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ERP studies of visual and auditory processing of negated sentences

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Introduction

Previous research shows that negation is ignored in initial processing and the event-related potential (ERP) component N400 is insensitive to negation in the presence of semantic priming effects [2-3, 5]. But other evidence has shown that negation can be readily integrated and incongruities in negated sentences can elicit an N400 [6]. Most of this research has focused on negated forms such as not, or any while little is known about prefactually negated words (e.g. unauthorized, unintentional) despite their high frequency of occurrence in human language use [7].

Aim and research questions

- Two ERP experiments in visual and auditory modalities to investigate affirmatives (authorized), negation (unauthorized) and sentential negation (not authorized) in sentential contexts such as example 1:

1) The White House announced that the new Obama biography was authorized/unauthorized/not authorized and the details in the book were correct/wrong in actual fact.

- ERPs time-locked to the critical word (underlined), the congruency of which was determined by the adjective (bold) in the first part of the sentence. We asked the following questions:

**Visual study:**
- Is there a delay in the integration of negated meanings?
- Is prefactual negation processed similar to the negated form or the affirmative form?

**Auditory study:**
- Is auditory presentation of sentences more natural and easier than visual processing?

Summary of findings

**Visual:**
- **Affirmative:** N400-P600: successful detection of incongruities (N400) followed by re-evaluation of content to repair meaning (P600)
- **Sentential negation:** no N400, but a negativity with a longer latency than the typical N400: negation not entirely ignored in processing but negated meaning not fully present in memory either
- **Prefactual negation:** sustained anterior negativity: negated meaning needed to be retrieved from working memory, which was taxing

**Auditory:**
- **Affirmative:** N400-P600
- **Negation:** no N400 but a P600: re-evaluation of content
- **Prefactual negation:** late positivity (P600): re-evaluation of content

Conclusions

- Negated sentences were not ignored in early processing [unlike 2-3, 5], nor were they processed the same way as affirmative sentences [unlike 6].
- We found evidence for a more nuanced processing of negation suggesting that incongruities in negated sentences involved different processing mechanisms than those in affirmative sentences.
- Prefactual negation was the most difficult form to process in both studies, hence was not likely to be processed the same way as affirmative forms.
- Auditory processing of negated sentences was easier (clearer ERP effects) than word-by-word visual processing.

Results

<table>
<thead>
<tr>
<th>Affirmative</th>
<th>Sentential negation</th>
<th>Prefactual negation</th>
</tr>
</thead>
<tbody>
<tr>
<td>The White House announced that the new Obama biography was authorized/unauthorized/not authorized and the details in the book were correct/wrong in actual fact.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Visual</th>
<th>Auditory</th>
</tr>
</thead>
<tbody>
<tr>
<td>The White House announced that the new Obama biography was authorized/unauthorized and the details in the book were correct/wrong in actual fact.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ERP components</th>
<th>Congruent</th>
<th>Incongruent</th>
</tr>
</thead>
<tbody>
<tr>
<td>N400</td>
<td>1.03 (0.11)</td>
<td>0.58 (0.10)</td>
</tr>
<tr>
<td>P600</td>
<td>2.04 (0.20)</td>
<td>1.14 (0.20)</td>
</tr>
</tbody>
</table>

Note: In the two figures above, the shaded areas indicate all the time windows where a significant difference between the congruent and incongruent conditions in each sentence type was found. For presentation purposes, only parts of the (significant) results are reported where the estimated difference (β) is larger than or equal to 0.5.

Method

**Material**
- 3 pseudo-randomized lists each including 108 (visual) and 102 (auditory) items

**Participants**
- 26 English native speakers (18 F, mean age=29.9)

**Presentation**
- Counter-balanced, 9 and 11 ms before the adjectives and critical words

**Participants**
- 32 English native speakers (21 F, mean age=24.8)

**Procedure**
- 200 ms word presentation
- 200 ms fixation cross (depicted upon button press)
- Question mark to prompt an answer: “Did the sentence make sense, logically?”

**Visual**
- Auditory presentation of sentence one by one
- Fixation cross (participants kept their eyes focused while listening)

**Auditory**
- Fixation cross (participants kept their eyes focused while listening)

**Open questions**
- Prefactual negation more difficult than sentential negation. Why? Unnatural use?
- Early positivity for prefactual negation in auditory study?
- Positive effects in negated sentences in auditory study, P600?
- ERP effects in auditory studies later than those in visual study, unlike previous research?
- Pre-N400 negativity in auditory study (affirmatives), an N250 [1,4,7]

EEG recording and processing
- Offline referenced to average of both mastoids
- Filters of 0.01 and 40 Hz
- ICA for removing eye artifacts
- Epochs of 1000 ms (plus 100 ms baseline)
- Amplitudes for congruent and incongruent conditions analyzed for each negation type and each time-window separately
- Mixed effects modeling, multiple models of various complexity compared, model with lowest AIC reported
- Regions of interest (anterior/posterior) and hemisphere (left/right) added as predictors
- Subject and electrode as random factors

Analysis
- Time-windows for detecting N400, P600, and a late effect [5]:
  - Visual: 300-400, 400-500, 500-700, 800-1000 ms
  - Auditory: 200-400, 400-600, 600-800, 800-1000 ms
- Amplitudes for congruent and incongruent conditions analyzed for each negation type and each time-window separately
- Mixed effects modeling, multiple models of various complexity compared, model with lowest AIC reported
- Regions of interest (anterior/posterior) and hemisphere (left/right) added as predictors
- Subject and electrode as random factors

References


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