

*Multiple influences of semantic memory on sentence processing:
Distinct effects of semantic relatedness on violations
of real-world event/state knowledge and
animacy selection restrictions*

Martin Paczynski, Gina R. Kuperberg

Antoaneta Marinova

Outline:

- Overview
- Background and motivation
 - Semantic relatedness networks
 - Real-world event/state knowledge
 - Selection restrictions on verb arguments
 - Semantic memory-based processing:
 - The P600 and propositional implausibility
- Methods
- Results
- Discussion and open questions
 - N400
 - P600

Overview of the study

Aimed to determine whether semantic relatedness between an incoming word and its preceding context can override expectations based on two types of stored knowledge:

- Real-world knowledge about the specific events and states conveyed by a verb
- The verb's broader selection restrictions on the animacy of its argument.

Related Studies:

- Semantic relatedness networks
- Real-world event/state knowledge
- Selection restrictions on verb arguments
- Semantic memory-based processing:
- The P600 and propositional implausibility

Semantic relatedness networks

- Lexico-semantic processing of one word can be facilitated by a preceding semantically related word (*Meyer & Schvaneveldt, 1971*)
- N400 attenuation is seen to target words that are related to prime words along a variety of semantic dimensions, including category membership (e.g. tulip-ROSE) (*Grose-Fifer & Deacon, 2004*), semantic features (e.g. wig-MOP) (*Deacon et al., 2004*), through an indirectly related mediator (e.g. lion-[tiger]-STRIPES) (*Chwilla et al., 2000, Kreher et al., 2006 and Silva-Pereyra et al., 1999*), and through common schema membership, e.g. scalpel-SURGEON (*Deacon et al., 2004*) or director-bribe-DISMISSAL (*Chwilla & Kolk, 2005*).

Real-world event/state knowledge

- We are faster to detect (*Marslen-Wilson, Brown, & Tyler, 1988*) and read (*Camblin et al., 2007, Rayner et al., 2004 and Warren and McConnell, 2007*) words that are plausible and congruous with our real-world knowledge than words which are incongruous and implausible.
- This type of facilitation also manifests as an attenuation of the N400 (*Bicknell et al., 2010, Ferretti et al., 2007, Filik and Leuthold, 2008, Hagoort et al., 2004, Kuperberg et al., 2003 and van de Meerendonk et al., 2010*).

Selection restrictions on verb arguments

- Distinction between real-world event/state knowledge and selection restrictions (Chomsky, 1965 and Katz and Fodor, 1963)
- It is possible to violate real-world event/state knowledge without violating the broader animacy selection restrictions of a verb.

“In front of the crowd, the guitarist slept”

Semantic memory-based processing

- Evidence that semantic relatedness between a target and its preceding context can lead to facilitated processing of a target, even when it violates more specific real-world event/state expectations set up by the context (Duffy et al., 1989 and Morris, 1994, Experiment 1).
- '*semantic illusion*' - Kolk, Chwilla, van Herten, and Oor (2003) and van Herten, Kolk, and Chwilla (2005) saw no N400 effect at all to words that violated real-world knowledge, but that shared close semantic and thematic relationships with their context

The P600 and propositional implausibility

- Disrupting a combinatorial analysis by violating syntactic constraints can trigger a posteriorly-distributed late positivity effect P600. (Hagoort et al., 1993 and Osterhout and Holcomb, 1992).
- **‘semantic P600’** - under some circumstances, a P600 effect is evoked by certain semantic violations (Hoeks et al., 2004, Kolk et al., 2003 and Kuperberg et al., 2003)

The present study

The present study

ERPs are used to investigate the online use of three types semantic information:

1. Semantic relatedness between content words
2. Knowledge about who is likely to take part in familiar real-world events or states
3. A verb's selection restrictions for animate Agentive arguments

Real-world event/state knowledge VS verb-based animacy selection restrictions

Conditions:

1. Plausible control
2. Semantically related violations of real-world event/state knowledge
3. Semantically unrelated violations of real-world event/state knowledge
4. Semantically related violations of animacy selection restrictions
5. Semantically unrelated violations of animacy selection restrictions

Construction and ratings of materials

Methods

Construction of materials

- 5 types of sentences
- 120 verbs that required animate Agents
- no animate critical nouns are repeated
- critical nouns in the Control and Real-World Knowledge Violation sentences have almost the same length
- 240 experimental sentences (48 sentences in each of the five sentence types) and 144 filler sentences

Types of linguistic violations:

1. Control

The pianist played his music while the bass was strummed by the guitarist during the song.

The critical animate noun (e.g. guitarist) is semantically related to the general message conveyed by the group of content words in the preceding context (pianist, played, music, bass, strummed).

It conforms to expectations based on real-world knowledge about how likely it is for the Agent to be carrying out this action in this particular context.

Types of linguistic violations:

2. Related Real-World Knowledge Violations

The pianist played his music while the bass was strummed by the drummer during the song.

The critical animate noun (e.g. drummer) is semantically related to the general context, but it violates expectations based on real-world knowledge.

This event is implausible but not impossible.

The Agent is animate and therefore matches the animacy selection restrictions of the verb.

Types of linguistic violations:

3. Unrelated Real-World Knowledge Violations

The pianist played his music while the bass was strummed by the gravedigger during the song.

The critical animate NP (e.g. gravedigger) is not related to the general message conveyed by the context and it violates expectations based on real-world knowledge.

This event is implausible but not impossible.

The Agent is animate and therefore matches the animacy selection restrictions of the verb.

Types of linguistic violations:

4. Related Animacy Selection Restriction Violations

The pianist played his music while the bass was strummed by the drum during the song.

The critical inanimate noun (e.g. drum) is semantically related to context, but it violates the animacy-based selection restrictions of the verb for an animate Agent.

This event is impossible, rather than simply implausible.

Types of linguistic violations:

5. Unrelated Animacy Selection Restriction Violations

*The pianist played his music while the bass was
strummed by the coffin during the song.*

The critical inanimate noun (e.g. coffin) is not semantically related to the context and it also violates the animacy-based selection restrictions of the verb for an animate Agent.

This event is impossible, rather than simply implausible.

Methods

Ratings of materials

- Semantic Similarity Values (SSVs) using Latent semantic analysis (LSA)

*“the chef cooked the pasta” &
“the pasta cooked the *chef”*

- Term-by-term pair-wise comparisons, between the critical noun and the content words that preceded it

Methods

Ratings of materials

- 20 student volunteers rated whether sentence describes something that would be likely to occur in the real world (Scale: 1-7)
- Agentive VS Lovative

“ ... the bass was strummed by the drummer/drum ... ”

Characteristics of experimental stimuli

Table 2
Characteristics of experimental stimuli.

Sentence type	Critical noun length		Critical noun frequency		SSV		Plausibility ratings*	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1. Control	7.54	2.08	2.45	0.89	0.22	0.02	6.3	0.3
2. Related Real-World Knowledge Violation	7.58	1.92	2.37	0.80	0.18	0.02	2.4	0.4
3. Unrelated Real-World Knowledge Violation	7.56	1.98	2.31	0.81	0.00	0.01	2.2	0.5
4. Related Animacy Selection Restriction Violation	6.23	1.98	2.74	0.74	0.18	0.02	1.8	0.5
5. Unrelated Animacy Selection Restriction Violation	6.23	1.98	2.74	0.74	0.01	0.01	1.3	0.3

SD: Standard deviation.

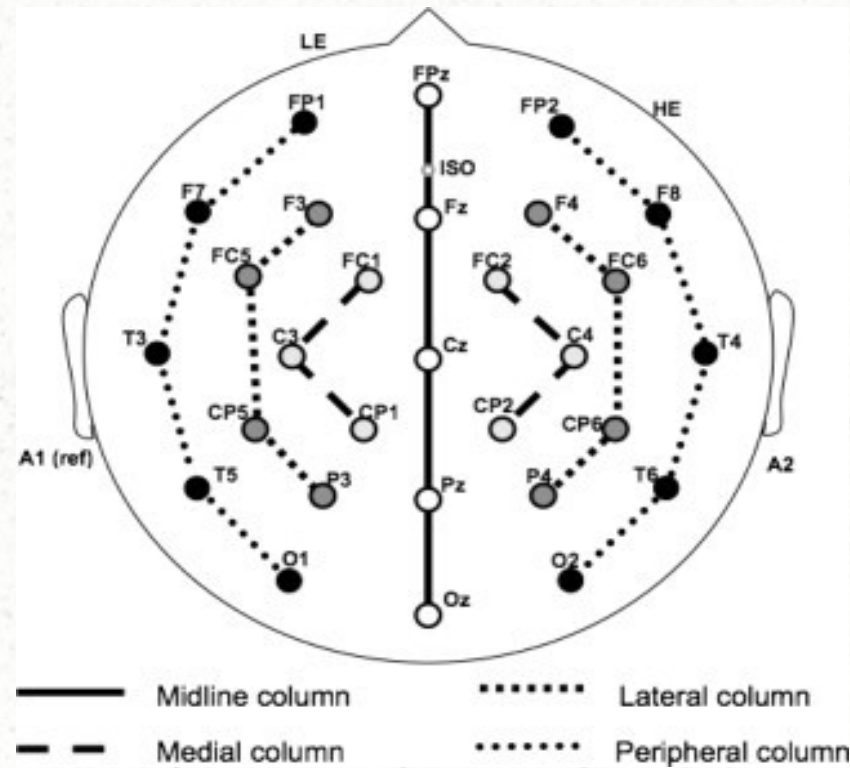
Length: number of letters.

Frequency based on the SUBTLEXus Corpus' log of word form frequency per million, $LgSUBTL_{WF}$ (Brysbaert & New, 2009); available on the Internet through the English Lexicon Project <http://elexicon.wustl.edu/>.

SSVs: Semantic Similarity Values, as determined using Latent Semantic Analysis (LSA; Landauer & Dumais, 1997; Landauer, 1998; available on the internet at <http://lsa.colorado.edu>) between critical noun and preceding sentence context.

* Plausibility ratings on a 7-point Likert scale up until and including the critical noun. Plausibility ratings of the fillers: Mean: 6.2, *SD*: 0.4.

Event-related potentials



ERP procedure

Participants:

- 20 participants (12 female; mean age 19.75)
- All right-handed native speakers of English, who had not learned any other language before the age of 5
- Normal or corrected-to-normal vision

ERP procedure

Trials:

- 15 practice trials
- Fixation point – 450 ms
- Blank screen – 100 ms
- Word by word for 450 ms
- Blank screen – 750 ms
- ?

ERP procedure

Participants' task:

- Decide whether or not each sentence make sense by pressing one of two buttons
- Wait until the “?” cue before responding

The delayed response is designed to reduce any contamination of the ERP waveform by response sensitive components such as the P300 (Donchin & Coles, 1988).

ERP analysis

ERPs are averaged offline from trials that are free of both ocular and muscular artifacts, and are time-locked to the onset of the words of interest.

Analysis of variances (ANOVA)

- Comparison of the ERPs evoked by each type of Violation with the ERPs to non-violated critical nouns in the Control sentences
- Effects and interactions between Violation Type and Relatedness on the ERPs in the four Violation conditions

Results

Participants' responses

Table 3

Percentage of participants' 'make sense' and 'does not make sense' judgments for each experimental condition, and filler sentences, during the ERP experiment.

Sentence type	'Makes sense' judgment	'Does not make sense' judgment
Control	89% (5.7)	
Related Real-World Knowledge Violations		79% (11.4)
Unrelated Real-World Knowledge Violations		89% (7.8)
Related Animacy Selection Restriction Violations		93% (4.9)
Unrelated Animacy Selection Restriction Violations		97% (4.3)
Plausible Fillers	93% (5.2)	

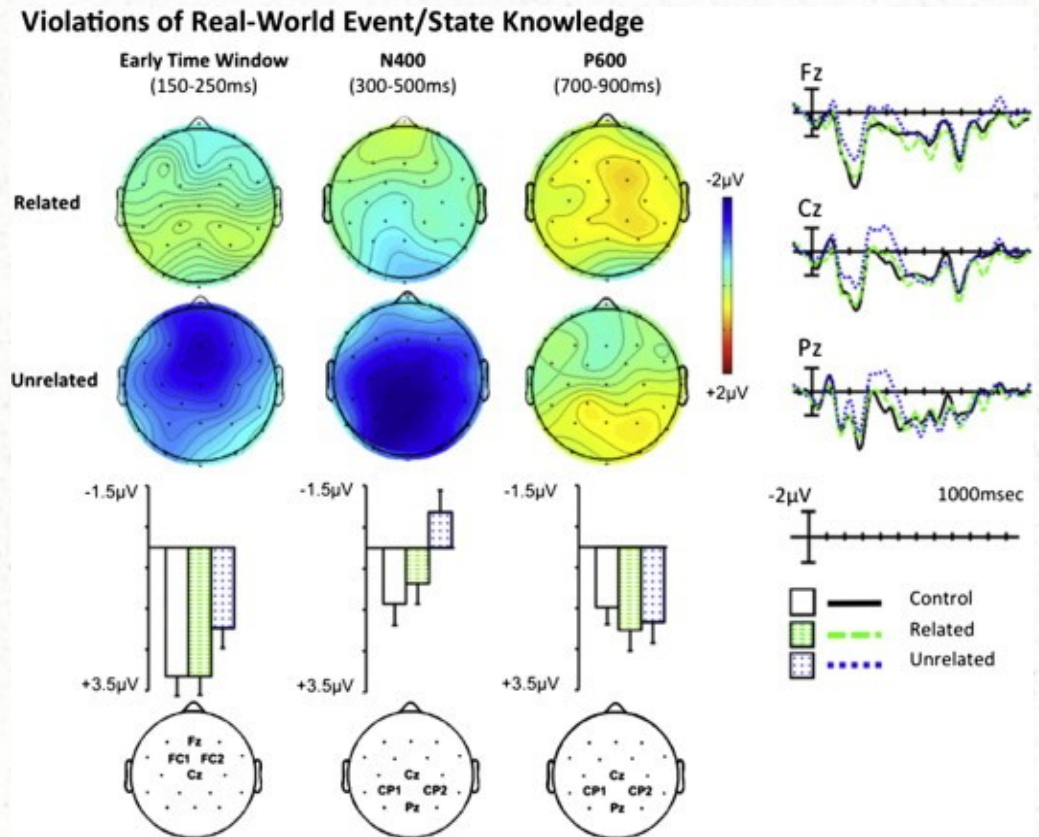
Mean percentages are shown with standard deviations in brackets.

Participants' judgments matched the prior categorizations 90% of the time

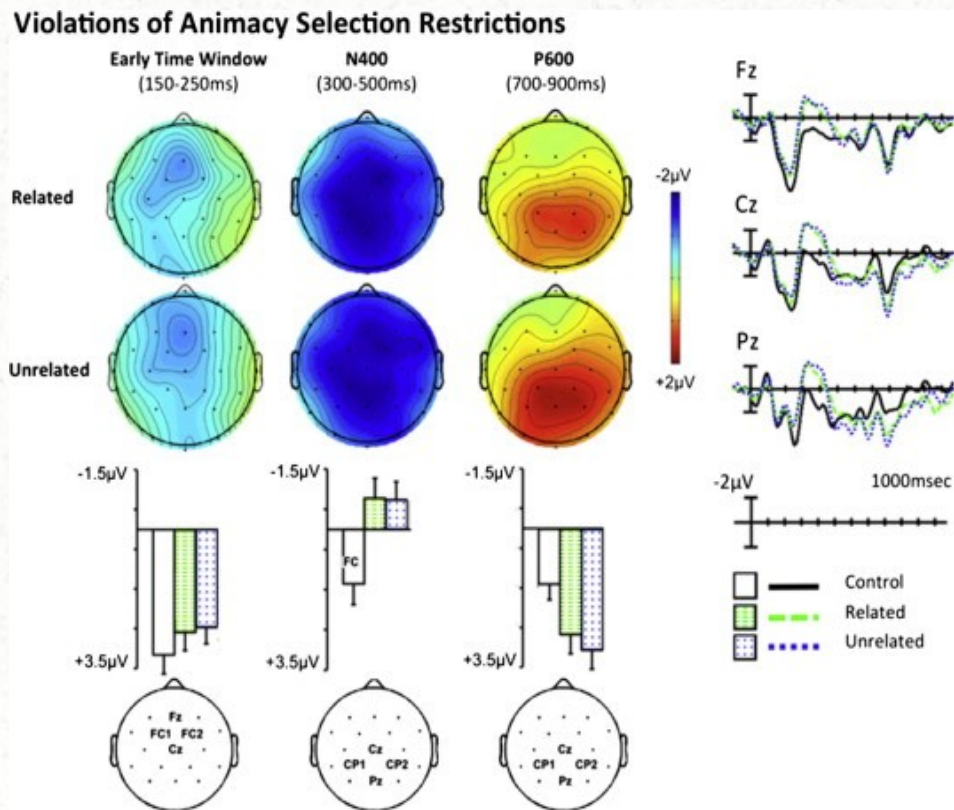
ERP data

- ~5% of the trials are rejected for artifact
- ERP analyses only included trials in which participants' judgments matched the prior categorizations of the five sentence types.

ERPs on critical nouns



ERPs on critical nouns



The N400 (300–500 ms)

- Semantically unrelated violations of real-world knowledge evoke a significant N400 effect (relative to non-violated nouns)
- Near-complete attenuation of the N400 effect evoked by Related Real-World Knowledge Violations
- No difference in the N400 evoked by the Related and Unrelated Animacy Selection Restriction Violations

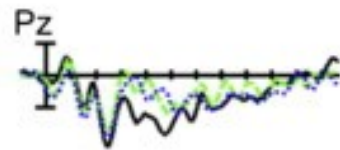
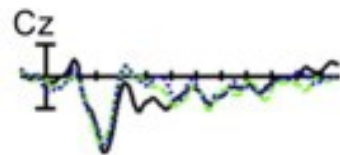
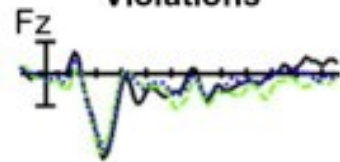
The P600 (700–900 ms)

- Larger posteriorly-distributed P600 to both types of Animacy Selection Restriction Violations than to both types of Real-World Knowledge Violations
- No significant main effects of Relatedness and no interactions involving Violation Type and Relatedness

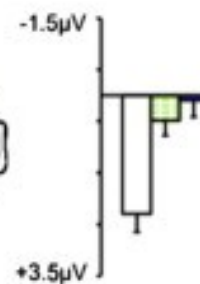
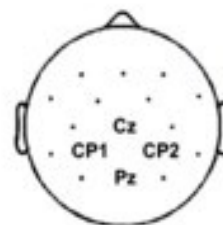
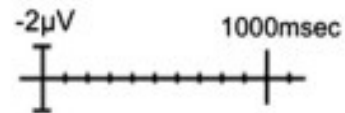
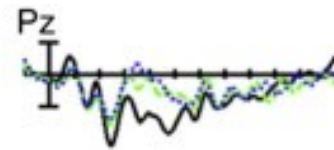
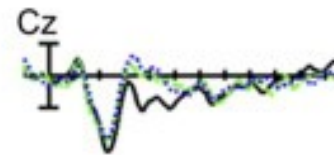
ERPs on sentence-final words

ERPs on Sentence Final Words

Read-World Knowledge Violations



Selection Restriction Violations



*Discussion
and
Open Questions*

The N400

Effects of semantic relatedness on violations of real-world event/state knowledge

Semantically unrelated violations of real-world knowledge evoke a significant N400 effect (relative to non-violated nouns)

- **Possible explanation:** reflecting the implausibility of the proposition formed by full semantic–syntactic integration of a critical word into its context.
 - Does not explain the near-complete attenuation of the N400 effect evoked by Related Real-World Knowledge Violations

The N400

Effects of semantic relatedness on violations of real-world event/state knowledge

- N400 reflects the results of a semantic memory-based analysis that matched its semantic features with expected representations that were generated by the interaction between the context and semantic information stored within semantic memory.
- Attenuation of the N400 - the context activated schema-based relatedness networks, which encode general script-level relationships between words and concepts, perhaps through top-down passive resonance mechanisms (Gerrig and McKoon, 1998 and Myers and O'Brien, 1998)

The N400

Effects of semantic relatedness on violations of real-world event/state knowledge

- The critical word is integrated with the context, by heuristic or semantic combinatorial mechanisms to form an intermediate plausible representation of meaning.
- In this study, however, the thematic roles are not easily reversible.

“The wreckage of the sunken ship was salvaged by the victims ... ,”

Victims are unlikely to either salvage or to be salvaged.

The N400

Effects of semantic relatedness on violations of animacy selection restrictions

- Larger N400 to selection restriction violations than to non-violated words
- Reflects mismatch between the verb's selection restrictions and the argument's semantic features

*“The pianist played his music while the bass was **strummed** by the ... ,” /Strum suggests Animate agent/*
- Unlikely: implausibility of the proposition formed by integrating the critical word with its preceding context

The N400

Effects of semantic relatedness on violations of animacy selection restrictions

- The N400 effect to the selection restriction violations was not modulated by semantic relatedness between the critical noun and the preceding content words

Inconsistent with Nieuwland and Van Berkum (2005) who report a reduced N400 on selection restriction violating inanimate nouns that were related to the general discourse context

The N400

Effects of semantic relatedness on violations of animacy selection restrictions

Semantic relatedness has different effects on the real-world event/state knowledge violations and the animacy selection restriction violations

- **Hypothesis 1:** during expectancy generation, the verb's broad animacy selection restrictions are inherently more constraining or predictive than real-world event/state knowledge

"The pianist played his music while the bass ... ,"

- **Hypothesis 2:** animacy is prioritized over real-world event/state knowledge during semantic matching

The P600: effects of severe implausibility

Selection restriction violations evoked a P600 effect, regardless of whether the critical noun was semantically related or unrelated to the preceding verb or other words in the context

Inconsistent with:

- Kim and Osterhout's (2005) 'semantic attraction' hypothesis
- Hagoort et al. (2009) - linguistic errors trigger an N400 when syntactic cues are strong but semantic cues are weak, while a P600 is triggered if semantic cues are strong but syntactic cues are weak

The P600: effects of severe implausibility

The P600 effect is triggered by the detection of overall implausibility/impossibility of the proposition that is derived by combinatorially syntactically and semantically integrating the critical word with its preceding context

Open questions

- N400 modulation: a balance between predictive processing and passive resonance
- The semantic P600: conflict between semantic memory-based predictions and the detection of propositional incoherence

References

- Kutas, M., & Federmeier, K. D. (2011). Thirty years and counting: Finding meaning in the N400 component of the event-related brain potential (ERP). *Annual Review of Psychology*, 62, 621–647.
- Meyer, D. E., & Schvaneveldt, R. W. (1971). Facilitation in recognizing pairs of words: Evidence of a dependence between retrieval operation. *Journal of Experimental Psychology*, 90, 227–234
- Bentin, S., McCarthy, G., & Wood, C. C. (1985). Event-related potentials, lexical decision and semantic priming. *Electroencephalography and Clinical Neurophysiology*, 60, 343–355.
- Bentin, S., McCarthy, G., & Wood, C. C. (1985). Event-related potentials, lexical decision and semantic priming. *Electroencephalography and Clinical Neurophysiology*, 60, 343–355.
- Chomsky, N. (1965). *Aspects of the theory of syntax*. MIT Press.
- Chwilla, D. J., & Kolk, H. H. (2005). Accessing world knowledge: Evidence from N400 and reaction time priming. *Cognitive Brain Research*, 25(3), 589–606.
- Chwilla, D. J., Kolk, H. H. J., & Mulder, G. (2000). Mediated priming in the lexical decision task: Evidence from event-related potentials and reaction time. *Journal of Memory and Language*, 42, 314–341.

References

- Marslen-Wilson, W., Brown, C., & Tyler, L. K. (1988). Lexical representations in spoken language comprehension. *Language and Cognitive Processes*, 3, 1–16.
- Matsuki, K., Chow, T., Hare, M., Elman, J. L., Scheepers, C., & McRae, K. (2011). Event-based plausibility immediately influences on-line language comprehension. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 37, 913–934.
- Donchin, E., & Coles, M. G. H. (1988). Is the P300 component a manifestation of context updating? *Behavioral and Brain Science*, 11, 355–372.
- Duffy, S., Henderson, J. M., & Morris, R. K. (1989). Semantic facilitation of lexical access during sentence processing. *Journal of Experimental Psychology, Learning, Memory, and Cognition*, 15, 791–801.

Thank you!