Motion Correction in MRI:

Some Retrospective Software Packages for Motion Correction of fMRI

Speaker Name: Mark Jenkinson
Email: mark@fmrib.ox.ac.uk
Organization/employer: University of Oxford
Address:
FMRIB Centre
University of Oxford
John Radcliffe Hospital
Oxford OX3 9DU
UK

Highlights

- Retrospective motion correction is part of the standard fMRI analysis pipeline
- Even perfect motion correction does not remove all motion artifacts
- This talk will cover a range of different options that are readily available for motion correction and motion artifact removal
- The theory of the corrections and the available software implementations will both be discussed

Problem summary

Subject motion creates not only problems in localization but also artifacts that affect the intensity. These artifacts are often greater than the BOLD-induced changes of interest and combining accurate motion correction and motion artifact removal is important for getting accurate, unbiased results in task-based or resting-state fMRI.

Body

Motion-induced changes, due to mislocations and artifacts, often exceed BOLD-induced signal changes, which are typically less than 1% of the mean signal. Even when prospective motion correction is used, residual motions and artifacts often need to be corrected for in the retrospective (i.e. post-reconstruction) analysis pipeline. Both motion correction (i.e. realignment, or spatial transformation) and artifact removal/reduction methods are used in most analysis pipelines, but there is no single, standardized approach to these methods. In fact, a range of different options are implemented in commonly available fMRI analysis software packages (e.g. SPM, FSL, AFNI, BrainVoyager, etc.).
Rigid-body retrospective motion correction methods differ in the following ways:

- Interpolation methods
- Cost functions
- Optimisation methods
- Slice-wise vs volumetric transformation models
- Modelling interaction of motion and susceptibility-induced distortions

Furthermore, common motion artifact reduction methods include:

- Regression of motion parameters
- Detection and removal of outlier timepoints/volumes
- Denoising

The pros and cons of the above methods and options will be discussed theoretically and in the context of what is available in commonly used software packages for fMRI analysis. How these methods interact with prospective methods and acquisition strategies will also be examined.

Summary

- A range of different motion correction and artifact reduction methods are available in commonly used software packages for fMRI analysis
- This talk will discuss the different options for these corrections, highlighting what is currently available and used in practice

REFERENCES

1. Andersson, J. L., Hutton, C., Ashburner, J., Turner, R., & Friston, K. (2001). Modeling geometric deformations in EPI time series. *Neuroimage*, *13*(5), 903-919.
2. Bullmore, E. T., Brammer, M. J., Rabe-Hesketh, S., Curtis, V. A., Morris, R. G., Williams, S. C. R., ... & McGuire, P. K. (1999). Methods for diagnosis and treatment of stimulus-correlated motion in generic brain activation studies using fMRI. *Human brain mapping*, *7*(1), 38-48.
3. Cox, R. W., & Jesmanowicz, A. (1999). Real-time 3D image registration for functional MRI. *Magnetic resonance in medicine*, *42*(6), 1014-1018.
4. Friston, K., Ashburner, J., Frith, C. D., Poline, J. B., Heather, J. D., & Frackowiak, R. S. (1995). Spatial registration and normalization of images. *Human brain mapping*, *3*(3), 165-189.
5. Friston, K. J., Williams, S., Howard, R., Frackowiak, R. S., & Turner, R. (1996). Movement-related effects in fMRI time-series. *Magnetic resonance in medicine*,*35*(3), 346-355.
6. Goebel, R. (1996). Brainvoyager: A program for analyzing and visualizing functional and structural magnetic resonance data sets. *Neuroimage*, *3*(3), S604.
7. Jenkinson, M., Bannister, P., Brady, M., & Smith, S. (2002). Improved optimization for the robust and accurate linear registration and motion correction of brain images. *Neuroimage*, *17*(2), 825-841.
8. Power, J. D., Barnes, K. A., Snyder, A. Z., Schlaggar, B. L., & Petersen, S. E. (2012). Spurious but systematic correlations in functional connectivity MRI networks arise from subject motion. *Neuroimage*, *59*(3), 2142-2154.
9. Roche, A. (2011). A four-dimensional registration algorithm with application to joint correction of motion and slice timing in fMRI. *Medical Imaging, IEEE Transactions on*, *30*(8), 1546-1554.
10. Salimi-Khorshidi, G., Douaud, G., Beckmann, C. F., Glasser, M. F., Griffanti, L., & Smith, S. M. (2014). Automatic Denoising of Functional MRI Data: Combining Independent Component Analysis and Hierarchical Fusion of Classifiers. *NeuroImage*.