Motion Detection and Removal from Registered fMRI Data by Independent Component Analysis Method

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Introduction: In fMRI studies, head motion, which costs serious damage to data, needs to be prevented during scans and corrected in data processing. In the latter, registration is usually performed by a rigid-body transformation. Three translational parameters and three rotational parameters are obtained for each image relative to a reference image. Registration can greatly improve data quality, but it does not answer the question if a motion component still remains in the data after initial motion correction. McKeown etc. [1] demonstrated that independent component analysis (ICA) can extract the motion component from raw fMRI data. In this study, we applied the ICA method to find the remaining motion component and to remove it from registered fMRI data.

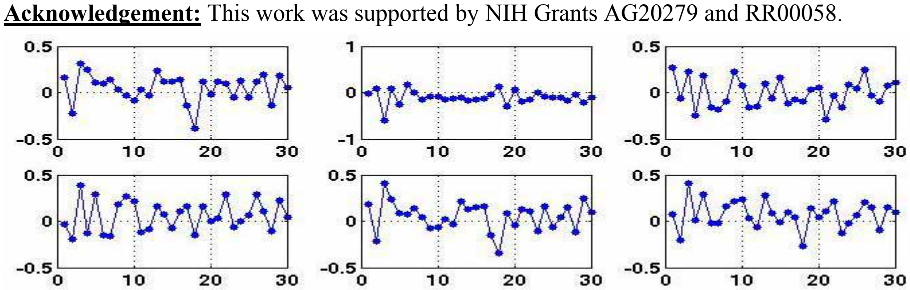
Materials and Methods: The whole brains of 17 subjects were scanned at resting state without performing any tasks. BOLD weighted functional data (6 min) were acquired on a 3-T GE scanner using GRE EPI sequence; TE = 25 ms, TR = 2,000 ms, flip angle = 90º, slice thickness = 4 mm, matrix size = 64×64, filed of view = 240×240 mm^2. High resolution 3D images were acquired for anatomical reference. Registration was first performed on the resting-state fMRI data by AFNI [2] and the three translational parameters and three rotational parameters for each image were given. Thus, we obtained six motion vectors through registration. The registered data was further linearly detrended to remove system drift and Gaussian smoothed (4-mm kernel) to reduce spatial noise, both by AFNI. Out of the 180-point time series for each voxel, 173 time points were kept while the first 5 and the last 2 time points were discarded to preserve equilibrium data only. ICA [3] was then performed in the hippocampus to extract 30 components as $\mathbf{X}=\mathbf{AS}$, where $\mathbf{X}$ was a matrix of the fMRI data in the hippocampus, $\mathbf{A}$ was a mixture coefficient matrix, and $\mathbf{S}$ was the independent component matrix. Each independent component was cross correlated to the six motion vectors with the first 5 and the last 2 elements discarded. The absolute values of the six cross correlation coefficients were summed as a motion score for each independent component. The component with the largest motion score was the motion component, which remained in the registered data. To remove the motion component from fMRI data, we discarded the motion component from $\mathbf{S}$ to form a new independent component matrix $\tilde{\mathbf{S}}$, discarded the corresponding coefficients from $\mathbf{A}$ to form a new coefficient matrix $\tilde{\mathbf{A}}$. The new data $\tilde{\mathbf{X}}$ without this motion component was thus obtained by $\tilde{\mathbf{X}}=\tilde{\mathbf{A}}\tilde{\mathbf{S}}$.

Results: Fig. 1 shows the cross correlation coefficients between the six motion vectors and the independent components for a subject, along with the motion score. It is clearly seen that Component 3 has the largest motion score, and therefore, Component 3 is a motion component. To further demonstrate the effect of the motion component on fMRI data analysis, we calculated the cross correlation between each independent component and the whole brain. A voxel was considered active if the cross correlation coefficient was above a threshold of 0.25. The percentage of active voxels relative to the whole brain volume for each independent component was calculated. Fig. 2 illustrates the percentage of active voxels for each component. The motion component has the highest active percentage with an extremely high value of 87%. It would severely affect further analysis if this motion component is not removed. In our experiment with 17 subjects, the average percentage of active voxels for the detected motion component was 63%.

Discussion: It is evident that most brain voxels have a similar motion component if head motion occurs. A strong cross correlation existed between most of the brain voxels and the motion component detected by ICA. We tested and proved this method on resting-state data. For task-related fMRI data, this method would be still valid if there are a sufficient number of voxels applied in the ICA, as it is very unlikely to have many voxels active to the task. In our current study, we treated only one component with the largest motion score as the motion component. In practice, it is possible that more than one component represents motion. Further studies are needed to identify the number of motion components remaining in the registered fMRI data.

References: 1. McKeown, MJ., etc., *Human Brain Mapping*, 6:160-188, 1998. 2. Cox, RW., *Computers and Biomedical Research*, 29:162, 1996. 3. Hyvärinen, A., etc., *Neural Comput*. 9:1483, 1997.

Acknowledgement: This work was supported by NIH Grants AG20279 and RR00058.



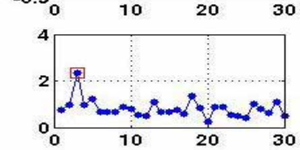


Fig. 1. Cross correlation between the 6 motion (translational in the 1st row and rotational in the 2nd row) vectors and the 30 independent components. The last one shows the motion score for all the independent components.

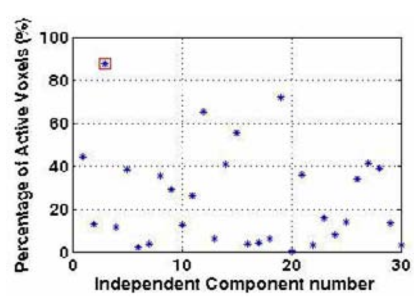


Fig. 2. Percentage of active voxels in the whole brain for each component. The motion component with the highest value is boxed.