A matched filter decomposition of task fMRI for extraction of dynamical components

Anand Joshi[1], Jian Li[1], Haleh Akrami[1], Richard M. Leahy[1]

[1] Signal and Image Processing Institute, University of Southern California, Los Angeles, CA, USA

Introduction

A great amount of effort has been spent on dynamic functional connectivity (dFC) characterization using fMRI, both in resting state as well as using event-related task paradigms. Most existing methods for exploring dFC are based on windowed Pearson correlation. However, the choice of window length is always debatable. Here we propose a method that decomposes fMRI signals into 'baseline' and residual 'task-related' dynamical components. We define the baseline as the signal component that has the correlation structure matching the resting state data, and the task-related component is the residual of this decomposition. For this purpose, we develop a windowed extension of BrainSync[1] transform to perform a matched filtering of fMRI data. By removing the confounding baseline component from the data, the proposed decomposition approach allows the study of the dFC at a high spatial resolution.

Methods

As an input, we assume resting and task grayordinate fMRI data as defined by HCP[2]. We first develop a baseline template by performing a temporal PCA of the resting fMRI (rfMRI) data. The temporal dimensionality is reduced to T=21 based on the singular value spread of rfMRI. The recently developed BrainSync transform is an orthogonal transform which can be used for comparisons of fMRI scans across subjects that are collected during resting or task paradigms[3]. For matched filtering of task fMRI data, the baseline template is synchronized to a window around each time point using a windowed extension of the BrainSync transform. Subtraction of the resulting 'matched filter' synchronized template leaves only the portion of brain activity directly related to the task. We present a closed-form expression for the windowed synchronizing transform. We demonstrate the performance in application to the minimally preprocessed (ICA-FIX denoised) resting and 'Motor' and 'Language' task fMRI data using 40 independent subjects (all right-handed, age 26-30, 16 male and 24 female) from HCP[2]. We show that by removing the baseline activity we are able to more clearly identify task activated regions in the brain.

Results

In 'motor' task after using the proposed signal decomposition (Figure 1), it can be seen that while the baseline activity forms a significant part of the signal power, it does not contain any task associated activity. The dynamic component of the decomposition retains the high signal at the task associated area of the brain, and the activity in rest of the brain is significantly reduced. In 'language' tasks, the average signal over the 'story' blocks shows clear delineation of language areas. Similarly, during the 'math' block, the angular gyrus that is responsible for arithmetic processing is clearly seen in the dynamical component, while it seems to be missing without the matched filtering (Figure 2).

Conclusion

This paper presents a matched filter approach for decomposition of fMRI data into the baseline and task-related dynamic components. By removing the confounding baseline signal from the fMRI data, the contrasts in the task data blocks are enhanced.

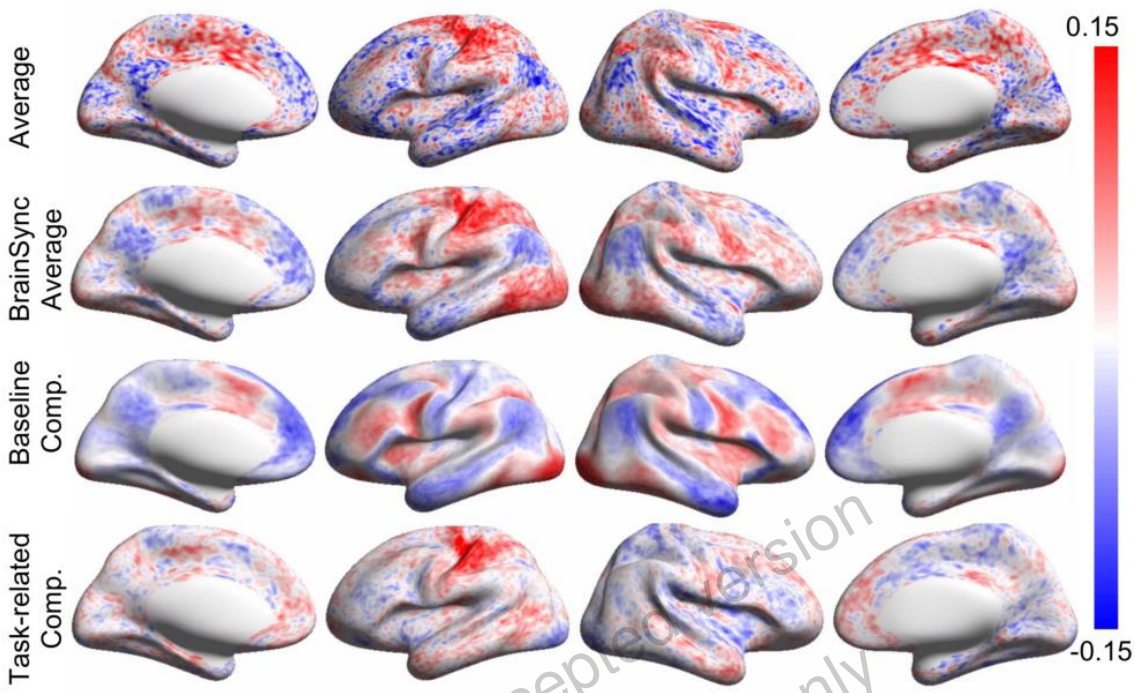

Figure 1: The fMRI signal for at a single time point during the 'right hand' block in the motor task data. The signal is displayed for the four methods (top row): direct average of the signal over 40 subjects; (second row) applying brainsync to all subjects and average; (third row) the extracted baseline component; and (bottom column) extracted task-related component. It can be seen that the signal component that can be explained by the baseline-resting connectivity forms a significant part of the activation during this task, and removal of this signal highlights the task associated region.

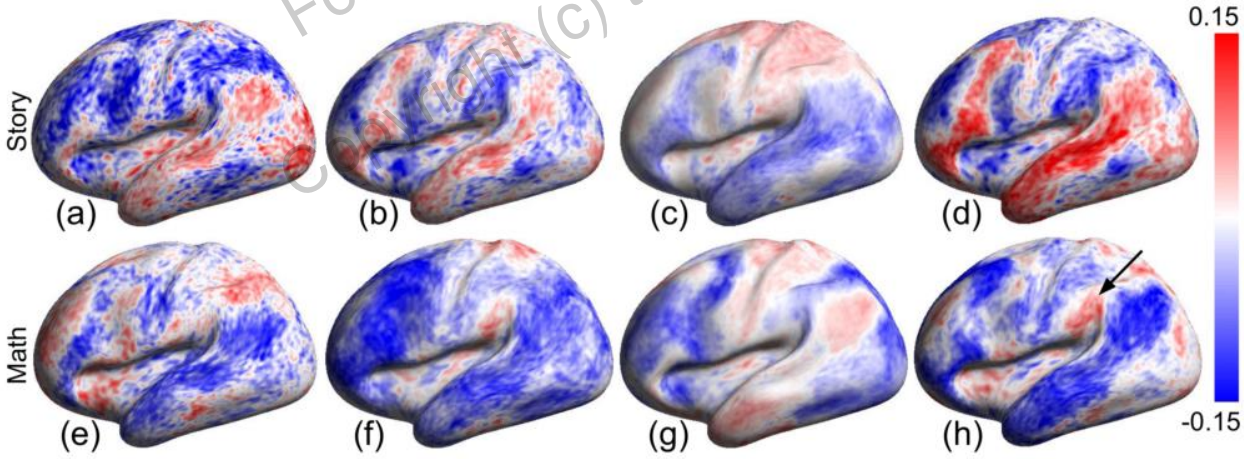

Figure 2: The fMRI at a single time point during the 'story' block (a-d) and 'math' block (e-h) in the language task: (a,e) direct average over subjects; (b,f) BrainSync and average; (c,g) baseline-resting component and (d,h) dynamical components extracted using matched filtering. It can be seen that in case of 'story' block, the activation of the language areas (Broch's and Wernicke's) areas is much clearer in the extracted dynamical component. Similarly, for the 'math' block, the angular gyrus (indicated by arrow in (h)), which is known for association to arithmetic is revealed after the matched filtering.

References

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