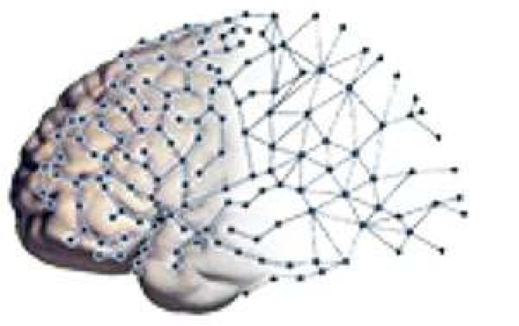
Poster # 2764

USC Viterbi School of Engineering

# A matched filter decomposition of fMRI into resting and task components



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## Abstract


- The human brain exhibits dynamic interactions between brain regions when responding to stimuli and executing tasks, which can be imaged using functional magnetic resonance imaging (fMRI). The fMRI signal collected during tasks is a combination of task-related signal and spontaneous brain activation related to body regulation and other non-task related activity.
- By exploiting the highly structured spatiotemporal patterns of resting state networks, this paper presents a matched-filter approach to decomposing fMRI signal into task and non-task-related components.
- We show qualitatively and quantitatively that by removing the resting activity we are able to more clearly identify task activated regions in the brain. Additionally, using multivariate pattern analysis (MVPA), we show improved prediction accuracy when using the matched filtered data.


## Materials and Methods

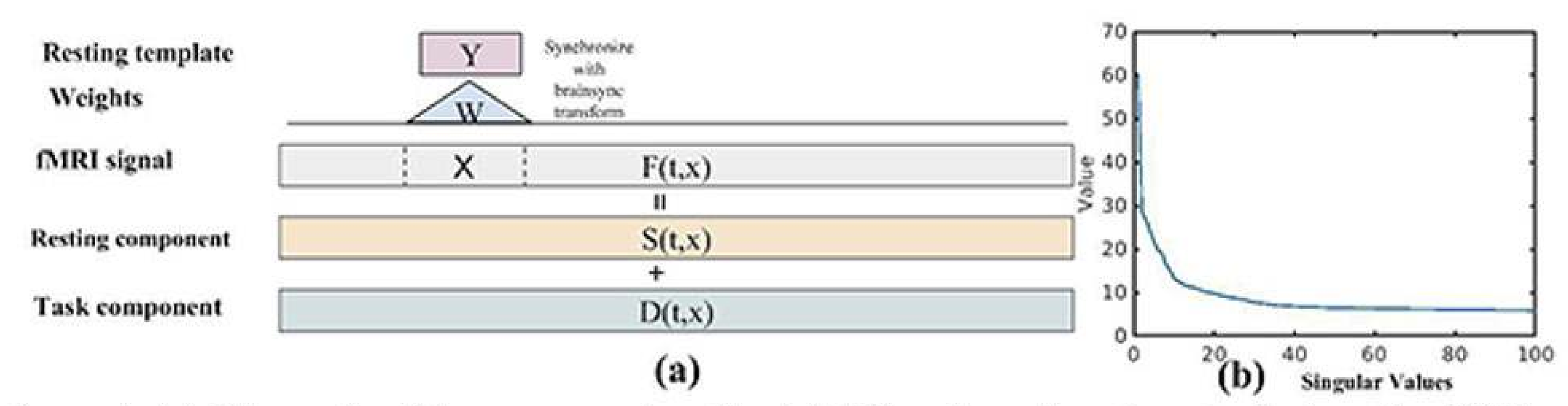


**Figure 1: (a) Schematic of the proposed method; (b) Singular values for a typical resting fMRI scan.**

- We use the resting template pattern $Y$ to identify and remove the components in the task data which exhibit the same connectivity (correlation) pattern as the template.
- In order to estimate the resting component we synchronize [2,3] the template $Y$ to a windowed (with arbitrary window $W$) data segment $X$ at each time point of the target fMRI data $F$ (Fig. 1). For this purpose we solve the orthogonal Procrustes problem with a weighting defined by $W$.

$$E = \|W(\alpha OY - X)\|_F^2$$
$$R = B\Lambda A^T; O = BA^T$$
$$\alpha = \frac{\mathrm{trace}\left((WX)^T(WOY)\right)}{\mathrm{trace}\left((WOY)^T(WOY)\right)}$$

## Results

### Motor Task

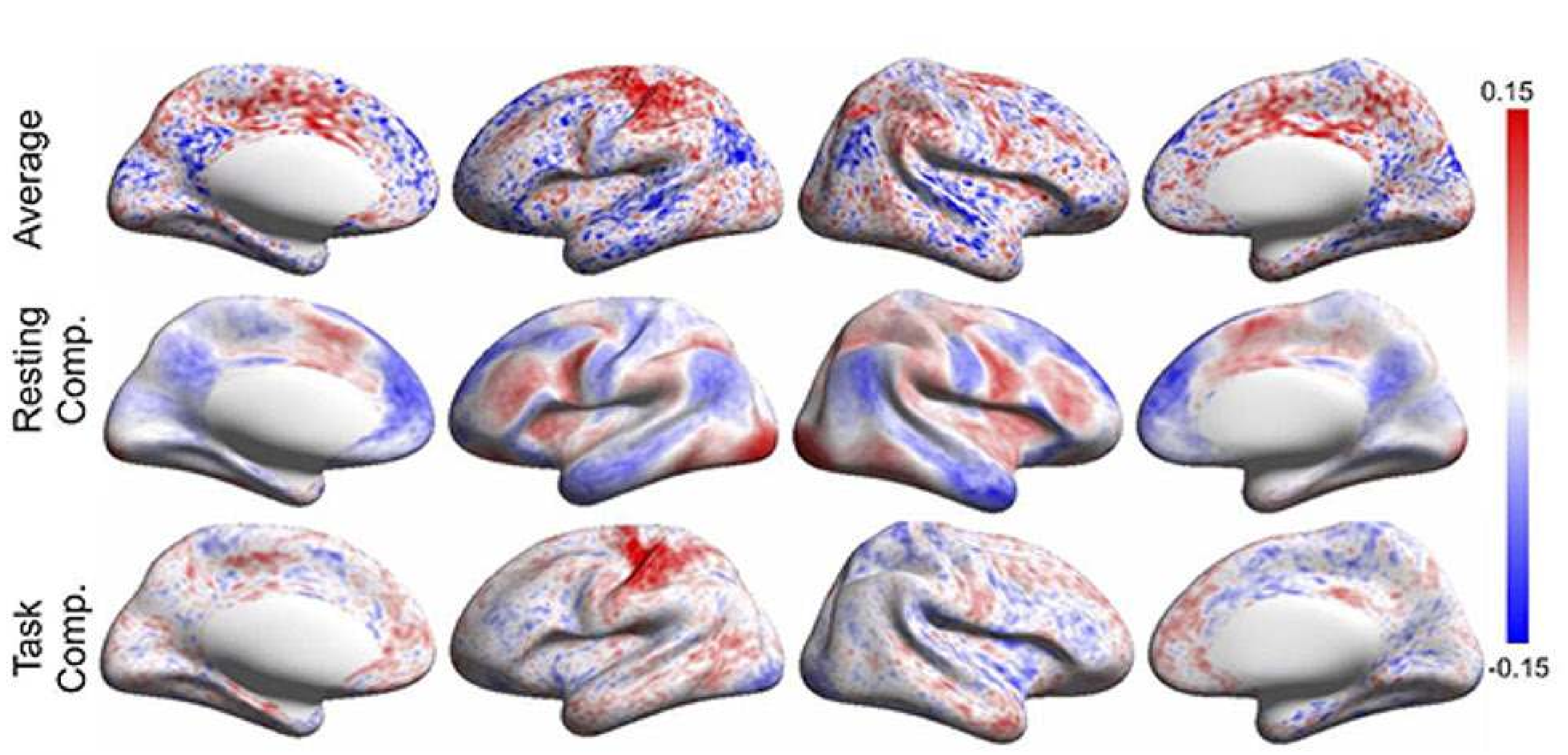


**Figure 2: The fMRI signal a single time point during the `right hand' block in the motor task data. Top row shows the direct average of the signal over 40 subjects; The second row shows the extracted resting component; and the bottom row shows the extracted task component.**

- We used motor task data for 40 subjects from HCP dataset [1,4] for this study. It can be seen that while the direct average signal clearly shows the hand associated region, there is also a large amount of activity in other areas of the brain.
- After subtraction of the estimated resting component it can be seen that while the resting-related activity forms a significant part of the signal power, it does not contain significant task-related activity.
- The task component from the decomposition retains a relatively large signal in the left somatomotor cortex while the activity elsewhere in the brain is significantly reduced.

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### Language Task

- The language task in the HCP [4] data contains two design blocks: auditory story presentation with comprehension questions and a set of math problems.

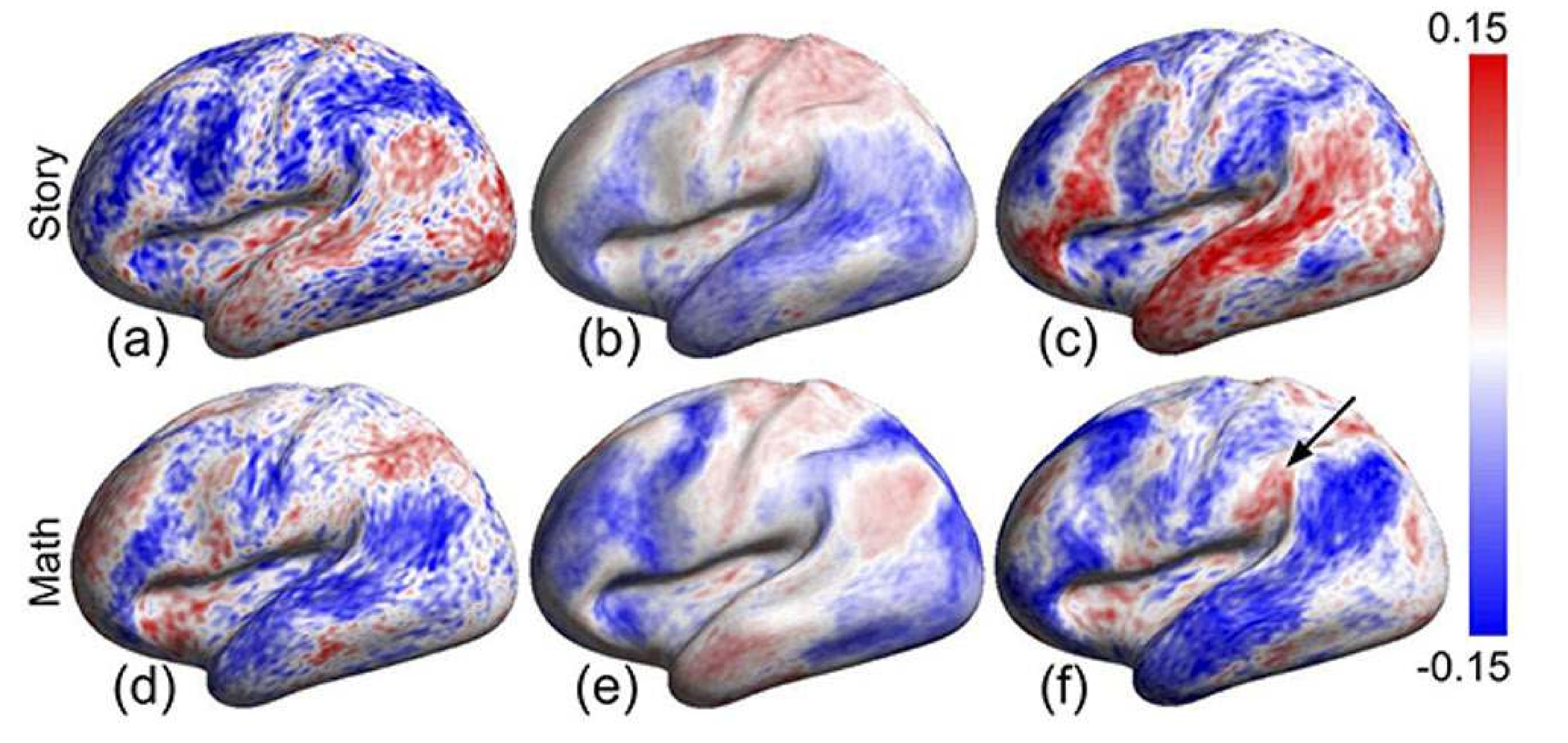


**Figure 3:** The fMRI at a single time point during the `story' block (a-c) and `math' block (d-f) in the language task: (a,d) direct average over subjects; (b,e) resting component and (c,f) task components extracted using matched filtering.

- For the study block, the activation in Broca's and Wernicke's areas during the language task is much clearer after subtraction of the estimate resting component. We also see much stronger activation of the anterior temporal lobe associated with language comprehension and processing.
- For the math block, It can be seen in Fig. 3(h) that the angular gyrus (indicated by an arrow in Fig. 3(h)) that is associated with arithmetic processing is clearly seen in the task component, while it is more difficult to discern without the matched filtering (Fig. 3(e)).

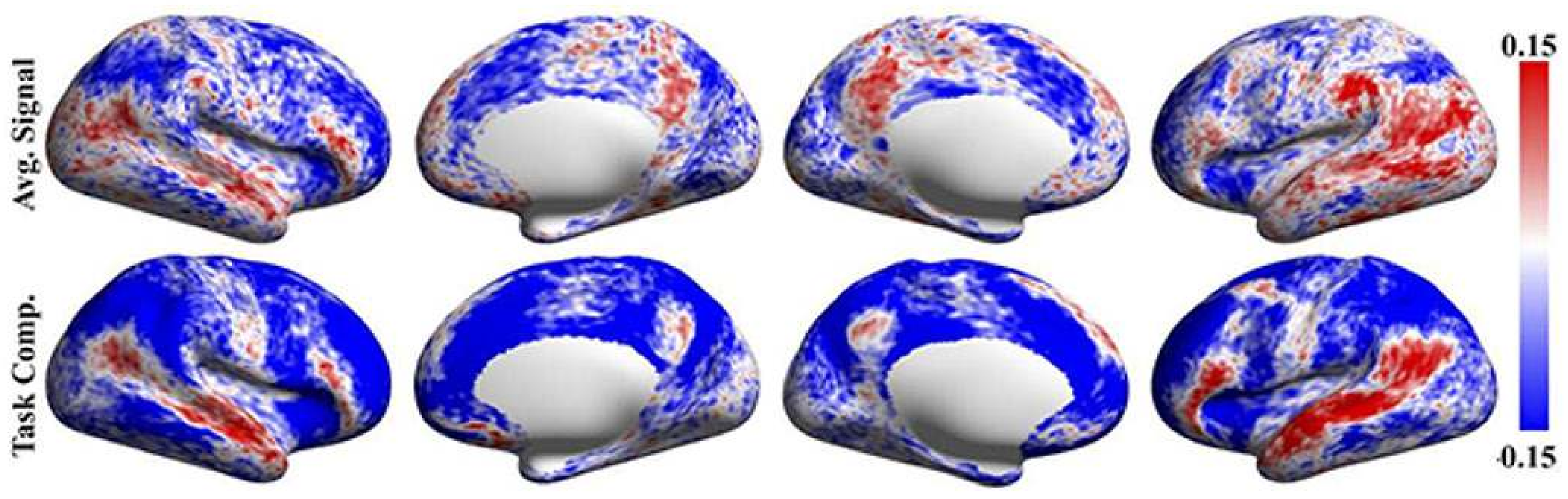


**Figure 4:** The fMRI signal averaged over the 'story' block in the language task: (top row) direct average; (bottom row) averaged task components extracted using the proposed matched filtering.

### MVPA analysis

- We performed MVPA analysis [cite] of story vs math blocks with and without the proposed filtering. The MVPA analysis uses SVM classification of the annotated time series fMRI data. We performed 5-fold cross-validation (CV), which involves iteratively training the SVM classifier using 80% of the time series and its annotations and making predictions of the annotation for the remaining 20% of the time series. The mean(std) CV accuracy for story vs math paradigm,for the original data was 0.7815(0.1232) and for the matched filtered data it was0.8054(0.1423).
- When subblocks of the data were considered, The CV accuracy for this case, for the original data, was 0.7423 (0.1026) and for the matched filtered data, it was 0.8423 (0.0976).

## Conclusion

- This paper presents a matched filter approach for decomposition of fMRI data into resting and task-related component. By removing the confounding non task-related on-going (or 'resting') activity from the fMRI data, the contrasts in the task data are enhanced.
- An alternative approach could be to design separate matched filters for different sub-networks within the resting state network. We will explore this approach in the future.

### References

[1] Glasser MF, *et al*., The minimal preprocessing pipelines for the Human Connectome Project, Neuroimage 2013.
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[4] Barch et al., Function in the Human Connectome: Task-fMRI and Individual Differences in Behavior. NeuroImage 80, 169–189 (Oct 2013).