Identifying the Default Mode Network Structure Using Dynamic Causal Modeling on Resting-state fMRI

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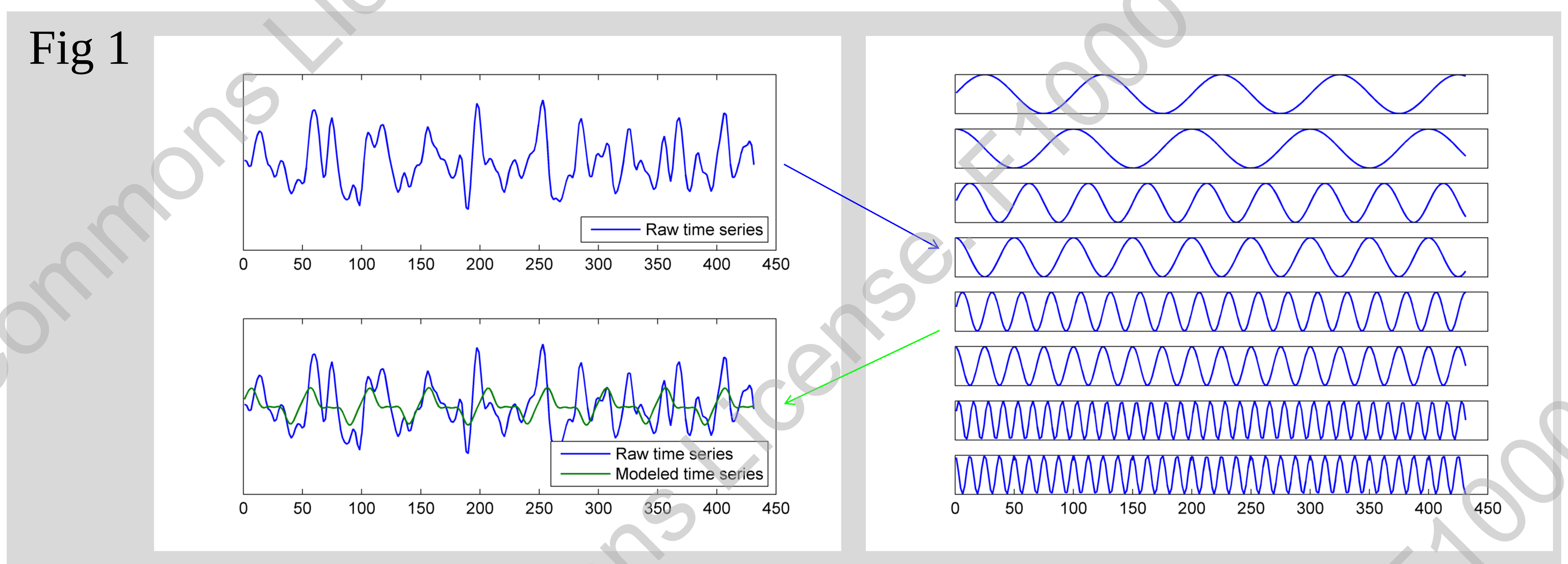
Background

- There is a growing interest to study brain network structures using dynamic causal modeling (DCM)[1] in resting-state fMRI data.
- It was suggested to model the spontaneous fluctuations as stochastic processes[2]. However, we suggest to explicitly model the low-frequency fluctuation signals using Fourier series.
- We aimed to use Fourier series to model the input of DCM, and study the network structure underlying the default mode network (DMN)[3, 4].

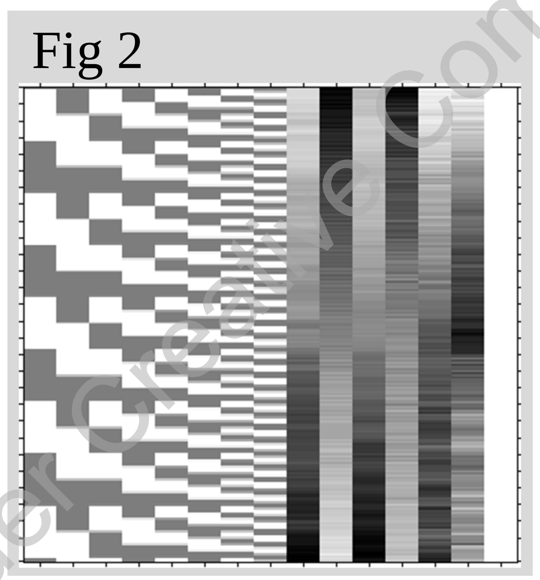
Modeling low-frequency fluctuations using Fourier Series

Fig 1



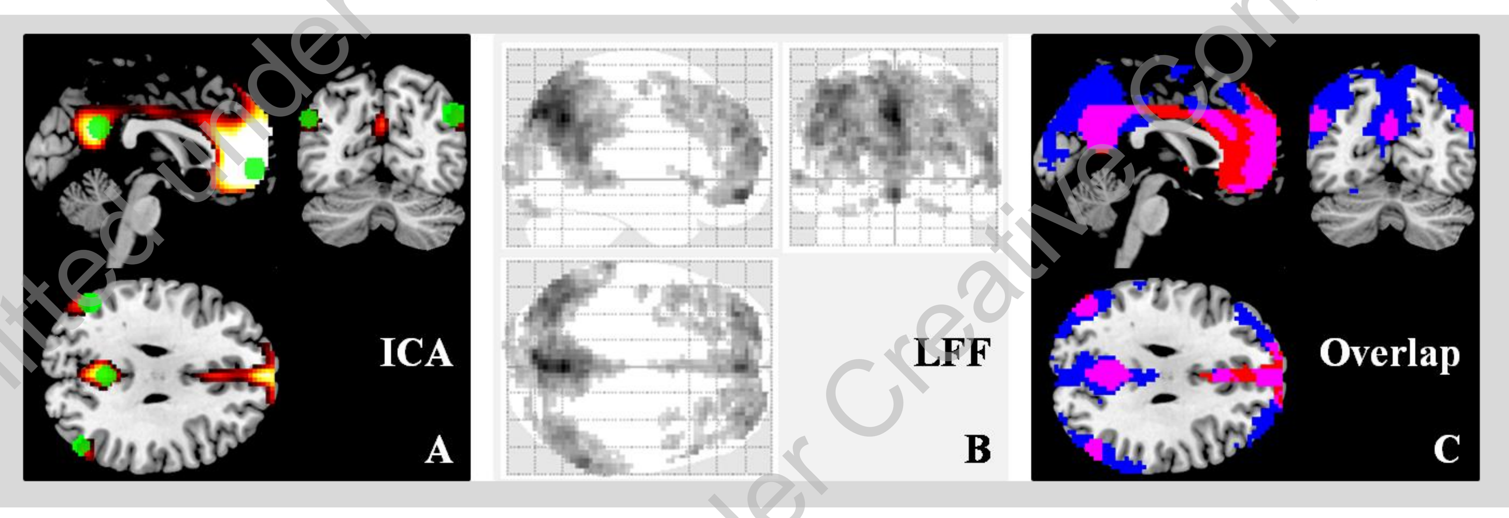
Raw and modeled time series   Fourier series

Fig 2



- For a given periodic function such as low-frequency fluctuation, it can be approximated by the sum of a set of sine and cosine periodic functions, which is called Fourier series (Fig 1).
- The Fourier series (binarized) can be implemented in the general linear model to capture the low-frequency fluctuations in the resting-state (Fig 2).
- The regions whose variance can be highly captured by the Fourier series regressors resemble the default mode network (DMN) (Fig 3B). It overlapped with the DMN map obtained using an independent component analysis (ICA) (Fig 3A & 3C).

Fig 3



Resting-state fMRI data and analysis

- Resting-state data of 64 subjects from the 1000 Functional Connectomes Project was analyzed (http://fcon_1000.projects.nitrc.org/) (21 male, mean age 21.2 years)[5].
- 230 images were acquired for each subject using a TR of 2s. Scanning parameters can be found in the project website.
- Preprocessing using SPM8 included motion correction, spatial normalization of the functional images via normalizing the anatomical image, and spatial smoothing using an 8mm Gaussian kernel.
- Spatial independent component analysis was conducted to define the DMN using GIFT[6].

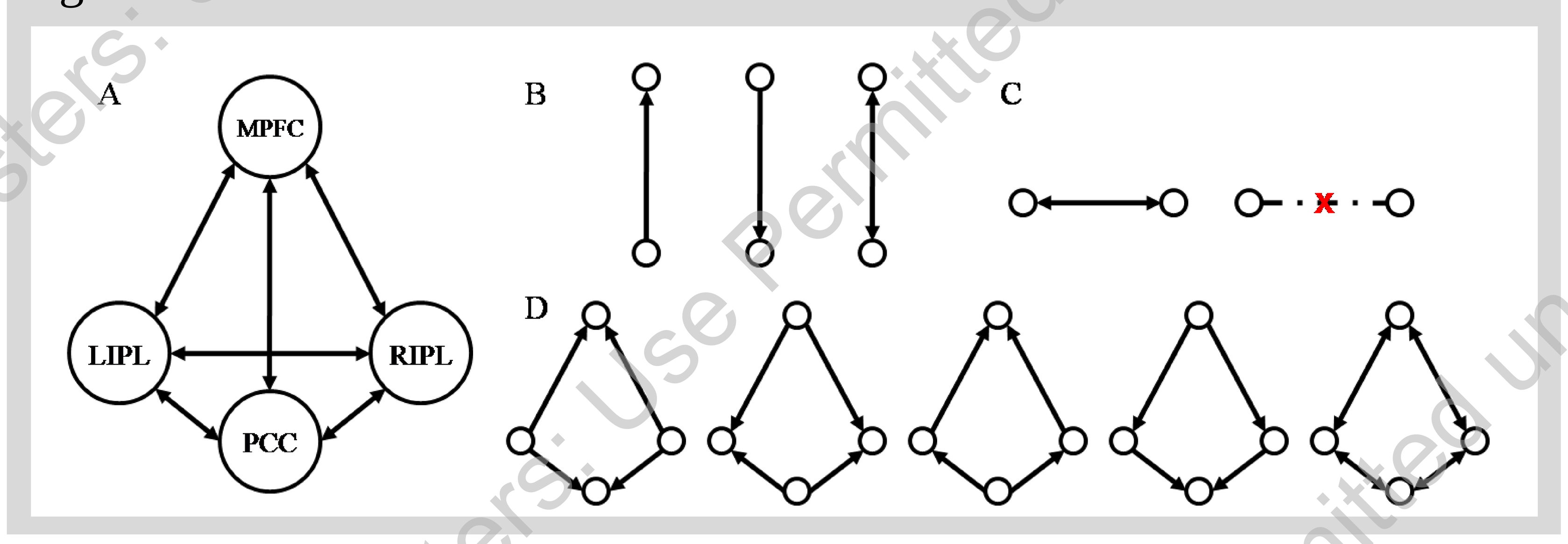
Resting-state fMRI data and analysis (cont.)

- The four ROIs of the DMN were the medial prefrontal cortex (MPFC) (centered at 3, 54, -2), posterior cingulate cortex (PCC) (0, -52 26), left inferior parietal lobule (LIPL) (-50, -63, 32), and right IPL (RIPL) (48, -69, 35) (green circles in Fig 1A).

Dynamic causal modeling of the default mode network (DMN)

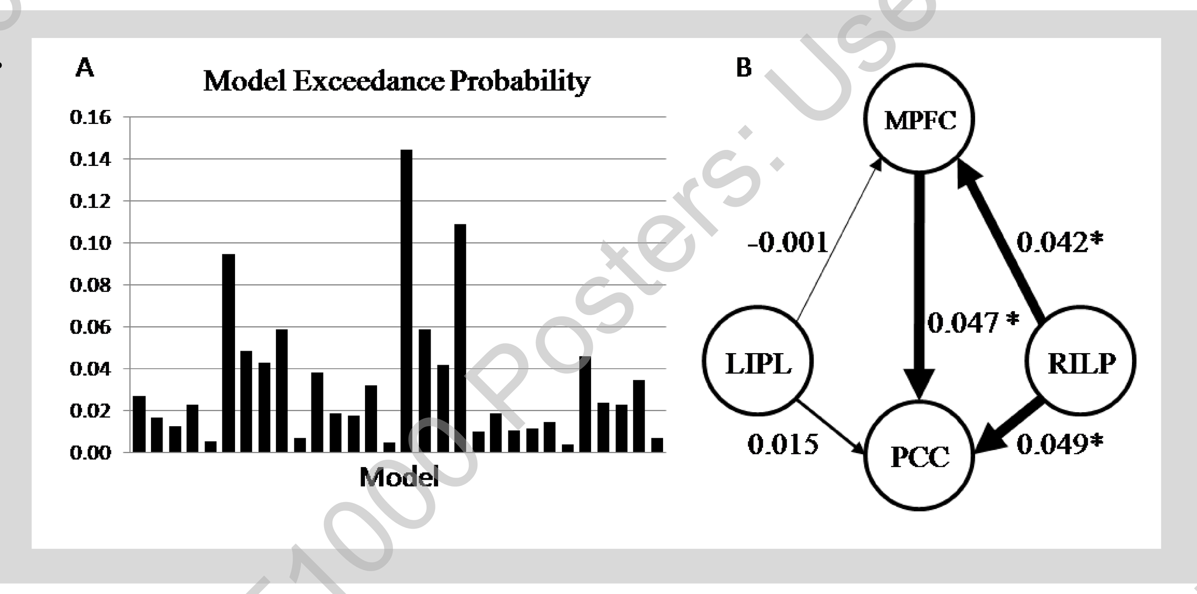
- DCM models included four ROIs (the green circles in Fig 3A).
- Eight Fourier series were set as inputs (C parameter) for all the four ROIs.

Fig 4.



- Endogenous connectivity (A parameter) was manipulated to define the different network structures underlying the DMN (Fig 4).

Fig 5.



- The model with the best evidence is shown in Fig 5.
- The connectivity from the right IPL to the MPFC and PCC were greater than the connectivity from the left IPL ($F(1,62) = 7.251$, MSE = 0.011, $p = 0.009$).

Conclusion

- Fourier series can be used to model the low-frequency fluctuations in resting-state fMRI.
- The usage of Fourier series enables the application of DCM to study resting-state network structures.
- Modulations of the IPL to the MPFC and PCC are right lateralized.

References:

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