



# Task-merging for finer separation of functional brain networks in working memory

Nicole Sanford<sup>1,2</sup> and Todd S. Woodward<sup>1,2</sup>

<sup>1</sup>Department of Psychiatry, University of British Columbia, Vancouver, Canada  
<sup>2</sup>BC Children's Hospital Research Institute, Vancouver, Canada



## INTRODUCTION

### Background

- Functional MRI (fMRI) has limited ability to delineate networks underlying overlapping cognitive processes, due to temporal limitations of the blood oxygen level-dependent (BOLD) signal.
- The network(s) underlying working memory (WM) maintenance processes are not well characterized, despite being theoretically separable from encoding and response.
- Combining tasks with theoretically relevant differences and similarities facilitates comparisons for interpreting network functions and may produce finer parcellations.

### Aims

- Investigate task-state brain networks common to WM and thought generation tasks using an fMRI functional connectivity approach.
- Determine whether WM maintenance processes are separable from encoding and response processes when analysed with a task involving volitional thought generation.

## METHODS

### Participants

Demographic characteristics (standard deviations in parentheses)

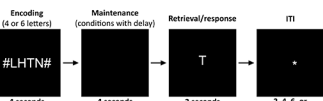
	Working Memory Task (n = 37)	Thought Generation Task (n = 32)
Mean age	28.16 (8.70)	28.75 (8.58)
Mean years of education	15.86 (2.16)	15.58 (1.81)
Mean estimated IQ <sup>a</sup>	99.59 (11.89)	97.09 (11.21)
Sex distribution	10 males; 27 females	19 males; 13 females
Handedness (R/L/mixed)	32/3/2	29/3/0

<sup>a</sup>estimated IQ based on the Quick IQ task.

### Materials

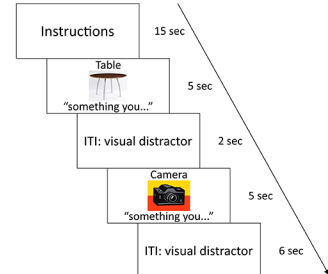
#### Working Memory Task (WM)

- String of consonants is presented, followed by a "probe" letter immediately or after a delay.
- Participant responds "yes" or "no" as to whether the probe letter was part of the first string of letters (button-press response).
- 2 factors:**
  - Cognitive load: 4 letters vs. 6 letters to remember.
  - Delay: 4-second delay vs. no delay period.



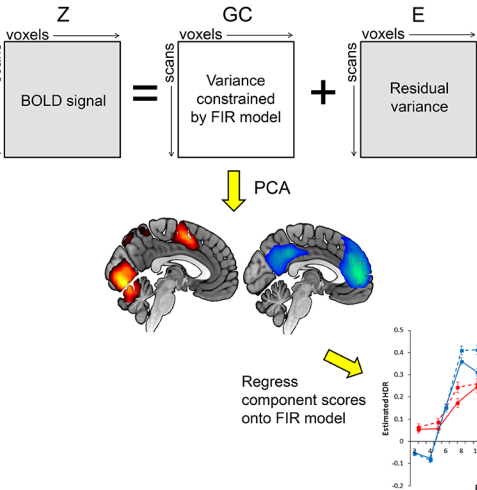
#### Thought-Generation Task (TGT)<sup>1</sup>

- Picture of a noun is presented for 5 seconds.
- Hearing condition:** listen to a definition.
- Generating condition:** internally think of a definition.



### Functional Connectivity Analysis

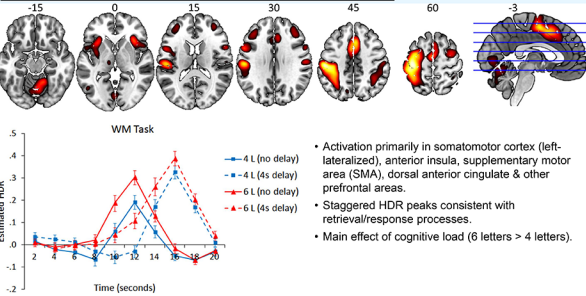
- Task-state networks extracted using fMRI-constrained principal component analysis (fMRI-CPCA; see figure below).<sup>2</sup>
  - Analysis 1:** WM data only.
  - Analysis 2:** WM data and TGT data combined.
- Analysis of hemodynamic response (HDR) performed using repeated measures analysis of variance (ANOVA):
  - WM:** 2 (4 vs. 6 letters) x 2 (delay vs. no delay) x 10 (post-stimulus time bins)
  - TGT:** 2 (hearing vs. generating) x 10 (post-stimulus time bins)



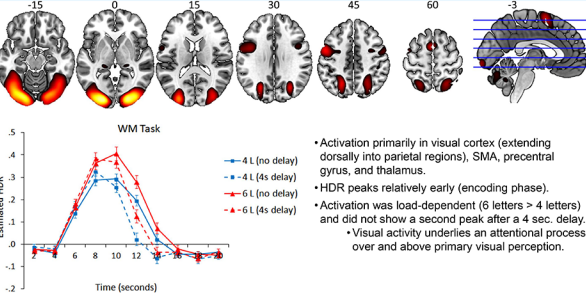
## RESULTS

### ANALYSIS 1: WM TASK ONLY

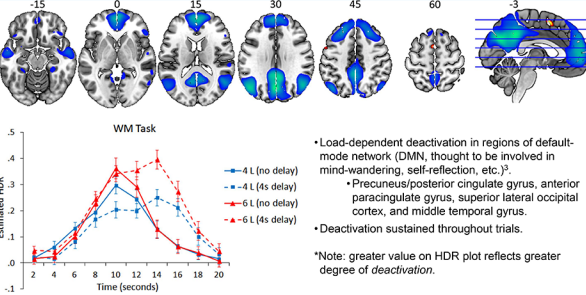
#### Component 1 – response/attention\*\*



#### Component 2 – visual attention

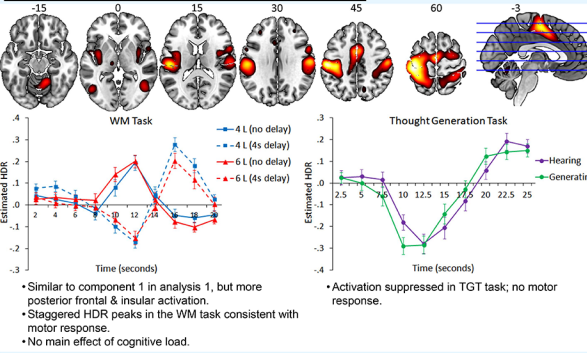


#### Component 3 – default-mode network<sup>3</sup>

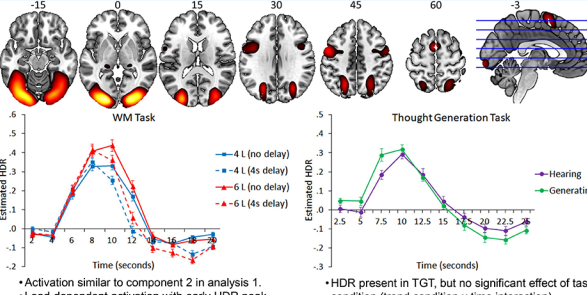


### ANALYSIS 2: WM TASK + TGT

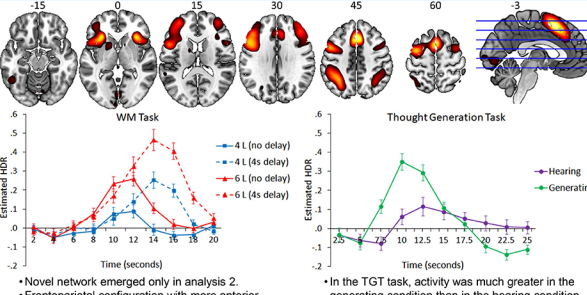
#### Component 1 – motor response\*\*



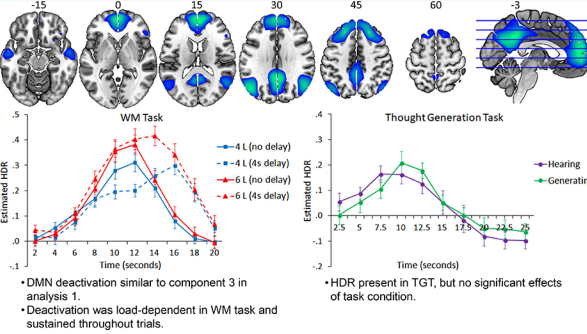
#### Component 2 – visual attention



#### Component 3 – internal attention\*\*



#### Component 4 – default-mode network<sup>3</sup>



## SUMMARY

#### Analysis 1 (WM task only):

- 3 components extracted.
- 1. Response/attention:** somatomotor activation & staggered HDR peaks suggest motor response, but dependence on cognitive load suggests role in cognition/attention as well. **\*\* May reflect merging of components 1 & 3 from analysis 2.**
- 2. Visual attention:** load-dependent visual activity with early HDR peak (encoding phase); effects cannot be explained by basic visual perception.
- 3. DMN deactivation:** load-dependent deactivation, sustained throughout trials; typical pattern thought to reflect suppression of resting processes during tasks.

#### Analysis 2 (WM task + TGT):

- 7 components extracted; only 1-4 were meaningful for WM analysis.
- 1. Motor response:** only engaged during WM task; similar to component 1 in analysis 1. **\*\* More clearly related to motor responses rather than attention.**
- 2. Visual attention:** similar to component 2 in analysis 1.
- 3. Internal attention:** underlies maintenance (WM task) and volitional thought generation (TGT). **\*\* Not identified in analysis 1; BOLD signal may have blurred with motor response.**
- 4. DMN deactivation:** similar to component 3 in analysis 1.

## CONCLUSIONS

- At least three frontoparietal networks are engaged during the WM task, underlying motor response processes, visual attention, and internal attention.
- The results provide a biological basis for cognitive models of WM/attention, whereby sequential activations of the visual attention and internal attention networks reflect a shift from attention to external visual stimuli (encoding) to internal mental representations of stimuli (maintenance).
- The multi-experiment approach extends previous analyses of WM by allowing the examination of spatial and temporal replication of more finely parcellated networks across different types of task demands.

## REFERENCES

- Lavigne KM, et al. (2015) left-dominant temporal-frontal hypercoupling in schizophrenia patients with hallucinations during speech perception. *Schiz Bull*, 41, 259-67.
- Metzak PD, et al. (2011) Constrained principal component analysis reveals functionally connected load-dependent networks involved in multiple stages of working memory. *Hum Brain Mapp*, 32, 856-71.
- Buckner RL, et al. (2008) The brain's default network: Anatomy, function, and relevance to disease. *Ann N Y Acad Sci*, 1124, 1-38.

## ACKNOWLEDGEMENT

This work was supported by graduate studentships from UBC and BCCRI.