

BOLD signal correlates of Semantic Plausibility as a function of Working Memory and Task Demand

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Introduction

Previous neuroimaging research has found that sentence comprehension is affected by plausibility, such that implausible sentences have greater BOLD signal than plausible sentences (e.g., Kuperberg et., 2003).

We investigated how plausibility affects sentence comprehension, as measured by BOLD signal, by varying the following:

1. degree of plausibility
2. working memory capacity
3. task demands

Method

Subjects for Experiments 1 and 2

8 high and 8 low working memory capacity subjects age 18-30 were recruited for each experiment. Three subjects were eliminated from Experiment 2 (2 low, 1 high).

Working memory capacity was determined by Reading Span, Subtract 2 Span, and Alphabet Span scores.

Stimuli for Experiments 1 and 2

Subjects saw 240 sentences using RSVP, one from each triplet below:

- 80 Plausible:** 6.4/7 average plausibility rating
Vanessa threw the javelin but did not win the competition.
- 80 Implausible:** 3.9/7 average plausibility rating
Vanessa threw the feather but did not win the competition.
- 80 Anomalous:** 1.7/7 average plausibility rating
Vanessa threw the situation but did not win the competition.

Task for Experiments 1 and 2

Experiment 1 Task: Yes/No Comprehension question

Was the throw good enough to win?

Experiment 2 Task: Plausibility judgment

1 = Plausible, 2 = Implausible, 3 = Anomalous

Data Acquisition for Experiments 1 and 2

3T Allegra scanner at Massachusetts General Hospital

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 FSL (Massachusetts General Hospital). SPMs were computed with a random effects model ($p < .05$). Clusters reported individually exceeded a cluster-threshold of $p < .05$ with a cluster-size of 300 mm².

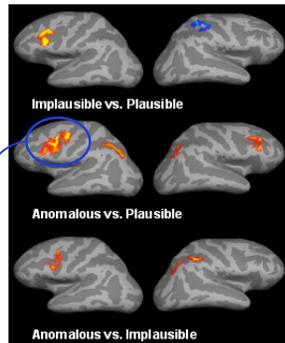
Exp 1 Results

Behavioral: 2 (WM) x 3 (Plausibility) ANOVAs

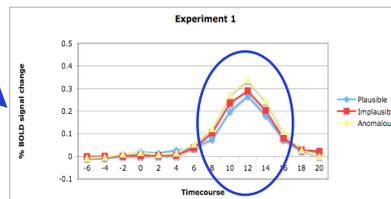
RTs from answering comprehension questions produced a main effect of plausibility, such that Anomalous sentences had longer RTs than either Implausible or Plausible sentences. No working memory effects or interactions were found.

Subjects were about 90% accurate in all three conditions. Comprehension questions never probed the plausibility information in the first clause.

Neuroimaging Results: all responses included



Change in BOLD signal increased as plausibility decreased, that is BOLD signal change was greatest for Anomalous sentences. The left frontal region is the only area that is sensitive to differences in plausibility across all three contrasts. No interactions with working memory were found.



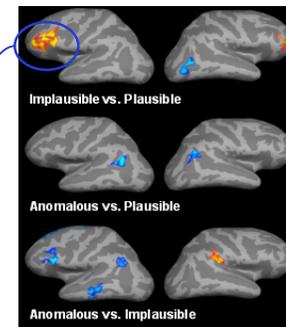
Exp 2 Results

Behavioral: 2 (WM) x 3 (Plausibility) ANOVAs

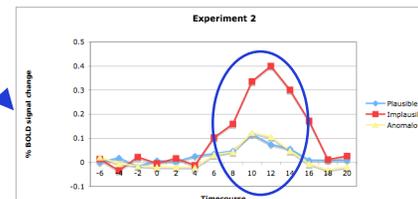
RTs from plausibility judgments produced a main effect of plausibility, such that Implausible sentences had longer RTs than either Anomalous or Plausible sentences. No working memory effects or interactions were found.

Subjects were 90% accurate at identifying Plausible sentences, 80% accurate at Anomalous sentences, and 36% accurate at Implausible sentences.

Neuroimaging Results: correct responses



Change in BOLD signal was greatest for the Implausible sentences, which were the most difficult to categorize. The left frontal region is the only area that is sensitive to differences between Implausible sentences and the other two conditions. No interactions with working memory were found.



Discussion

Our results suggest that BOLD signal is sensitive to differences in plausibility. Significant clusters were found in all three paired contrasts in both experiments.

No significant interactions with working memory were found in the behavioral or neuroimaging data in either Experiment 1 or 2. These results may indicate that working memory resources are independent of processing plausibility information (Caplan & Waters, 1999; Pearlmuter & MacDonald, 1995)

Task demands interacted with plausibility. For the comprehension task in Experiment 1, plausibility ratings correlated with task difficulty, such that as plausibility decreased, task difficulty increased. Anomalous sentences were the most difficult to comprehend, yielding the largest BOLD signal changes. For the plausibility judgment task in Experiment 2, plausibility ratings did not correlate with task difficulty, as the intermediate level of plausibility was the most difficult to categorize and yielded the largest BOLD signal changes. The interaction of task demand and plausibility would not have been revealed using only two levels of plausibility.

Conclusion

The left frontal region was activated most consistently across contrasts and experiments. It was also sensitive to the interaction between plausibility and task demands, indicating that this region may be sensitive to the way plausibility information is used for task completion.

References

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- Kuperberg G. et al. (2003). *Journal of Cognitive Neuroscience*, 12, 321-341.
- Pearlmutter, N. & MacDonald, M. (1995). *Journal of Memory and Language*, 34, 521-542.

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