C by V . When W was invertible, $X = W^{-1}M$. By removing non-task related component(s) in M , the original X can be modified.

(2) Chinese Covert Naming Task (CCNT)

Seven right-handed Chinese subjects (age: 23±4, F/M = 3/4) were recruited for the studies with written consent form. All subjects were healthy without history of neurological disorders. Blocked-designed paradigm (FRFRFRFRFRFRFRF, F: 24-second eye fixation and R: 24-second covert reading of two-character Chinese words by visual projection with a reflection mirror) was conducted with head fixation by a vacuum pad.

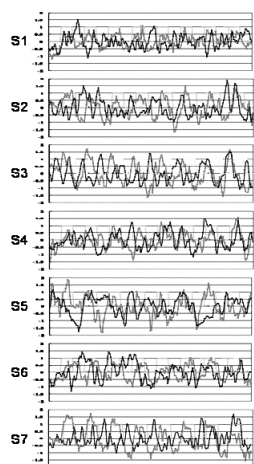
Brain MRI studies were conducted using a 1.5T system (Siemens, Erlangen, Germany). Single-shot FID echo planar images (64x64 matrix, slice thickness = 5 mm, gap = 1 mm, 20 slices) covering whole brain were acquired with TE = 40 milliseconds, TR = 2000 milliseconds, number of repetition = 204 and dummy scans = 5.

(3) Data Analyses

Off-line analysis using modified AFNI (Analysis of Functional NeuroImages, NIMH, Bethesda, USA) ensured the head motion with head translation < 1 mm and head rotation < 0.5 degree. Identification of task-irrelevant (aliasing physiological, resting rhythms) and task-relevant signals was performed by informax ICA and correlation analysis using paradigm template. Removal of the task-irrelevant resting rhythms (e.g. tripod component) was obtained by the back-projection of ICA. For the original X and back-projected X with removal of resting tripod component, correlation analyses of task-relevant ICA component and designed matrix of paradigm convolved with a hemodynamic function provided the maps of functional activation. Normalization and inter-subject penetration maps were obtained with specified correlation coefficient (0.4) and cluster volume (270 mm³).

Results

By spatial informax ICA, separated signal components of task-relevant and resting tripod activation were consistently identified as **Figure 1** for seven subjects (task-relevant activation: dark gray lines; resting tripod: black lines; designed paradigm: light gray squares). Resting tripod signals did not correlate to the design paradigm as shown in **Table 1**, when task-relevant components had high correlation coefficients. By using statistical criteria of correlation coefficient of 0.4 and cluster volume of 270 mm³, the improvement of activation extension by a factor of 4 was observed by removal of resting tripod signals from raw data.



Subjects	Max. correlation of task-relevant comp.	Max. correlation of resting comp.	Activation by correlation of the task-related component (voxels)		
			Original (O)	Removal (R)	R/O
S1	0.86	-0.14	15305	53885	3.5
S2	0.82	-0.20	8891	36273	4.1
S3	0.81	-0.07	13149	51439	3.9
S4	0.70	-0.25	8262	23328	2.8
S5	0.34	0.19	11711	43626	3.7
S6	0.87	-0.14	1657	5369	3.2
S7	0.85	-0.24	794	6876	8.6
mean ± SD	0.75 ± 0.19	-0.12 ± 0.15			4.3 ± 2.0

▲ **Table 1** Correlation analyses of task-relevant and resting components (2nd and 3rd columns were the maximal correlation coefficients by adjusting the hemodynamic delays of the design paradigms. And 4th-6th columns showed activation extension before and after removal resting signals by back projection.)

◀ **Figure 1** Consistent task-relevant and resting tripod components identified by ICA in seven subjects (S1-S7)

Conclusion

Task-irrelevant resting rhythms (e.g. tripod component) co-existed with task-relevant activities in the fMRI studies of Chinese covert naming task. Role and dependence of this default network of resting rhythm needs further studies. Improved statistical significance and spatial extension were achieved by removal of resting component from the original signals in the Chinese covert naming task.

Acknowledgement

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References

Yeh et al 2002 8th Functional Mapping of Human Brain p431; Kuo et al 2003 Neuroimage 18, 720-730; Kuo et al 2004 Neuroimage 21, 1721-1731.