An improved model of motion-related signal changes in fMRI

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Background: Head motion is a significant source of noise in the estimation of functional connectivity from resting-state functional MRI (rs-fMRI). Current strategies to reduce this noise include image realignment, censoring time points corrupted by motion, and including motion realignment parameters and their derivatives as additional nuisance regressors in the general linear model. However, this nuisance regression approach assumes that the motion-induced signal changes are linearly related to the estimated realignment parameters, which is not always the case. In this study, we develop an improved model of motion-related signal changes.

Methods: Functional MRI data was acquired from 55 healthy adults (27 females; 40.9 ± 17.5 years). (TR = 2.6 s, TE = 25 ms, flip angle=60°, FOV=224mm×224mm, matrix size=64×64, slice thickness = 3.5 mm, number of slices = 40). First, we derive a voxel-wise estimate of the signal changes induced by the head motion during the scan by taking one of the acquired echo-planar imaging volumes and rotating and translating it according to the inverse of the estimated motion parameters. This “motion simulated” (MotSim) dataset models the motion-related signal changes in the original data that are entirely due to motion. The MotSim dataset is then motion corrected with rigid body volume registration, which models the imperfections introduced by interpolation and errors in estimating the motion. We compare the common approach of including the 6 realignment parameters and their derivatives (12mot) as nuisance regressors to using the first 12 principal components (PCs) of all brain voxels in the MotSim & MotSimReg datasets (12MotSim).

Results: The 12MotSim model explained significantly more variance than 12mot (p<0.05). On average across the whole brain, the 12MotSim model explained 4.1% more variance. 10% of the voxels in the brain showed at least an additional 12.7% of explained variance, and 5% of the voxels showed at least an additional 17% of explained variance.

Conclusions: Motion reduction using the current common approach of regressing out the 6 realignment parameters and their derivatives can be significantly improved by using time series derived from a PCA decomposition of simulated motion-induced signal changes. That is, instead of using the realignment parameters themselves, we are using an estimate of the signal changes that this motion would produce. This improved reduction of motion artifacts should lead to more accurate estimates of functional connectivity, particularly in populations where motion is prevalent, such as patients and young children.