The neural correlates of working memory for temporal order information: An fMRI study

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INTRODUCTION

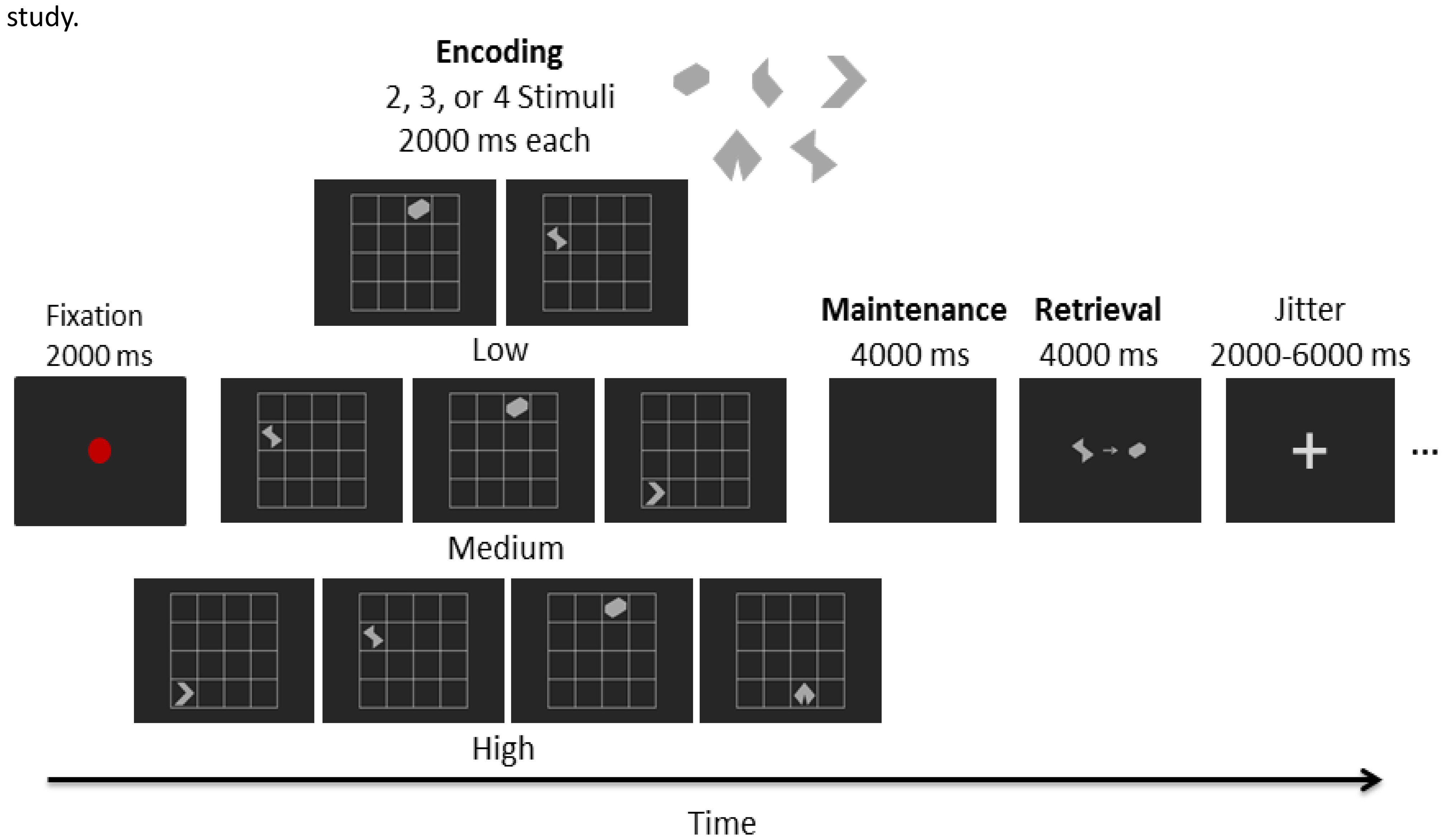
Working memory refers to the executive processes responsible for temporary storage and manipulation of various domains of information to guide goal-directed behavior. Great amount of neuroimaging studies have explored neural mechanisms of working memory for vosio-spatial, verbal and object-based contents. Few studies have focused on serial-order information in working memory, and the results from those studies have yielded mixed results (Marshuetz et al., 2006).

In the present study, we used event-related functional Magnetic Resonance Imaging (fMRI) to investigate the neural mechanisms of effects of temporal order and cognitive load on working memory during encoding, maintenance, and retrieval phases.In order to minimize the influence of verbal working memory, five abstract objects from previous study by Parra et al. (Parra et al., 2010) were used. In addition, we used item numbers to explore load effect, different from other studies using lag interval.

METHODS

Participants

Eighteen healthy and right-handed adults (8 males; mean age 23.2 years, age range 20-26 years) participated in this study.



Experimental procedure

Each trial began with a red point for 2 s and followed by an encoding phase. During encoding, different levels of task with set sizes two through four were manipulated. The stimuli consisted of one of five abstract objects and a 4-by-4 square grid. In each trial, two (low load), three (medium load), or four (high load) of five abstract objects were randomly chose and put in one of the sixteen small squares. Participants were instructed to memorize the order of those abstract objects. The encoding phase was followed by 4-second blank as a maintenance phase in which participants were asked to remind the order of the just presented abstract objects. During retrieval, two abstract objects were presented with a right arrow in between which indicated the present order of those two objects. Participants were instructed to indicate if the temporal order is correct by pressing one of two buttons by index or middle finger of right hand once the probe was presented. Trials were separated by a jittered interval of 2, 4, or 6 s. There were total 3 sessions, each consisting of 21, 7 trials for each level.

Imaging Protocol and Data Analysis

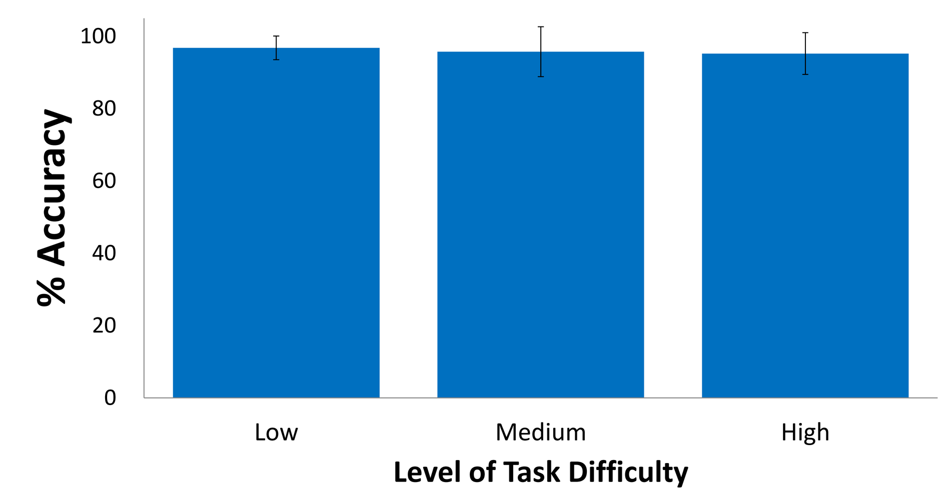
A 3T MRI scanner equipped with a high-resolution 12-channel head array coil (Magnetom Trio, Siemens, Erlangen, German) was used to acquire functional magnetic resonance images. Functional images were acquired using a gradient-echo EPI sequence with following parameters: TR = 2000 ms, TE = 27 ms, FOV = 220 mm, 33 axial interleaved slices.

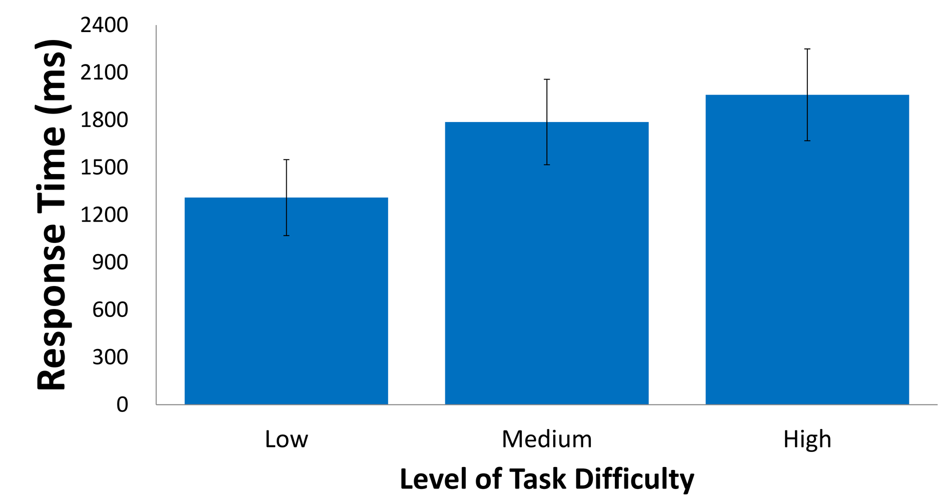
Functional images were pre-processed and analyzed using SPM8. Images were slice-time corrected, realigned, spatially normalized, smoothed with 6 mm FWHM. Event-related BOLD response was modeled by convolving with the canonical hemodynamic response function. Significant regions of activation were identified with threshold uncorrected $p < 0.001$ and cluster size>10.

RESULT & DISSCUSSION

Behavioral results

Participants revealed equivalent accuracy across three levels of task difficulty but showed slower response time as task load increases.

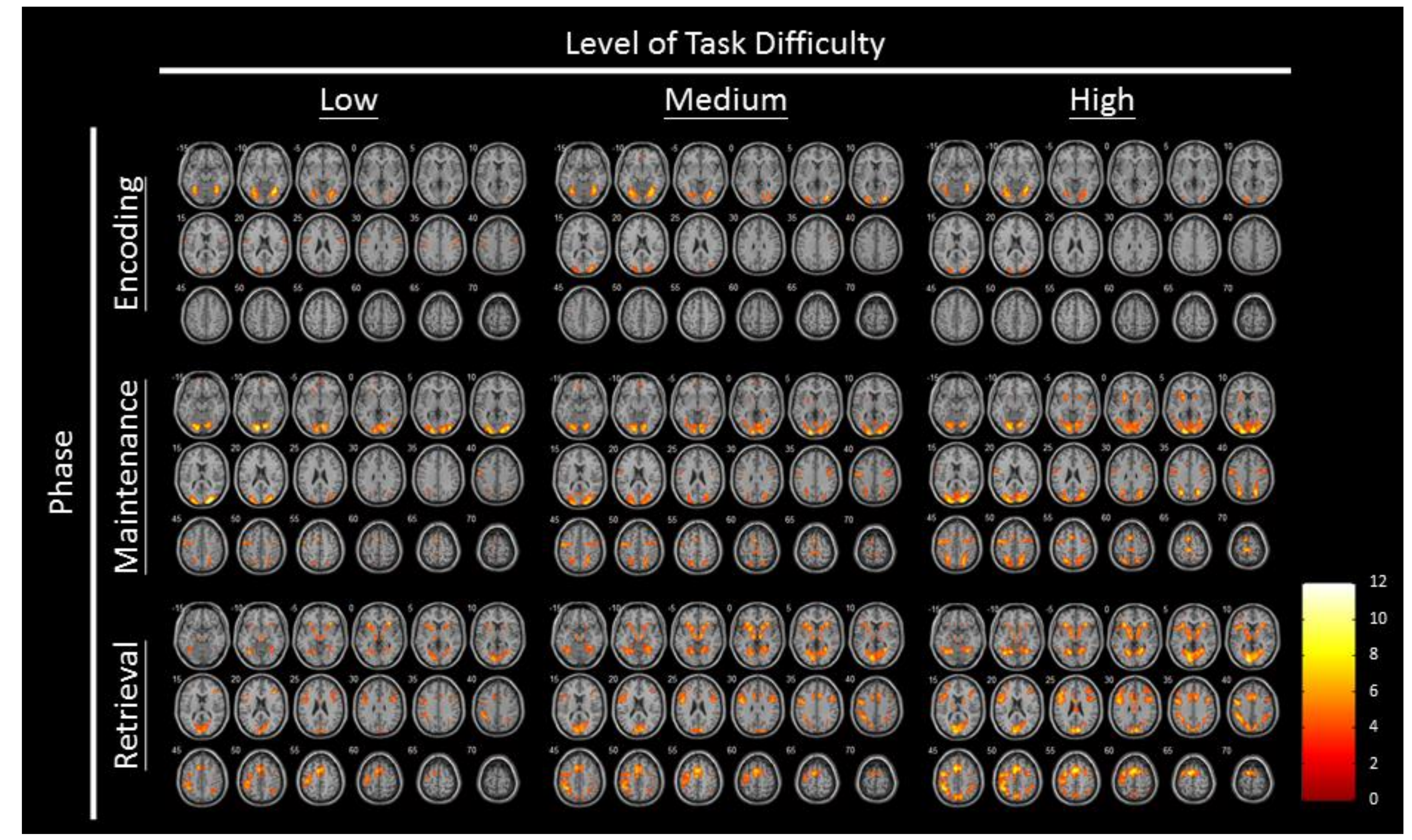




fMRI results

Whole brain analysis

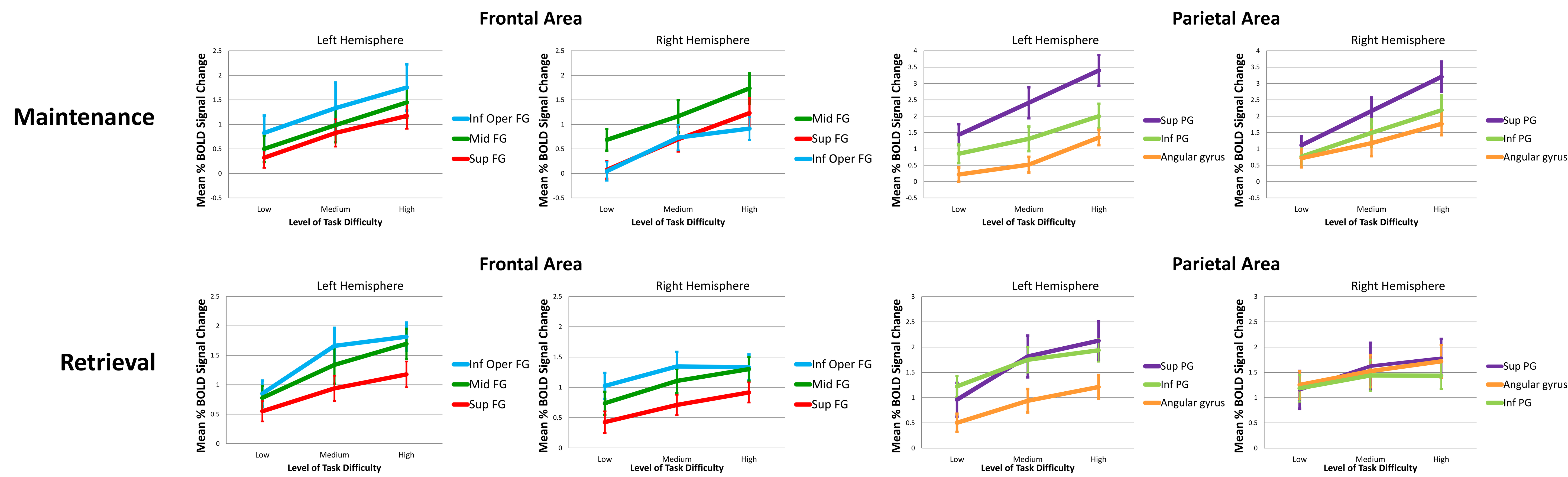
A whole brain analysis revealed broad fronto-parietal activation during maintenance and retrieval for temporal order information, consistent with previous working memory fMRI studies.



ROI analysis

For the maintenance phase, fronto-parietal networks showed load-dependent BOLD signal changes in bilateral hemispheres, but not in medial temporal lobe which was frequently mentioned in temporal context memory (Jenkins & Ranganath, 2010).

For the retrieval phase, bilateral frontal and superior parietal regions showed load-dependent BOLD signal changes. Moreover, left inferior parietal gyrus (IPG), not right IPG, showed load-dependent BOLD signal changes.



CONLUSION

These results are consistent with findings from previous visuo-spatial working memory studies and provide additional evidence that, in addition to prefrontal cortex, posterior parietal region may play a functional role in modulation of working memory capacity for serial order information. Previous studies for temporal working memory, however, have rarely shown activation in parietal area. We speculate that it might results from most studies used lag interval, as opposed to item numbers in our study, to manipulate working memory load.

REFERENCES & ACKNOWLEDGEMENT

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