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An Event-Related fMRI Study of Competition in Selecting among Semantically Ambiguous Word Meanings

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INTRODUCTION

Recent neuroimaging studies have argued that the left inferior frontal gyrus (IFG) is involved in selecting among competing semantic alternatives (Thompson-Schill et al., 1997). As previous studies have employed explicit tasks in which subjects are aware of the dimension along which the stimuli are competing, the extent to which the neural activation patterns are driven by the task versus competition remains unclear. The present study investigated the neural correlates of competition in selecting among meanings of semantically ambiguous words (e.g., *toast: bread/honor*) using an implicit task.

The following prediction was tested:

Competition Effect

If competition demands greater neural resources, increased neural activation should be observed in the left IFG when competing meanings of an ambiguous word appear in the same stimulus array.

METHODS

Participants

15 right-handed native English speakers (8 female, mean age = 22)

Materials

35 homonyms

Target consistent with subordinate (i.e., less-preferred) meaning

CONCORDANT
⇨ **NO COMPETITION**

DISCORDANT
⇨ **COMPETITION**

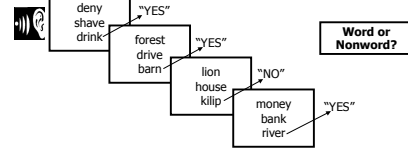
NEUTRAL
⇨ **BASELINE**

Condition	Example		
	Prime	Homonym	Target
Concordant	honor	toast	drink
Discordant	butter	toast	drink
Neutral	descend	toast	drink
Unrelated	deny	shave	drink

Task

Lexical (word/nonword) decision on third stimulus of auditorily presented triplets
100 ms inter-stimulus interval (ISI) between stimuli in a trial

Event-Related fMRI Paradigm



fMRI Data Acquisition

Siemens Symphony 1.5T scanner

5 functional runs: 495 vols (45 axial slices/vol, 3 mm thick, 3 x 3 x 3 mm, TR = 3.62 sec)

Trials from 4 conditions randomly intermixed in rapid event-related fMRI design

fMRI Data Analysis

Statistical analyses conducted using AFNI

Contrasts: CON-DIS, CON-NEUT, CON-UNREL, DIS-NEUT, DIS-UNREL, NEUT-UNREL
Data thresholded at voxel level $p < .025$, cluster level $p < .05$ (≥ 51 contiguous voxels)

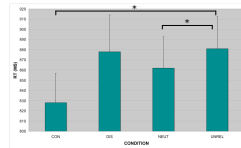
RESULTS: BEHAVIORAL

Competition Effect

RT in discordant condition = RT in unrelated condition

Semantic Priming Effect

RT in concordant and neutral conditions < RT in unrelated condition

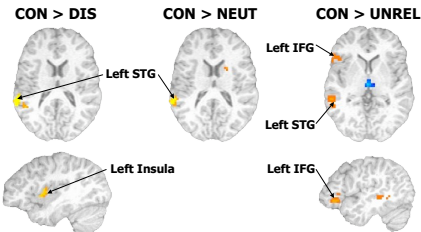


Behavioral findings are as in previous studies (Hagoort, 1993; Milberg et al., 1987).

Lack of priming in the discordant condition, with a 100 ms ISI, is due to a garden-path effect that occurs when switching from the preferred to less-preferred meaning.

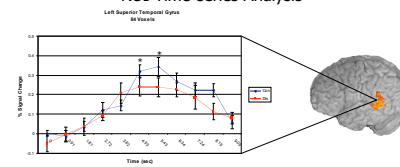
In discordant conditions, some previous studies have found weak priming when ambiguous words are resolved toward the subordinate (i.e., less-preferred) meaning and robust priming when ambiguous words are resolved toward the dominant (i.e., preferred) meaning (Titone & Salisbury, 2004).

RESULTS: FMRI



Contrary to predictions, the discordant condition produced significantly **less** activation than the concordant condition in frontal as well as temporal areas, specifically the left insula and superior temporal gyrus (STG). Interestingly, the concordant condition produced greater activation than all other conditions in both frontal and temporal language areas, including the left insula, IFG and STG.

ROI Time-series Analysis



In the left STG, significant differences were found in the peak of activation (between 3.6 and 6.3 sec post-stimulus) of the concordant and discordant conditions. Increased activation in the concordant condition begins to emerge at 4.5 sec post-stimulus. For the discordant condition, activation appears to plateau between 3.6 and 6.3 sec, which may reflect the difficulty in maintaining the multiple competing meanings of an ambiguous word.

CONCLUSION

Role of Left IFG in Resolving Semantic Competition

Lack of competition effects in the left IFG could be due to:

1. Task

The present task did not require a decision about the meanings of ambiguous words. The left IFG may only be recruited when the task requires semantics (or other stimulus-relevant properties) to be evaluated.

2. Context

The minimal word context did not require selection of a particular meaning. The left IFG may be implicated when a biasing sentence context requires selection of an appropriate meaning.

3. Time-course

The time-course examined (i.e., 100 ms ISI) was too brief to capture context-based selection (and integration) of meaning. The left IFG may be invoked later in the comprehension process (i.e., at longer ISIs).

Data from Broca's aphasics, who have damage to left anterior structures including the left IFG, suggest that both context and time-course are critical factors. Broca's aphasics show aberrant priming later in the comprehension process (>500 ms ISIs; Hagoort, 1993; Milberg et al., 1987) and when resolving competition in sentence contexts (Grindrod & Baum, 2003).

Role of Left STG in Summation Priming

Findings provide further support that the left STG is involved in semantic processing. Increased neural activation in the concordant condition may reflect summation within the semantic system. Data from aphasic patients support the view that summation priming may be mediated by posterior structures. Milberg et al. (2003) showed that Broca's aphasics exhibit overadditive summation priming relative to normals, whereas Wernicke's aphasics, who have damage to left posterior temporal and parietal structures, exhibit no summation priming at a 200 ms ISI.

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