Cortical Representation of Verb Processing in Sentence Comprehension: Number of Complements, Subcategorization, and Thematic Frames

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Introduction

“Verbs play a key role in sentence production and comprehension because they specify the relations among words in a sentence. It is well accepted that some crucial aspects of sentence processing are determined by the semantic and syntactic attributes of the verbs that appear in the sentence […] , but it is still undetermined which of these are available and accessed online.”
Introduction

What “semantic and syntactic attributes of the verbs” are under investigation?

• Number of complements
Introduction

Number of Complements:

- No complement: John smiled (intransitive)
- One complement: John lost the keys (transitive)
- Two complements: John gave Anna a present (ditransitive)
Introduction

What “semantic and syntactic attributes of the verbs” are under investigation?

• Number of complements

• Number of subcategorization options
Introduction

Number of Subcategorization Options:

- One option:
  - John lost \{the keys\}_NP
  - Mary depends \{on the spell checker\}_PP

- Two options:
  - John discovered \{the story\}_NP
  - John discovered \{that the story is real\}_CP

- Three options:
  - John demanded \{the book\}_NP
  - John demanded \{to read the book\}_IP
  - John demanded \{that someone will read the book\}_CP
Introduction

What “semantic and syntactic attributes of the verbs” are under investigation?

• Number of complements

• Number of subcategorization options

• Number of thematic options
Introduction

Number of Thematic Options:

- One option:
  - $\langle John \rangle_{agent}$ lost $\langle the \ keys \rangle_{theme}$

- Two options:
  - $\langle John \rangle_{agent}$ discovered $\langle the \ story \rangle_{theme}$
  - $\langle John \rangle_{agent}$ discovered $\langle that \ the \ story \ is \ real \rangle_{proposition}$

- Three options:
  - $\langle John \rangle_{agent}$ demanded $\langle the \ book \rangle_{theme}$
  - $\langle John \rangle_{agent}$ demanded $\langle to \ read \ the \ book \rangle_{event}$
  - $\langle John \rangle_{agent}$ demanded $\langle that \ someone \ will \ read \ the \ book \rangle_{proposition}$
Introduction

“Mismatch” Verbs:

Thematic Frames:

\(<John>_{agent} \text{ tasted } <\text{the soup}>_{theme}\)
\(<John>_{agent} \text{ tasted } <\text{from the soup}>_{theme}\)

Subcategorization Frames:

\(\text{John tasted } \{\text{the soup}\}_{NP}\)
\(\text{John tasted } \{\text{from the soup}\}_{PP}\)
“All the above attributes—number of complements, subcategorization options, and thematic options—are assumed to be represented in the verb’s lexical entry. Yet, it is still unclear how crucial each of them is for sentence processing, which of them is accessed online, and what the related neural activations are.”
“Our key methodological assumption was that neural involvement would be specific to the investigated attribute if it reflected not only in simple contrasts between experimental conditions but also more strongly in a correlation between levels of activation and the number of complements or options. We refer to this correlation as ‘a graded pattern of activation.’ ”
Experiment 1

“The focus of this experiment was to identify brain regions that were sensitive to the number of complements. We did so by comparing verbs that took 0, 1, or 2 complements, presented in sentential context. This created a 3-point scale of the examined attribute. The number of subcategorization and thematic options was kept constant across conditions.”
Experiment 1 - Method

The Stimuli:

• 28 different Hebrew verbs, 7 in each category:

<table>
<thead>
<tr>
<th>Condition</th>
<th>Example for a sentence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unergatives</td>
<td>Dana shara [etmol] [b-a-miklaxat]</td>
</tr>
<tr>
<td></td>
<td>Dana sang [yesterday]_adjunct [in the shower]_adjunct</td>
</tr>
<tr>
<td>Transitives</td>
<td>Ron shavar [et ha-kos] [b-a-xatuna]</td>
</tr>
<tr>
<td></td>
<td>Ron broke [the glass]_theme [in the wedding]_adjunct</td>
</tr>
<tr>
<td></td>
<td>Keren sama [et ha-xulcot] [b-a-aron]</td>
</tr>
<tr>
<td></td>
<td>Keren put [the shirts]_theme [in the closet]_goal</td>
</tr>
<tr>
<td>Ditransitives</td>
<td></td>
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<td></td>
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</tbody>
</table>

Experiment 1 - Method

The Stimuli:

• Each verb appeared in 4 different sentences

• In each sentence, the verb was preceded by a person name and followed by two constituents:

  • Unergatives: two adjuncts or modifiers

  • Transitives: one complement and one adjunct or modifier

  • Ditransitives: two complements
Experiment 1 - Method

The Design:

- A block design: 28 blocks, each with four sentences of the same condition.

- The blocks and the sentences in each block were presented in a pseudorandom order.

- Sentences within a block were separated by silence periods of 1300 ms.

- Blocks were separated by silence periods of 6 or 9 seconds.
Experiment 1 - Method

The Task:

– The subjects were asked to decide whether the event described in the sentence is more likely to happen at home or not.

– Subjects were requested to press a “yes” or a “no” button with their left hand fingers after the end of the sentence.

– Responses were given during the intrablock silences.
Experiment 1 - Results

Figure 2. Graded activation clusters found in Experiment 1: right precuneus and right anterior cingulate.
“The second experiment manipulated the number of options of both subcategorization and thematic frames. Here, we compared sentences that included verbs of 1, 2, and 3 options where nonfinite clauses stood as a different semantic and syntactic category than finite clauses. [...] This created a 3-point scale for both subcategorization and thematic options.”
Experiment 2 - Method

The Stimuli:

- 28 different Hebrew verbs, 7 in each category:

<table>
<thead>
<tr>
<th>Condition</th>
<th>Example for a sentence</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-option verbs</td>
<td>Dan hidlik [esh] [b-a-kirayim]</td>
</tr>
<tr>
<td></td>
<td>Dan lit [fire]_theme [in-the-stove]_adjunct</td>
</tr>
<tr>
<td>2-option verbs</td>
<td>Gal syima [et ha-sefer] [b-a-xacot]</td>
</tr>
<tr>
<td></td>
<td>Gal finished [the-book]_theme [in-the-midnight]_adjunct</td>
</tr>
<tr>
<td>3-option verbs</td>
<td>Sara nista [et ha-kova] [b-a-xanut]</td>
</tr>
<tr>
<td></td>
<td>Sara tried [the-hat]_theme [in-the-shop]_adjunct</td>
</tr>
<tr>
<td>Subcat-thematic mismatch verbs</td>
<td>Avi lagam [mic] [b-a-mita]</td>
</tr>
<tr>
<td></td>
<td>Avi sipped [juice]_theme [in-the-bed]_adjunct</td>
</tr>
</tbody>
</table>
Figure 3. Graded activation clusters found in Experiment 2: left STG and left IFG (both BA 47 and BA 9).
Discussion

“The main finding was that whereas increasing the number of subcategorization and thematic options yielded graded activation in language areas, increasing the number of complements did not. Our results also bear on open questions in linguistics with respect to the representation of subcategorization and the separate representation of finite and nonfinite clause complements.”
Discussion