Spelling out the N400 integration hypothesis (reminder)

- Semantic anomalies elicit increased N400 amplitudes.

  He spread the warm bread with socks.

- If the amplitudes of the N400 reflect the difficulty of integrating the meaning of a word to the existing semantic representation, then semantic anomaly would have to be one of the factors that affects the process of integration.

  How would that work?

    - The ease of integration would be affected by whether or not the composed meaning describes a plausible state of affairs in the world. In order to evaluate that, you’d of course first first first need to perform the integration.
Spelling out the N400 integration hypothesis (reminder)

- For our ‘happy rock’ example this would mean that forming the intersection of ‘happiness’ and ‘rockness’ would be harder if no or few things are characterized by both of these properties (i.e., fall into the intersection).

John saw the happy rock

John saw an event such that it is a seeing event and it has \( x \) as its Agent and \( y \) as its Theme.

the unique (contextually determined) individual such that it has the property \( X \)

the property of being happy

the property of being a rock

the property of being happy and a rock
Integration of Word Meaning and World Knowledge in Language Comprehension

Peter Hagoort,¹²,₂⁺ Lea Hald,¹ Marcel Bastiaansen,¹ Karl Magnus Petersson¹

Although the sentences that we hear or read have meaning, this does not necessarily mean that they are also true. Relatively little is known about the critical brain structures for, and the relative time course of, establishing the meaning and truth of linguistic expressions. We present electroencephalogram data that show the rapid parallel integration of both semantic and world knowledge during the interpretation of a sentence. Data from functional magnetic resonance imaging revealed that the left inferior prefrontal cortex is involved in the integration of both meaning and world knowledge. Finally, oscillatory brain responses indicate that the brain keeps a record of what makes a sentence hard to interpret,
Stimuli

correct: The Dutch trains are yellow and very crowded.
world knowledge violation: The Dutch trains are white and very crowded.
semantic violation: The Dutch trains are sour and very crowded.
Under the integration hypothesis, what would it mean to get different effects for ‘white’ and ‘sour’?

(Somewhat idealizing:) In both cases there should be no cases in the real world of Dutch trains carrying the target property (sour or white).

So if N400 amplitude is modulated by how well the sentence meaning maps onto how things are in the world, both should elicit similar effects.

However, if the effort of integration is further modulated by our knowledge of what could be true under (some set of) standard assumptions about how the world works, then maybe the sour cases might pattern differently.
Main result: identical N400 effects for the two violations

- correct:
  - world knowledge violation: The Dutch trains are yellow and very crowded.
  - semantic violation: The Dutch trains are sour and very crowded.
Under the integration hypothesis, what would it mean to get different effects for ‘white’ and ‘sour’?

- (Somewhat idealizing:) In both cases there should be no cases in the real world of Dutch trains carrying the target property (sour or white).
- So if N400 amplitude is modulated by how well the sentence meaning maps onto how things are in the world, both should elicit similar effects.
- However, if the effort of integration is further modulated by our knowledge of what could be true under (some set of) standard assumptions about how the world works, then maybe the sour cases might pattern differently.
Conclusion

“While reading a sentence, the brain retrieves and integrates word meanings and world knowledge at the same time ... 

... it does not take longer to discover that a sentence is untrue than to detect that it is semantically anomalous.”
Under the lexical access hypothesis of the N400...

- ... this result is explainable entirely in terms of cloze probability: both white and sour probably have zero probability of occurring in the context below. Therefore neither are primed by the preceding context. ‘Yellow’, on the other hand would be heavily primed.
A prediction of the N400 integration hypothesis

- Any factor that affects the ease of semantic integration should affect N400 amplitudes.
Distinct effects of semantic plausibility and semantic composition in MEG

Liina Pylkkänen (1, 2), Rodolfo Llinás (3), Brian McElree(1)

(1) Department of Psychology, New York University
(2) Department of Linguistics, New York University
(3) Department of Physiology and Neuroscience, New York University School of Medicine
Complement coercion

The author began reading the book
Complement coercion

The author began the book

Coercion

- Coercion is behaviorally costly in a number of paradigms (McElree et al., 2001; Traxler, Pickering & McElree (2002).
Coercion is costly

• McElree et al. (2001):

Self-paced reading and eye-tracking measures on:

a. The author was *starting the book* in his house... (Coerced)
b. The author was *writing the book* in his house... (Simple, Preferred)
c. The author was *reading the book* in his house... (Simple, Dispreferred)
Not a general difficulty with aspectual verbs + NP


  The boy started the fight after school today. (event verb & event NP)
  The boy saw the fight after school today. (neutral verb & event NP)

  The boy started the puzzle after school today. (event verb & entity NP)
  The boy saw the puzzle after school today. (neutral verb & entity NP)
Not just ambiguity

- Traxler, McElree, Seely & Pickering (submitted):

**Context Sentence**

The student was *reading* all morning.  
* (Relevant Context)

The student was *relaxing* all morning.  
* (Neutral Context)

**Target Sentence**

After a while, he *started a book* about health care…  
* (Coercing Target)

After a while, he *read a book* about health care…  
* (Control Target)

- Coercion cost is not eliminated or even attenuated by lack of ambiguity.
Question

- Can we identify a neural correlate of the coercion cost?
- Does coercion elicit neural activity that is distinct from the N400 generator?

The pizza was too hot to *drink* ← N400
The pizza was too hot to *eat*
What to expect of the N400 in MEG?

- Helenius et al 1998:
  - Classic N400 paradigm in MEG.
  - Source of the N400 localizes where the M350 localizes: in the vicinity of the left auditory cortex.

Materials

Coerced:
the professor began the book before his evening tea

Implausible:
the professor disgusted the book before his evening tea

Control:
the professor read the book before his evening tea

• Control verbs determined by determined by a “fill-in-the-blank” test (*The author began ___ the book*).
• Sentences matched for length and frequency of the verb, and the coerced and control stimuli were matched for rated plausibility.
Materials

Coerced: the professor began the book before his evening tea

Implausible: the professor disgusted the book before his evening tea

Control: the professor read the book before his evening tea

• 70 stimuli per condition
• Word by word presentation
• Sensicality judgment task
• 16 subjects
### Sensicality judgment data

<table>
<thead>
<tr>
<th></th>
<th>RT</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coercion</td>
<td>757</td>
<td>86%</td>
</tr>
<tr>
<td>Control</td>
<td>763</td>
<td>86%</td>
</tr>
<tr>
<td>Anomalous</td>
<td>540</td>
<td>93%</td>
</tr>
</tbody>
</table>

- Sensicality judgments easiest for anomalous stimuli.
- No difference between coerced and control sentences.
All sources

Multi-source modelling
N400 effect
Coercion effect, Anterior Midline Field (AMF)
Where does the AMF come from?

Magnetic field  Minimum norm  Single dipole
Mean AMF dipole inside a standard MRI

![Graph showing AMF dipole inside a standard MRI with red and green lines representing COERCION and NO COERCION respectively.](image-url)
Estimation of current source density at the time of the AMF peak.
Where does the AMF come from?

- Ventromedial prefrontal cortex likely source.
- What do we know about this area?
  - Contains secondary taste cortex & secondary and tertiary olfactory cortices.
  - Involved in controlling and correcting reward-related and punishment related behavior.
  - Decision making.
  - Theory of mind.
  - Not a traditional language area, but has been found to be activated by linguistic stimuli in several previous studies as well (e.g. Halgren et al., 2002; Marinkovic et al., 2003).
  - Potential interface between language and other higher cognitive skills.
Connections to orbitofrontal cortex

- The area receives direct input from:
  - Inferior temporal cortex
  - Superior temporal sulcus
- The AMF follows temporal activity by 20-50ms.
Semantic Operations in Aphasic Comprehension: Implications for the Cortical Organization of Language

Maria Mercedes Piñango

Yale University

and

Edgar B. Zurif

Brandeis University and Aphasia Research Center, Boston University School of Medicine

Published online August 14, 2001
Goal

- To study the localization of coercion operations by studying them in Broca’s and Wernicke’s aphasics.

  - Background assumption: Wernicke’s aphasics have a “semantic” deficit -- therefore would be impaired on coercion.
Two tasks

- Complement coercion
  - Coerced: The boy began the book.
  - Transparent: The boy began reading the book.

- Aspectual coercion
  - Transparent: The horse jumped over the fence yesterday.
  - Coerced: The horse jumped for an hour yesterday.
Results: complement coercion

<table>
<thead>
<tr>
<th>Clinical Diagnosis</th>
<th>Patient</th>
<th>Condition</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Transparent</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Broca’s</td>
<td>HB</td>
<td>24 (96%)</td>
<td>22 (88%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>RD</td>
<td>23 (92%)</td>
<td>20 (80%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>JB</td>
<td>24 (96%)</td>
<td>24 (96%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>23.66 (94.6%)</td>
<td>22 (88%)</td>
<td></td>
</tr>
<tr>
<td>Wernicke’s</td>
<td>WN</td>
<td>21 (84%)</td>
<td>17 (68%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CC</td>
<td>25 (100%)</td>
<td>20 (80%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>23 (92%)</td>
<td>18.5 (74%)</td>
<td></td>
</tr>
</tbody>
</table>
## Results: aspectual coercion

<table>
<thead>
<tr>
<th>Clinical Diagnosis</th>
<th>Patient</th>
<th>Transparent</th>
<th>Enriched</th>
</tr>
</thead>
<tbody>
<tr>
<td>Broca’s</td>
<td>JC</td>
<td>14/16 (87.5%)</td>
<td>13/16 (81.2%)</td>
</tr>
<tr>
<td></td>
<td>RD</td>
<td>12/16 (75%)</td>
<td>14/16 (87.5%)</td>
</tr>
<tr>
<td></td>
<td>JB</td>
<td>16/16 (100%)</td>
<td>16/16 (100%)</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>14/16 (87.5%)</td>
<td>14.3/16 (89.3%)</td>
</tr>
<tr>
<td>Wernicke’s</td>
<td>WN</td>
<td>14/16 (87.5%)</td>
<td>9/16 (56.2%)</td>
</tr>
<tr>
<td></td>
<td>JM</td>
<td>12/16 (75%)</td>
<td>8/16 (50%)</td>
</tr>
<tr>
<td></td>
<td>CC</td>
<td>16/16 (100%)</td>
<td>10/16 (62.5%)</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>14/16 (87.5%)</td>
<td>9/16 (56.2%)</td>
</tr>
</tbody>
</table>
Alleged localization of coercion: Wernicke’s area

- But our results indicate a frontal lobe source for coercion. How to reconcile these results?
- Possible answer: Wernicke’s area (roughly) provides the input for coercion. If the input is blocked, coercion is blocked.