When effects appear before cause: An ERP study

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The sequence in which causally related events unfold during language comprehension does not necessarily mirror the sequence with which they unfold in the real world. Sometimes comprehenders receive explicit cues (e.g., discourse connectives) telling them whether to expect a canonical or non-canonical event sequence. Here we focused on the use of causal discourse connectives that either cue a forward canonical event sequence ("and so") or a backward non-canonical event sequence ("because"). We used ERPs to ask how these connectives influence (a) load on working memory (indexed by a frontally-distributed sustained negativity) and (b) semantic facilitation (indexed by the centro-parietally-distributed N400) during word-by-word comprehension.

**Results:**

This effect remained significant on the subsequent words at frontal sites ($p < 0.001$). Magnitude of N400 effect was smaller on predictable/coherent than unpredictable/incoherent critical words ($p < 0.001$). Magnitude of N400 effect was not influenced by the nature of the connective (no interaction between Predictability/Coherence and Connective Type).

**Conclusion:**

(1) Both the type of causal connectives (cueing non-canonical vs canonical event sequences) and the presence or absence of causal connectives, influence the WM load incurred during word-by-word comprehension. BUT

(2) Neither of these factors influence the degree to which readers draw upon their stored real-world knowledge about causal relationships across events to anticipate upcoming events, thereby facilitating semantic processing of incoming words.

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**Experiment 1**

**Methods:**

<table>
<thead>
<tr>
<th>Connective Type</th>
<th>Forward (and so)</th>
<th>Backward (because)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Predictability</td>
<td>Predictable</td>
<td>Unpredictable</td>
</tr>
<tr>
<td>Presence</td>
<td>45 scenarios per condition</td>
<td>45 non-causal filler sentences per list</td>
</tr>
</tbody>
</table>

- Coherence judgment task
- 32 participants

**Results:**

ERPs on connective: "because" evoked a larger widespread negativity than "and so" ($p < 0.03$). This effect remained significant on the subsequent words at frontal sites ($p < 0.05$).

- An increased WM load as comprehenders prepared to process the second clause following the backward (vs. forward) connective.
- This suggest that "because" cued comprehenders to predict a non-canonical event sequence, which led them to retain the event representation of the first clause within WM in order to integrate it with event representation of the second clause as it unfolded in real time.

ERPs on critical word: Smaller N400 on predictable/coherent than unpredictable/incoherent critical words ($p < 0.001$). Magnitude of N400 effect was not influenced by the nature of the connective (no interaction between Predictability/Coherence and Connective Type).

Causal expectations based on canonical sequencing did not influence semantic facilitation of incoming words.

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**Experiment 2**

**Methods:**

<table>
<thead>
<tr>
<th>Connective Type</th>
<th>Forward (canonical)</th>
<th>Backward (non-canonical)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Presence</td>
<td>38 scenarios per condition</td>
<td>(+ an additional condition)</td>
</tr>
<tr>
<td>Coherence judgment task</td>
<td>30 participants</td>
<td></td>
</tr>
</tbody>
</table>

- Predictable CW: The cleaners mopped the floor and it looked very tidy ...
- Unpredictable CW: The cleaners mopped the floor; it looked very slimy ...

**Results:**

ERPs on first word of the second clause: Larger frontal negativity following "because" and following no connectives, relative to following "and so".

This frontal negativity persisted across all the words in the second clause.

- Readers incur a sustained WM load both when they are (a) explicitly cued to predict a non-canonical event sequence (following "because"), and (b) uncertain about the causal or temporal relationship of upcoming events (absence of any connective cue).

ERPs on critical word: No N400 difference in contrasting connective vs. no-connective scenarios.

- The presence/absence of causal connectives did not influence semantic facilitation.

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**Conclusion**

(1) Both the type of causal connectives (cueing non-canonical vs canonical event sequences) and the presence or absence of causal connectives, influence the WM load incurred during word-by-word comprehension. BUT

(2) Neither of these factors influence the degree to which readers draw upon their stored real-world knowledge about causal relationships across events to anticipate upcoming events, thereby facilitating semantic processing of incoming words.

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