



Whole-Brain Task-Based BOLD Networks: Presenting the 'Big Five' for Working Memory



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Introduction

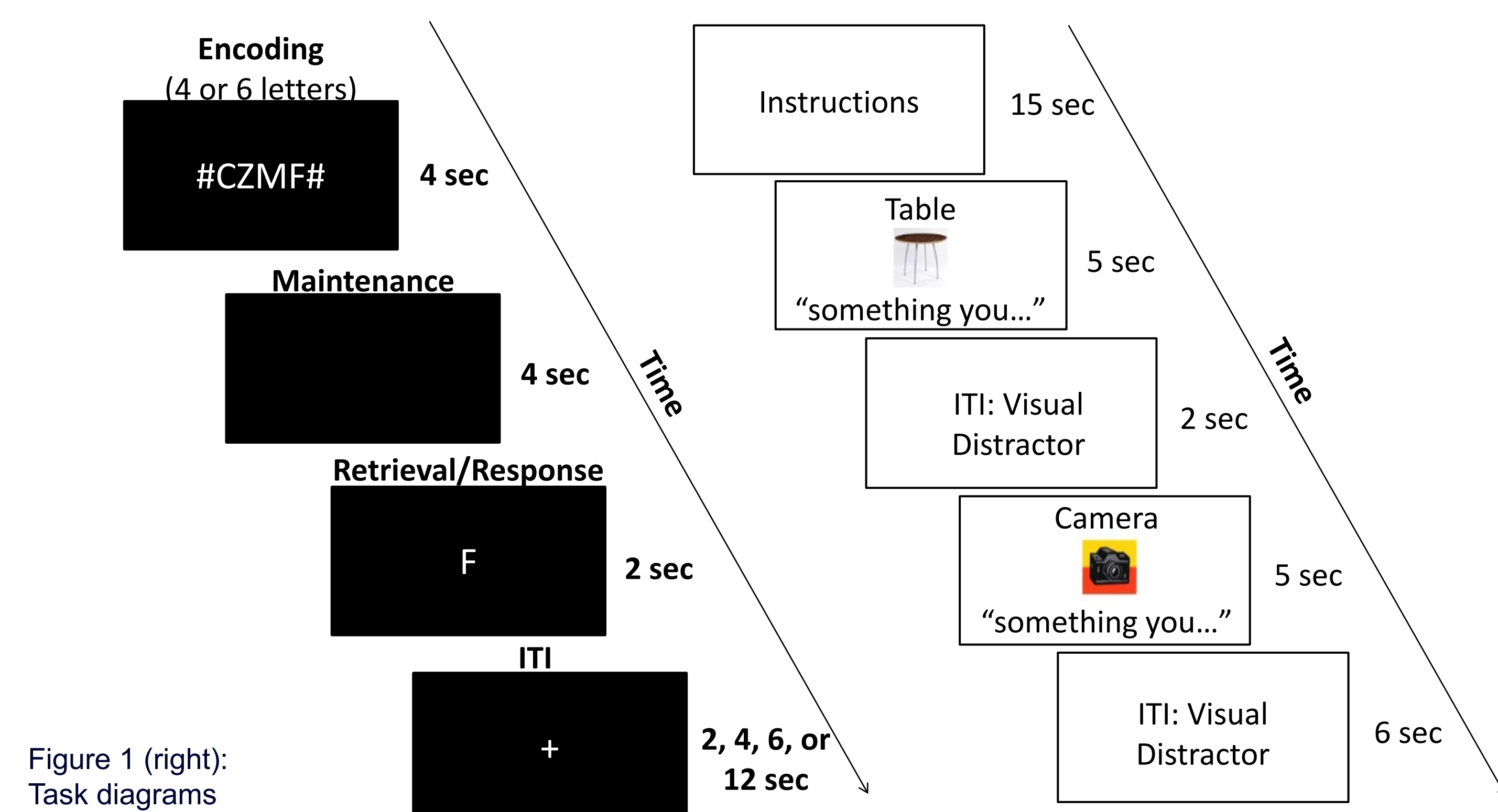
- Functional magnetic resonance imaging (fMRI) investigations of working memory (WM) using the Sternberg task could be greatly simplified if the set of BOLD-signals detectable involved in this task could be identified.
- This would allow merging of Sternberg task data across multiple sites and task versions, as has been successfully achieved with resting-state data.
- In addition, the task-evoked hemodynamic response (HDR) shapes can be inspected to test hypotheses about the WM-related cognitive processes associated with this task.

Objective

In the present study, we tested for the presence of the hypothesized 'Big Five' WM brain networks from past Sternberg studies.

Methods

- Thirty-eight adults completed the Sternberg WM task, whereby participants were required to remember a string of letters over a 4-second delay.
- Since the networks involving attention to internal processes (maintaining the memory) and overt behavioural responses (recalling and responding) follow a similar time course in this task, low temporal resolution of task-induced BOLD signal changes results in spatial and temporal blurring of these networks [1].
- Thus, we combined WM task data with previously published data from the Thought-Generating Task (TGT) [1], a task requiring attention to internal representations but no overt behavioural response, to separate networks involved in WM processes [2].

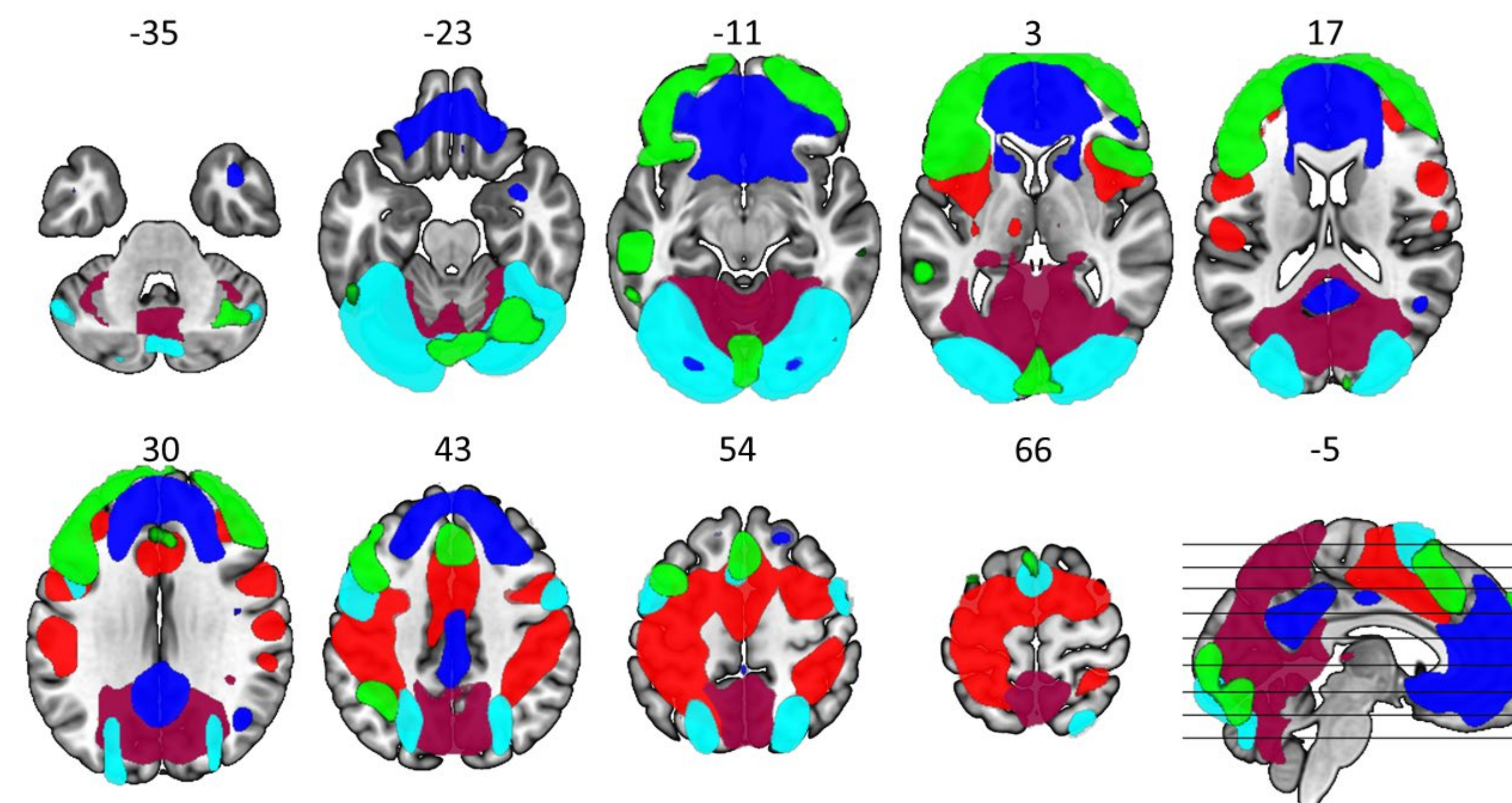


- Data were analyzed using Constrained Principal Component Analysis for fMRI (fMRI-CPCA) to identify functional brain networks elicited by the task and experimental manipulations of task conditions [3].
- Networks were not limited to an assumed-shape HDR model, predefined regions, or network masks. Dimensional analyses replaced one-to-one network-to-voxel correspondences. BOLD fluctuations related to task timing were analyzed.

Results

- Seven networks were extracted from the analysis. The extracted networks matched the hypothesized WM Big 5.
- Big Five 1: Response (RESP) peaked late in the trial for the WM task and deactivated mid-trial suggesting suppression when a response is not required.
- Big Five 2: Focus on Visual Features (FoVF) consisted of deactivation since details of the letter presentations (e.g., font, typeset, case) need not be attended to.
- Big Five 3: Initiation (INIT) is an early-peaking network (7s), with a higher peak for the high-load condition, associated with the general function of initiating a sequence of cognitive processes.
- Big Five 4: Maintaining Internal Attention (MAIN) was a mid-trial peaking network (11-15s) with a higher peak for the high-load condition, with activation starting early-to-mid-trial (7s), suggesting a role in volitionally attending to internal representations.
- Big Five 5: Default Mode Network (DMN) was a mid-trial peaking network (11-15s), consisting of negative loadings, and showed load-dependent deactivation, with the initiation of deactivation coinciding with the trial start. In this analysis, the DMN was split into two components.

Figure 2 (below): dominant 10% of loadings for the Big Five networks. Images are displayed in neurological orientation (left is left) with MNI z-axis coordinates.



Estimated HDR vs Time for High Load Condition

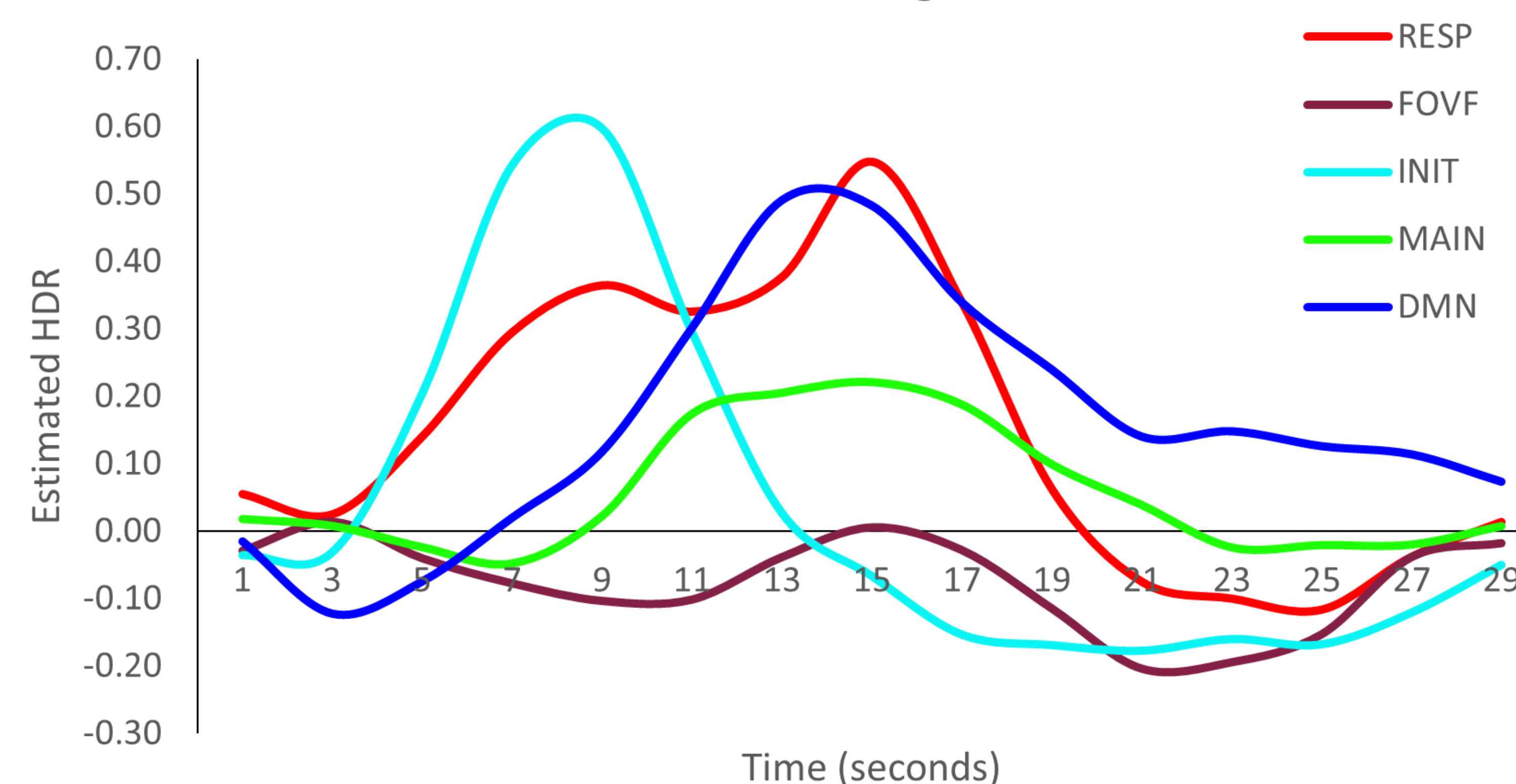


Figure 3 (above): mean finite impulse response (FIR)-based predictor weights plotted over post-stimulus time for each of the Big Five networks for the higher cognitive load (6-letter) condition. Positive predictor weights reflect increased signal in this network. HDR = hemodynamic response.

Discussion

- These results illustrate the replicability of identified functional networks across samples of individuals completing versions of the Sternberg WM task.
- The hypothesized WM 'Big Five' were retrieved; however, these networks are found across many tasks, like the TGT.
- This fact (that BOLD fMRI can reveal a consistent set of brain networks for diverse behaviours) has general implications for fMRI research that extends beyond WM.
- This methodology converges on a cognitive function assigned to each of the brain networks, which is based on task-timing information converging over many tasks (WM and non-WM) eliciting the same brain networks.
- We emphasize that the WM 'Big Five' does not imply that WM is carried out in the human brain using only five networks of neural activity, but instead applies only to BOLD activity, which is simplified by orders of magnitude relative to neural activity.

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