Assessing dynamical correlations between functional and structural brain connectivity

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Abstract

The link between resting-state functional connectivity (FC), measured by the correlations of the fMRI BOLD time courses, and structural connectivity (SC) has been repeatedly investigated recently (1). Meanwhile, the importance of considering the dynamics of neuronal processes has also been highlighted (2). In this work we show how the classical static (i.e. considered as constant) relationship between SC and FC could be enriched when the FC dynamics are taken into account.

We use a sliding window approach to explore these dynamics and show that the window width should be chosen in a particular range in order to unveil statistically significant (i.e. not due to noise) fluctuations of the FC-SC correlation.

Highlights

The correlation between structural and functional connectivities is not constant. One example of this dynamical connectivity and its corresponding power spectrum is shown below:

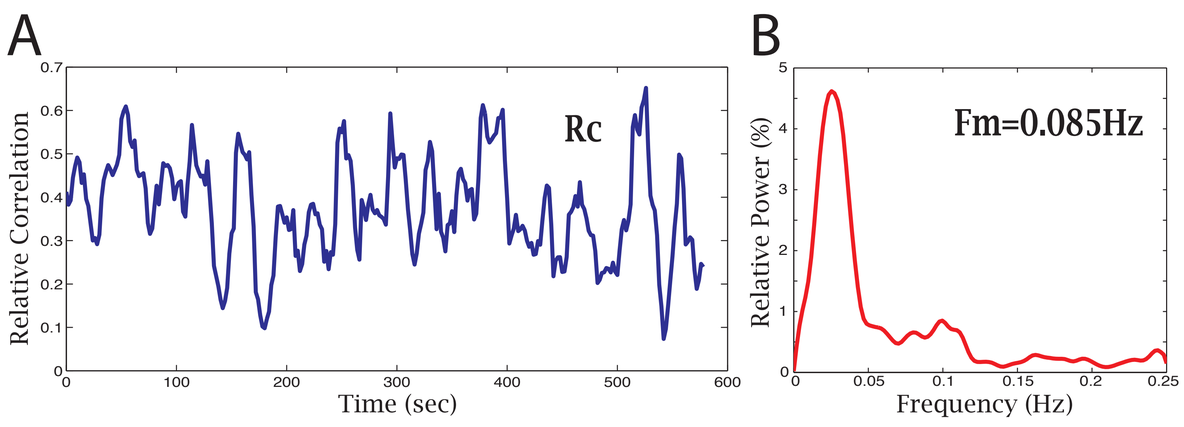

Figure1: Results for Subject 7 and window width = 6 TR. (A) Relative correlation (Rc) between SC and FC computed following the methods presented in Fig. 3D and normalized by the static correlation obtained with the classical static approach (Fig. 3C). (B) Power spectrum of Rc from which the average spectral content Fm is computed.

Questions:

① Which markers can we use to characterize these curves ?

② What is the impact of the window width ?

③ Are the fluctuations observed in Fig.1A significant (i.e. due to neuronal dynamics) ?

➔ We showed that the fluctuations are significant provided that the window width is chosen in a range that both allows to *capture the neuronal dynamics* and *reliably estimate the functional connectivity:*

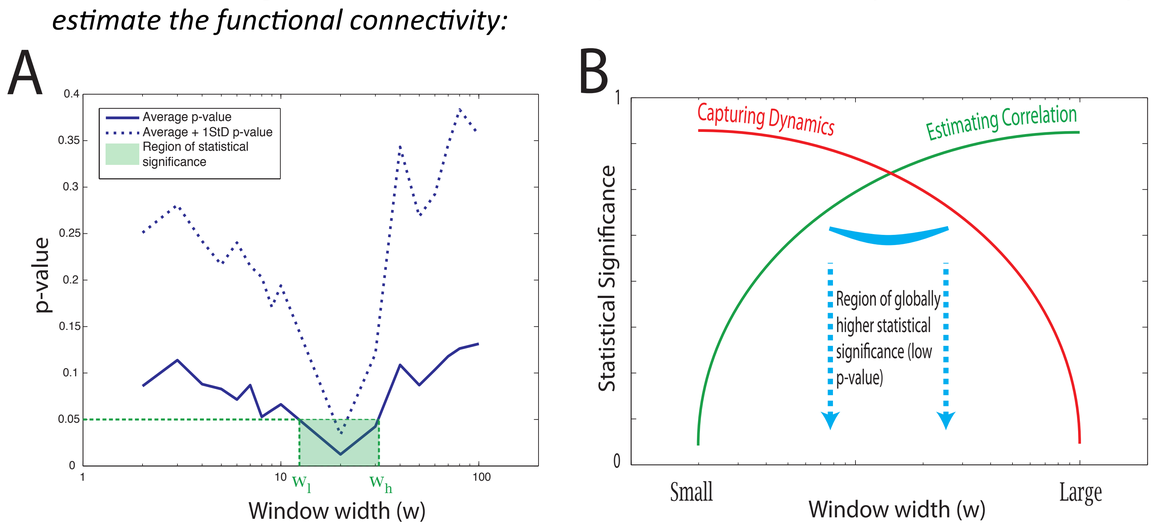

Figure 2: (A) Estimation of the significance region based on Fm and (B) its interpretation as a *tradeoff* between estimating functional connectivity and capturing its dynamics.

Methods and Answers

Data was collected from 14 healthy volunteers in resting state with TR=2 sec. To explore the FC-SC correlation dynamics we repeated the computation of FC for m-w+1 windows of the fMRI time series (Fig. 3B) where m is the number of volumes and *w* is the window width (e.g. (3)). The difference with the classical static approach is represented below:

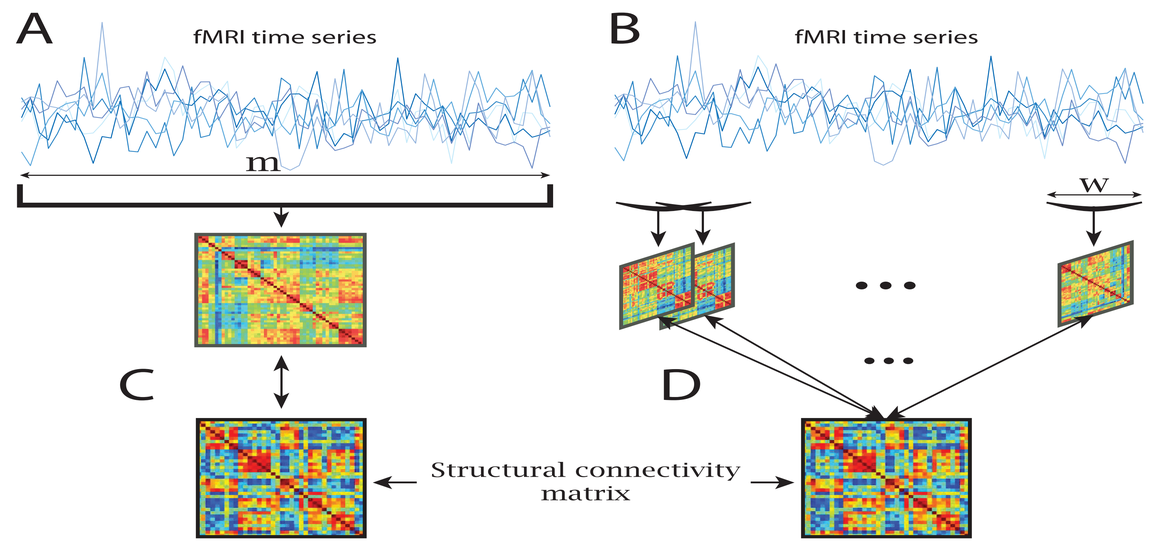

Figure 3: Comparison between the static and the dynamic analysis of the correlation between SC and FC. (A) FC is computed using the whole fMRI time courses. (B) FCs are computed in windows of the fMRI time courses that are slided over the whole fMRI time courses. (C) Classical static correlation between SC and FC, as computed in e.g. (4). (D) Time evolving correlation between SC and FC as used here.

Answers to the questions

① In order to characterize dynamics observed in the Rc curves, we used the mean frequency Fm contained in these curves, computed as $Fm = \int F * P(F)\,dF$.

② The curves obtained with various values of window width *w* are represented in Fig. 4A. We observe that the windowing acts as a low-pass filter, with a cutoff frequency that decreases when *w* increases.

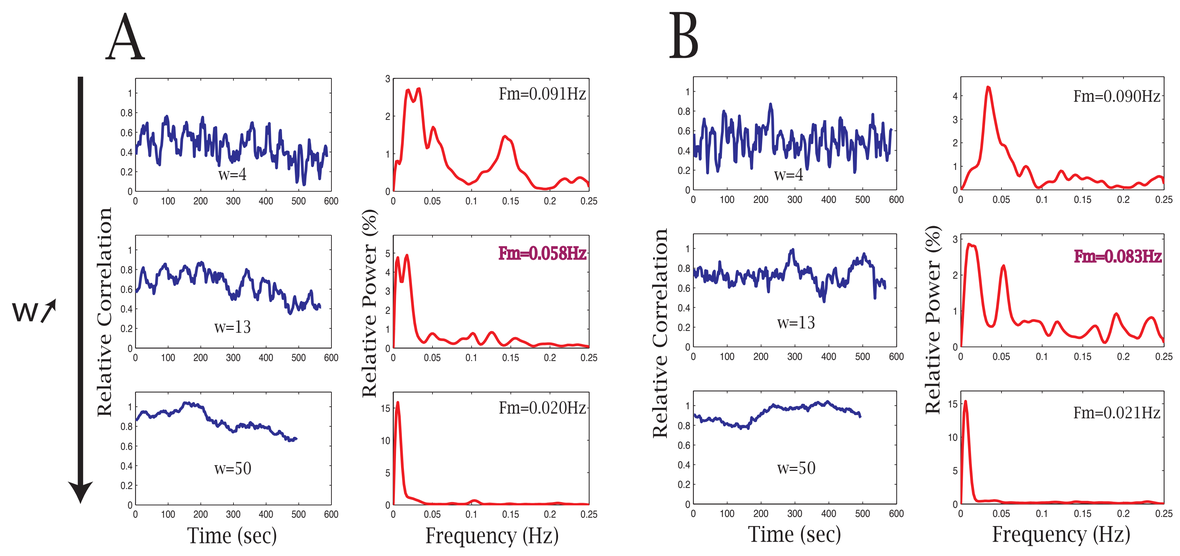

Figure 4: Effect of window width and comparison between starting from ordered (A) and permuted (B) fMRI time series.

③ In order to disentangle neuronal dynamics from noise we did the same computations as in Fig. 4A but with random permutations of the fMRI volumes (Fig. 4B). Doing so leaves the overall correlation unchanged whereas the evolution of Rc is totally rearranged. In the example of Fig. 4 we can observe that the distinction between the ordered and the resampled cases based on Fm is more pronounced for w=13 TR than for w=4 TR or w=50 TR. To test the statistical difference at the group level between the two configurations we compared Fm in both cases for all the subjects and window widths. The results are shown in Fig. 2A and we can observe a peak of statistical significance around *w*=20 TR.

Take-home Messages

We showed that there are significant dynamics of the FC-SC correlates which could be helpful to refine the current models based on a static FC-SC relationship (1,4).

➔ There is information contained in the fMRI time series *dynamics*
➔ The window width should be chosen carefully: sufficiently large to reliably estimate FC but sufficiently small to capture its dynamics
➔ Possible interpretations of these fluctuations such as mind-wandering should be further explored

REFERENCES [1] Deco, G. et al. (2012), 'How anatomy shapes dynamics: a semi-analytical study of the brain at rest by a simple spin model', Front Comput Neurosci, vol. 6, no. 68. [2] Hutchison, R.M. et al. (2013), 'Dynamic functional connectivity: Promise, issues, and interpretations', Neuroimage 80, pp. 360–78. [3] Leonardi, N. et al. (2013), 'Principal components of functional connectivity: A new approach to study dynamic brain connectivity during rest', Neuroimage, vol. 83, pp. 937-50. [4] Honey, C.J. et al. (2010), 'Can structure predict function in the human brain ?', NeuroImage 52, pp. 766–76.

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