Neural Correlates of Semantic Plausibility in Sentence Comprehension in High and Low Working Memory Groups

Neal Pearlmutter[1], Louise Stanczak[2], David Caplan[3], Gloria Waters[2]
1 Northeastern University, 2 Boston University, 3 Massachusetts General Hospital

Introduction

Although adults process novel semantic combinations frequently and with great efficiency, word combinations that are implausible based on prior semantic knowledge are more difficult to process. Sentence processing time increases as word combinations within a sentence are rated with greater implausibility (Rayner et al., 2004).

Neuroimaging studies have found a bilateral fronto-temporal network of activation when sentences with implausible words have been compared to sentences with plausible words, with greater activation in the left hemisphere (e.g., Kiel, Laurens, & Liddle, 2002; Kuperberg et al., 2003). These studies have used an overt plausibility judgment task.

Working memory studies have suggested that high span subjects are more sensitive to linguistic cues for semantic processing (e.g., Gunter, Wagner, & Friederici, 2003) and syntactic processing (e.g., Pearlmutter & MacDonald, 1995). Here, we investigate whether these differences persist when processing involves novel semantic combinations for which prior linguistic experience is unavailable.

In sum, this study investigates the neural correlates of sentence processing using implausible word combinations:

1. as a function of the strength of context association via plausibility ratings.

2. as a function of working memory capacity.

3. in more natural paradigm that does not require overt plausibility judgments.

Methods

Participants: 8 high and 8 low working memory span healthy adults

Task: Sentences were presented one word at a time (RSVP = 300 msec) followed by a comprehension question. 80 sentence triplets were presented (total = 240 sentences).

Stimuli:

Plausible: Mary vacuumed the carpet and later washed the kitchen floors.

Implausible: Mary vacuumed the computer and later washed the kitchen floors.

Anomalous: Mary vacuumed the idea and later washed the kitchen floors.

Comprehension Question: Was Mary cleaning? (Y)

fMRI Data Acquisition: 3T Allegra scanner

8 functional runs consisted of 30 slices along the AC-PC plane collected from an RF head coil (TR = 2 sec, TE = 30 msec, in-plane resolution = 3.1 mm, slice thickness = 3 mm, FOV = 200 mm).

Data analysis was conducted in FSFast (Massachusetts General Hospital). Activation time-locked to the critical word was averaged separately from activation time-locked to the comprehension question.

SPMs were computed with a random effects model (p<.05). Clusters reported individually exceed a cluster-threshold of p<.05 with a cluster-size of 200 mm^2.
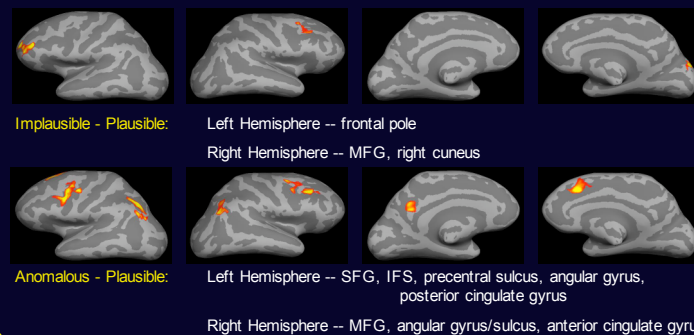
fMRI Results: Time-Locked to Critical Word

No significant working memory span differences were found in the random effect analysis or the ROI analyses.

Implausible - Plausible

Anomalous - Plausible

Anomalous - Implausible
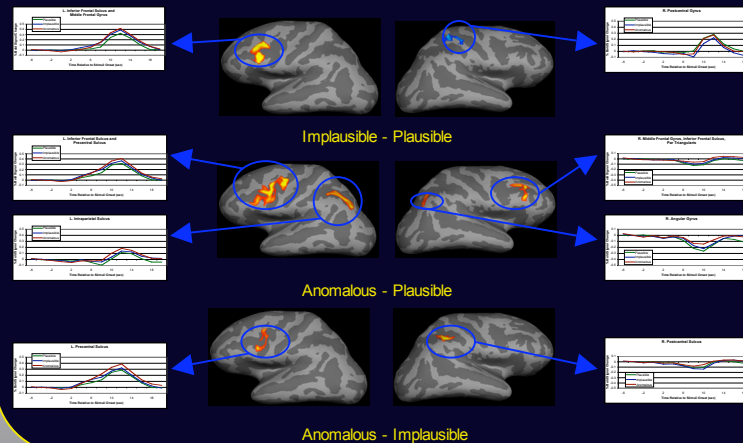
fMRI Results: Time-Locked to Comprehension Question

No significant working memory span differences were found.
No significant differences between Anomalous and Implausible sentences.

Implausible - Plausible: Left Hemisphere -- frontal pole

Right Hemisphere -- MFG, right cuneus

Anomalous - Plausible: Left Hemisphere -- SFG, IFS, precentral sulcus, angular gyrus, posterior cingulate gyrus

Right Hemisphere -- MFG, angular gyrus/sulcus, anterior cingulate gyrus

Behavioral Results

No significant differences in working memory groups were present. Anomalous sentences had significantly longer response times than Implausible or Plausible sentences, which did not significantly differ from each other.

	High Span			Low Span		
	P	I	A	P	I	A
RT (msec)	1911	1958	2021	2095	2104	2156
% Correct	90	90	91	93	91	88

Discussion

Activation time-locked to the critical word demonstrated significant effects in all comparisons, while activation time-locked to the comprehension question did not show differential activation between Anomalous and Implausible sentences. Therefore, activation time-locked to the critical word was more sensitive to implausibility. Both time intervals demonstrated a bilateral frontal-parietal network reflecting sentence processing with implausible word combinations.

Activation time-locked to the comprehension question demonstrated additional activation in the cingulate likely due to the additional demands of decision-making.

Novel word combinations produced a positive increase in activation in the left hemisphere and a negative increase in activation in the right hemisphere.

Working memory span had no effect on semantic processing during novel semantic combinations.

Conclusions

1. Neural activation was sensitive to plausibility ratings. A bilateral fronto-parietal network with laterality differences reflected processing of novel semantic information.

2. Working memory span differences in processing semantic knowledge may only emerge when previous linguistic knowledge can aid in processing. No working memory differences were found when novel semantic combinations were presented in sentences.

3. Neural activation was sensitive to plausibility ratings without overt plausibility judgments using a more natural comprehension question task.

References

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