

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

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#### 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
- 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.

- · 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)

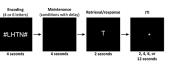
	Working Memory Task (n = 37)	Thought Generation Task (n = 32)
Mean age	28.16 (8.70)	28.75 (8.58)
Mean years of education	15.86 (2.16)	15.58 (1.81)
Mean estimated IQ <sup>a</sup>	99.59 (11.89)	97.09 (11.21)
Sex distribution	10 males; 27 females	19 males; 13 females
Handedness (R/L/mixed)	32/3/2	29/3/0

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

#### **Materials**

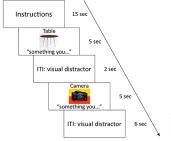
#### Working Memory Task (WM)

- 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).
- · Cognitive load: 4 letters vs. 6 letters to
- Delay: 4-second delay vs. no delay period.



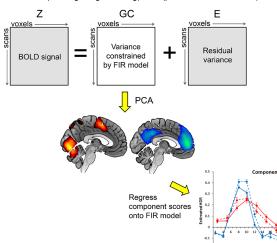
## Thought-Generation Task (TGT)<sup>1</sup>

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



#### **Functional Connectivity Analysis**

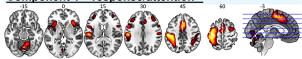
- · Task-state networks extracted using fMRI-constrained principal component analysis (fMRI-CPCA; see figure below).2
  - · Analysis 1: WM data only.
  - · Analysis 2: WM data and TGT data combined.
- Analysis of hemodynamic response (HDR) performed using repeated measures analysis of variance (ANOVA):
- 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)

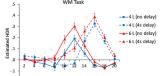


#### RESULTS

#### **ANALYSIS 1: WM TASK ONLY**

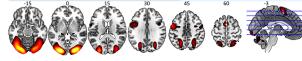
#### Component 1 - response/attention\*\*

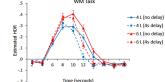




- Activation primarily in somatomotor cortex (left-lateralized), anterior insula, supplementary motor area (SMA), dorsal anterior cingulate & other
- Staggered HDR peaks consistent with
- Main effect of cognitive load (6 letters > 4 letters)

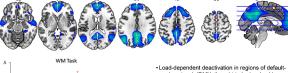
### Component 2 - visual attention

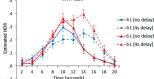




- Activation primarily in visual cortex (extending dorsally into parietal regions), SMA, precentral gyrus, and thalamus. HDR peaks relatively early (encoding phase)
- Activation was load-dependent (6 letters > 4 letters) and did not show a second peak after a 4 sec. delay.

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





- Load-dependent deactivation in regions of default-mode network (DMN, thought to be involved in mind-wandering, self-reflection, etc.)<sup>3</sup>. Precuneus/posterior cingulate gyrus, anterior paracingulate gyrus, superior lateral occipital cortex, and middle temporal gyrus.
- ctivation sustained throughout trials.
- Note: greater value on HDR plot reflects greater

#### **SUMMARY**

### Analysis 1 (WM task only):

- 3 components extracted
  - 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.
  - <u>Visual attention</u>: load-dependent visual activity with early HDR peak (encoding phase); effects cannot be explained by basic visual perception.
  - <u>DMN deactivation</u>: load-dependent deactivation, sustained throughout trials; typical pattern thought to reflect suppression of resting processes during tasks.

- 7 components extracted; only 1-4 were meaningful for WM analysis
  - 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.
  - 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.

- · 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.

[1] Lavigne KM, et al. (2015) left-dominant temporal-frontal hypercoupling in schizophrenia patients with hallucinations during speech perception. Schiz Bull, 41, 259-67. [2] Metzak PD, et al. (2011) Constrained principal component analysis reveals functionally connected load-dependent networks involved in multiple stages of working me

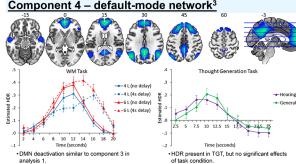
[3] Buckner RL, et al. (2008) The brain's default network: Anatomy, function, and relevance to disease. Ann N Y Acad Sci. 1124, 1-38.

# --- 6 L (no delay) Time (seconds) Similar to component 1 in analysis 1, but more posterior frontal & insular activation. Staggered HDR peaks in the WM task consistent with · Activation suppressed in TGT task; no motor Component 2 – visual attention - = -4 L (4s delay) 6 L (no delay) Activation similar to component 2 in analysis 1. Load-dependent activation with early HDR peak. · HDR present in TGT, but no significant effect of task

ANALYSIS 2: WM TASK + TGT

Component 1 - motor response\*\*

# Component 3 – internal attention\*\* → 6 L (no delay) - 4 - 6 L (4s delay) Novel network emerged only in analysis 2. Frontoparietal configuration with more anterior prefrontal and insula activation than components 1 & 2. Strong activation underlying maintenance in trials with a 4 sec. delay, but modest for trials with no delay. In the TGT task, activity was much greater in the generating condition than in the hearing condition •Activity in both tasks consistent with volitional attention to internal stimuli representations.



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