The effects of different preprocessing pipelines on network measures of functional connectivity

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Background: Brain functional connectivity (FC) measured by functional magnetic resonance imaging was shown to be influenced by preprocessing procedures. Many methods have been proposed targeting filtering at frequency bands, slice-timing correction (STC), motion artifacts, cardiac and respiratory-cycle effects or global signal (GS) filtering and cerebrospinal fluid (CSF) and white matter (WM) regression. Our study evaluates specific preprocessing steps and their impact on diverse features of FC.

Methods: Resting-state activity from 52 healthy subjects (21 females; 24.9±4.4 years old) was acquired on the 1.5 T Siemens Symphony MR scanner, TR = 3 s. The ECG and breathing signal data were recorded simultaneously. Functional data were preprocessed in SPM8 including realign and unwarp, optional STC and RETROICOR (cardiac and breathing activity; RTC) filtering (thus creating 4 variants of filtering: no filtering, STC, RTC, STC+RTC), co-registration to anatomical scan, spatial normalization and smoothing, motion artifacts correction (5 variants of corrections: no correction, 6 movement regressors (MR), 24 MR, 24 MR+CSF+WM, 24 MR+CSF+WM+GS). Functional connectivity was assessed as Pearson’s correlations between time-series of 80 regions of AAL atlas, the representative was computed as the first principal component. The influence of these 20 different preprocessing pipelines on network analytical measures – normalized clustering coefficient, normalized characteristic path length, average node strength and modularity – was estimated by generalized linear mixed model, p < 0.05, post-hoc tests were Bonferroni corrected for multiple comparisons.

Results: The corrections for 24 MR+WM+CSF increase normalized characteristic path length, clustering and modularity coefficients while they lower average node strength. The normalized clustering and average node strength were also increased by RTC and interactive effect of STC+RTC filtering and correction. These results are even more pronounced when correcting for global signal. The effect of STC on network measures is present only when used together with RTC.

Conclusions: The evaluation of effects of preprocessing pipelines on network structure revealed significant shift towards more regular network structure (higher normalized clustering coefficient and normalized characteristic path length) when filtering 24 MR, WM, CSF (and GS) signals. Higher level of correction also increases values of modularity describing the ability of network to form functionally similar clusters. We observed that RTC strongly influences the network measures. In agreement with previous studies we also show strong impact of GS correction. However, we did not find convincing evidence for standalone usage of STC.