Effect of scanner signal drift on evaluation of baseline connectivity

H. Cheng[1], and S. N. Brandfon[1]

[1]Psychological and Brain Sciences, Indiana University, Bloomington, IN, United States

Introduction

The baseline functional connectivity can be characterized by spontaneous signal correlation in BOLD imaging[1]. It has drawn a lot of interest in exploring the default modes of a resting state brain. Spectrum analysis indicates that the correlation is dominated by low frequency (< 0.08 Hz) components. Because of the low frequency feature, most of the studies have applied a low pass filter to the time course and have ignored the intrinsic signal drift of the MR scanner[2,3,4]. Our phantom experiments show that intrinsic signal drift of the scanner may contribute to the correlation significantly. We also show that low pass filtering can lead to overestimation of the correlation.

Methods

Acquisition and preprocessing: An ACR phantom was scanned once each day for 73 days. The protocol was: FOV = 220 mm, FA = 90, one slice with slice thickness = 4 mm, TR/TE = 2000/30. 200 volumes were acquired for each run. Alternatively, human subjects were scanned in two different conditions, one was a resting state with eyes closed; the other was block-designed task of right-hand finger tapping. The protocol was: FOV = 220 mm, FA = 90, 30 slices, slice thickness = 4 mm, gap = 1 mm, TR/TE = 2000/30. Two-hundred and forty volumes were acquired. Pulsation and respiration data were also acquired. The data preprocessing included motion correction, slice timing correction, and physiological noise correction using RETROICOR. The finger tapping data was processed using SPM2 to find the activated motor cortex, which will be used as the seed to search for the baseline connectivity.

Correlation: A ROI of 36 pixels was chosen in the phantom as a seed and its time course was calculated. The correlation to time courses for all of the pixels in the phantom was computed in 4 different ways: 1) without any correction; 2) the time courses were low-pass filtered, the cutoff frequency was 0.08 Hz; 3) the time course was scaled by the scanner signal drift, obtained by smoothing the global mean time course with a Gaussian kernel; 4) the time course was scaled by the global mean of each time points. The mean correlation value was obtained for each run. For human subjects, the correlation calculation was carried out in SPM2's "simple regression" and only method a), b) and d) were employed.

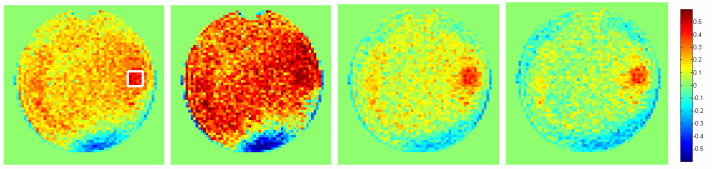

Fig. 1. Correlation coefficient maps obtained from 4 different approaches described in the text. A) with method1; b) with method 2; c) with method 3; d) with method 4.

Results

Fig. 1 shows an example of the result of one run. Fig. 1.a is the correlation map without any correction. The seed ROI is illustrated by the square. The scale is from -0.6 to 0.6. It demonstrates that the time courses of the voxels of a phantom are intrinsically correlated. Fig. 1b is the result from low pass filtering. The correlation values are largely elevated. Fig. 1c is the result by taking into account the signal drift. Fig. 1d is the result after scaling with global means. After getting ride of the global signal drift, only pixels in the seed are highly correlated to the seed time course. The mean correlation values from the four methods of the 73 phantom runs are plotted in Fig. 2. For most of the runs, the correlation value from low pass filtering or without correction is unreasonably high (> 0.2). But the value is down below 0.1 after mean value scaling; this is expected for a phantom. For each run, the correlation value from low pass filtering is always the biggest and that from scaling is always the smallest. The average values are 0.318, 0.206, 0.123, and 0.089 respectively. The sharp drops of correlation value from method 2 to method 1 and from method 1 to method 3 and 4 show that slowly varying global signal drift is the main source of signal correlation. The relatively large variance of correlation value with method 1 and 2 mean that the global signal drift can change wildly from day to day. Its contribution is essentially unpredictable for an individual study.

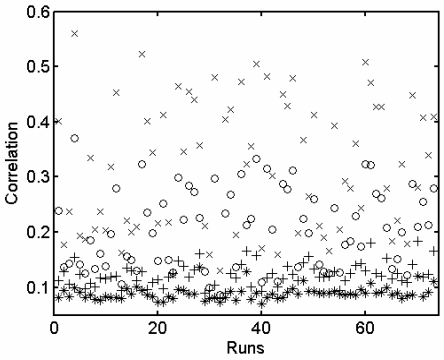

Fig. 2. Mean correlation coefficients distribution from 73 runs. Open circle for method 1; × for method 2; + for method 3; * for method 4.

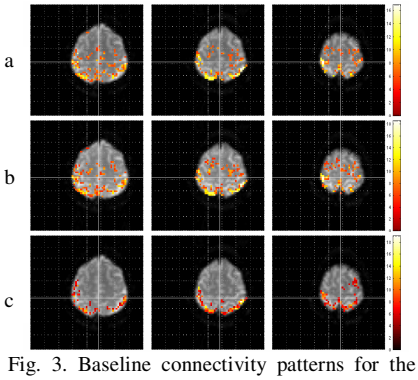

Fig. 3. Baseline connectivity patterns for the motor cortex obtained from SPM2. a) with method 1; b) with method 2; c) with method 4.

Fig. 3 is the result from one human subject. Only three slices are displayed. The motor cortex connectivity is observed as discovered by Biswal et al[1]. Although there was no significant difference by applying low pass filtering, it did increase the number of voxels in the connectivity, as we compare Fig. 3b with 3a. However, both methods produced sparse patterns. Contrastingly, the global mean value scaling decreased overall number of 'activated' voxels and the connectivity looked cleaner (Fig. 3c).

Discussion

As there is no ground truth of baseline connectivity in the human brain, it is difficult to evaluate which processing method is better. However, our results from the phantom demonstrated that global signal drift from the scanner is a big confound to the correlation evaluation. While difficult to isolate scanner drift from other sources of correlation, its effect can be mixed with physiological noise, which is another collective temporal signal change. In our studies, the signal fluctuation from a phantom is normally within 0.5% but more than doubled for the human subjects. Although most researchers do not apply global scaling to the functional data when extracting functional connectivity, our data of human subjects suggest that applying global scaling is a conservative way of detecting the baseline connectivity.

Reference

[1] Biswal, B. et al., MRM. 34:537-541, (1995). [2] Lowe, MJ. Et al., NeuroImage, 7:119-132, (1998). [3] Cordes D. et al., *AJNR* 22:1326–1333, (2001). [4] Hampson M. et al., Hum Brain Mapp, 15:247-262, (2002).