

# Prefrontal and Hippocampal Contributions to the Generation and Binding of Semantic Associations During Successful Encoding: A Parametric fMRI Study

Donna Rose Addis<sup>1,2</sup> and Mary Pat McAndrews<sup>1,2</sup>

<sup>1</sup>Toronto Western Research Institute, University Health Network, Toronto, Ontario; <sup>2</sup> Department of Psychology, University of Toronto, Toronto, Ontario



## INTRODUCTION

- The ability to form and bind associations between items is crucial to the successful encoding of new memories.
- It has been proposed that the hippocampus is involved in relational processing, binding into memory information about the relations between items<sup>1</sup>.
- Accordingly, this region is active during associative encoding<sup>2</sup>, and hippocampal damage is associated with deficits in this type of encoding<sup>3</sup>.
- Furthermore, regions in the prefrontal cortex (PFC), such as the inferior frontal gyrus (IFG), are thought to support the generation of such associations between items. For instance, left PFC is known to contribute to deep (vs. shallow) encoding<sup>4</sup>, and PFC dysfunction may underlie encoding deficits, for example, in aging<sup>5</sup>.
- The aim of the present fMRI study was to investigate the parametric responses of these regions to varying amounts of generative and relational processing during successful encoding.
- We presented word triads varying in the number of semantic associations between words<sup>6</sup>
  - Triads with fewer associations had higher *generative* load (i.e., associations had to be generated by the participant).
  - Triads with more associations had higher *relational* load (i.e., the relations presented had to be bound into memory).
- We had two hypotheses:
  1. Higher levels of *generative* load would be associated with greater levels of activation in *prefrontal* regions, including the IFG.
  2. Higher levels of *relational* load would be associated with greater levels of *hippocampal* activation, particularly on the left (LHC) due to the verbal nature of the task.

## METHODS

### Participants

- 12 young adults aged 21 – 30 years (5 male and 7 female)

### Scanning Protocol

- **Encoding Task:**
  - **Stimuli:** 105 word triads consisting of category name and two exemplars
  - Varied level of semantic relatedness: how many exemplars linked to category

0 – LINK	1 – LINK
TOYS Lily Wool	GAMES Jewish Chess

2 – LINK
BEVERAGES Beer Milk

- **Response:** Indicate how many associations within the triad (i.e., how many exemplars fit into the category)
- **Fixation Cross**

### Control task:

- **Stimuli:** Word triads consisting of a number word (zero, one, two) e.g.,

ZERO zero zero
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- **Response:** Respond with same number
- **Fixation cross**
- 3 Runs of 46 trials (control, 0, 1, 2 link)
- Trial lengths averaged 12 s
  - **Triad presentation & response:** 6 sec
  - **Fixation:** jittered between 4 & 8 s; avg 6 s.

### Post-scan Forced-Choice Recognition

- Two triads shown: OLD triad and NEW triad (with one new exemplar).
- Task: Identify OLD triad.
- Only subsequently recognized triads analyzed

BEVERAGES Beer Tea
BEVERAGES Beer Milk

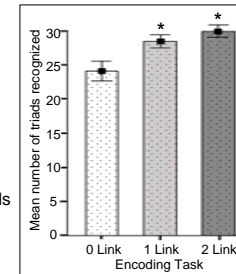
### Analyses

- All pre-processing and analysis: SPM2
- Contrasts: *Successful* encoding vs. control task
- Parametric Modulation:
  - (1) Increasing *generative* load (fewer links in triad)
  - (2) Increasing *relational* load (more links in triad)
- ROI analyses: IFG and LHC

## RESULTS

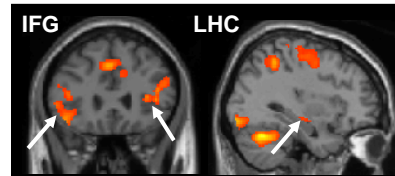
### Behavioural results

- Significant effect of semantic relatedness on number of correctly recognized triads ( $p = .002$ ):
  - increased recognition accuracy in 1 & 2 link triads relative to 0 link triads



### Successful Encoding

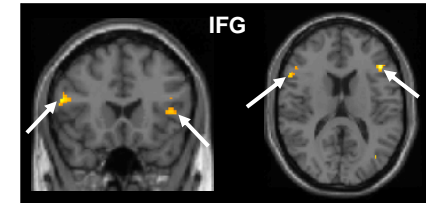
- Contrast of encoding trials of subsequently recognized triads with control tasks: IFG (BA 44/45/46) and LHC ( $p < .05$ , corr)



- Other activated regions: bilateral ACC, thalamus, fusiform; L middle & inferior occipital gyrus; and R middle frontal gyrus

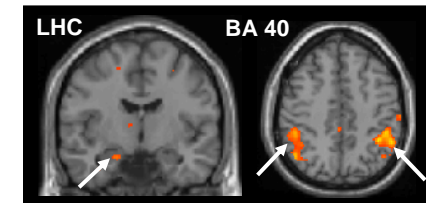
### Parametric Modulation of Generative Load

- Increasing Generative Load (i.e., triads with fewer links) resulted in increasing levels of activity in bilateral IFG ( $p < .001$ , uncorrected)



### Parametric Modulation of Relational Load

- Increasing Relational Load (i.e., triads with more links) resulted in increasing levels of activity in the anterior LHC and bilateral inferior parietal lobule (BA 40) ( $p < .001$ , uncorrected)



## Conclusions

- Both LHC and IFG regions were active during trials of successful semantic associative encoding.
- Bilateral IFG was modulated by the generative load of the encoding task in that greater activity was seen when fewer semantic links were provided.
- The anterior LHC was modulated by the relational load of encoding, as when there were more links in the triads, hippocampal activity was greater.
- The ability to isolate the IFG and hippocampal contributions to the generative and relational aspects of associative encoding with this task enable predictions about the impact of selective dysfunction in these regions on the formation of new associations in memory.

## REFERENCES

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