Connectionist Language Processing

Lecture 12: **Modeling the Electrophysiology of Language II**

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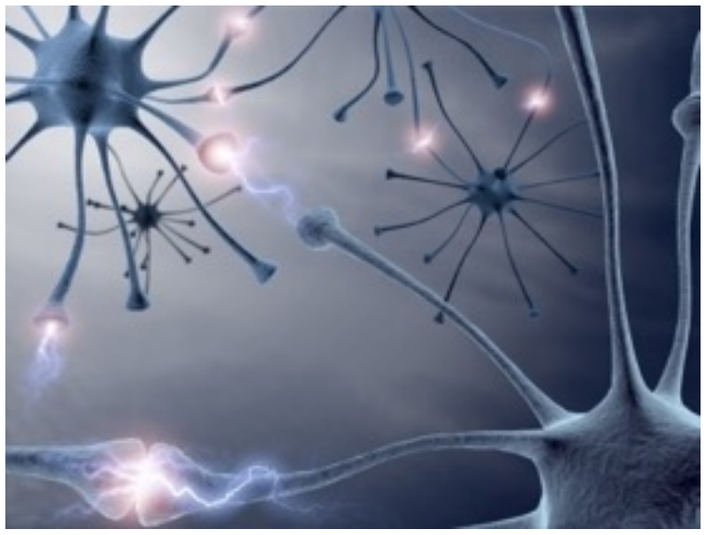
Event-Related Potentials (ERPs)



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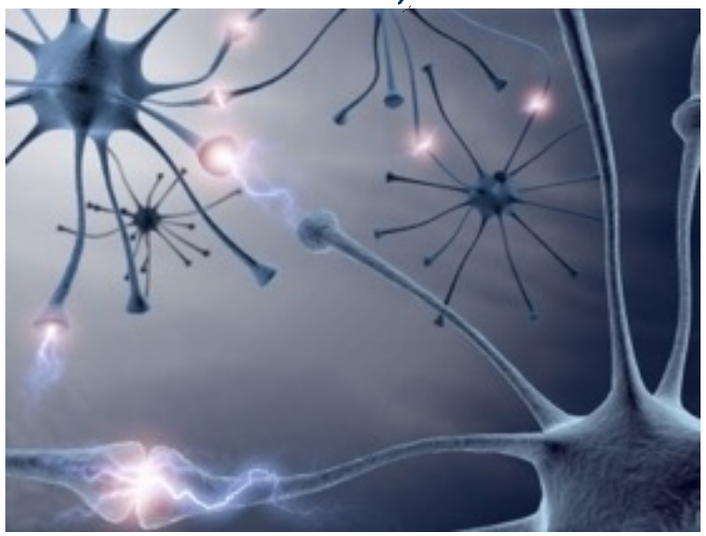

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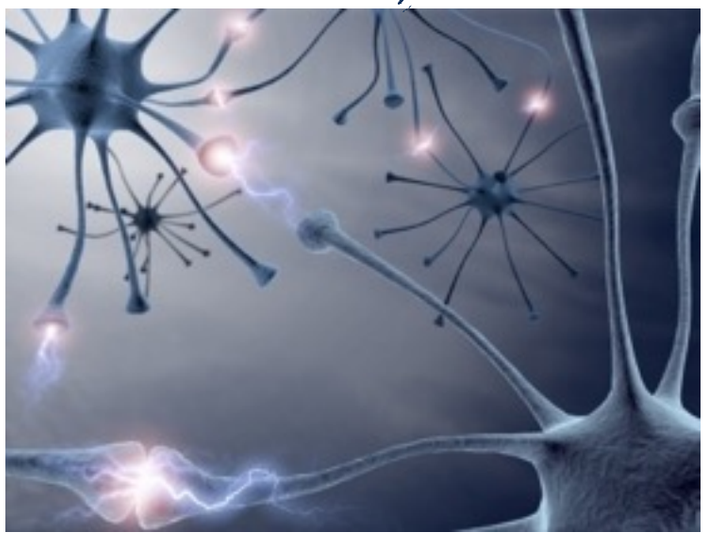
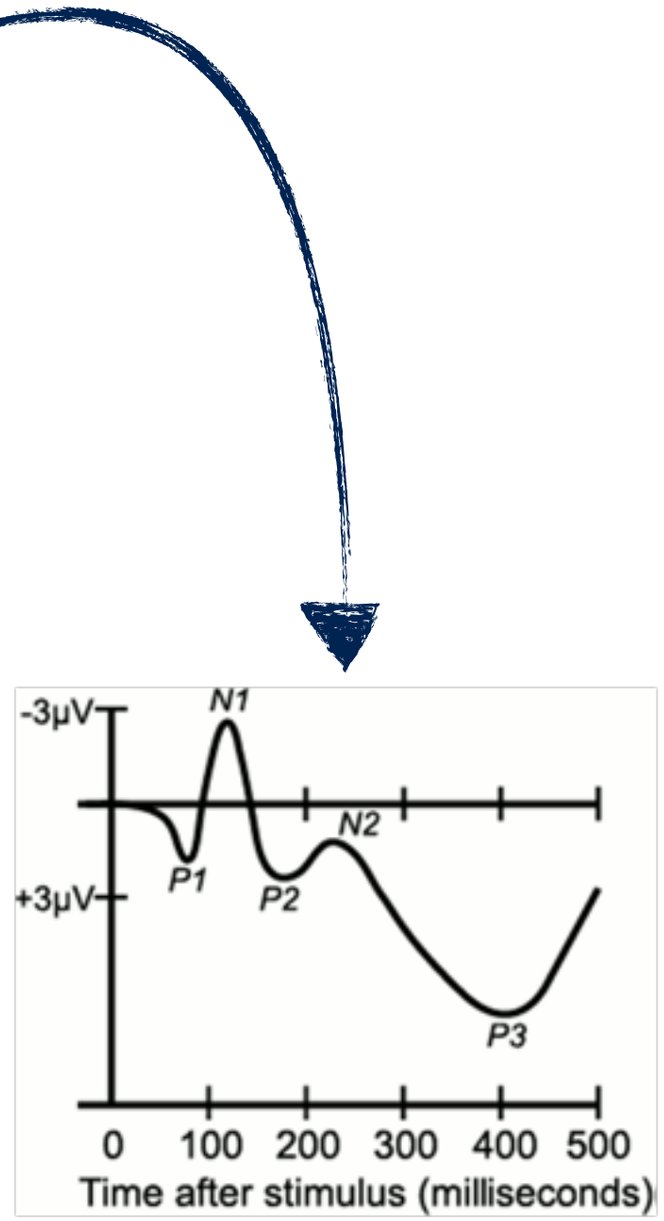




The standard view

N400 is semantic integration

P600 is syntactic processing

The new view

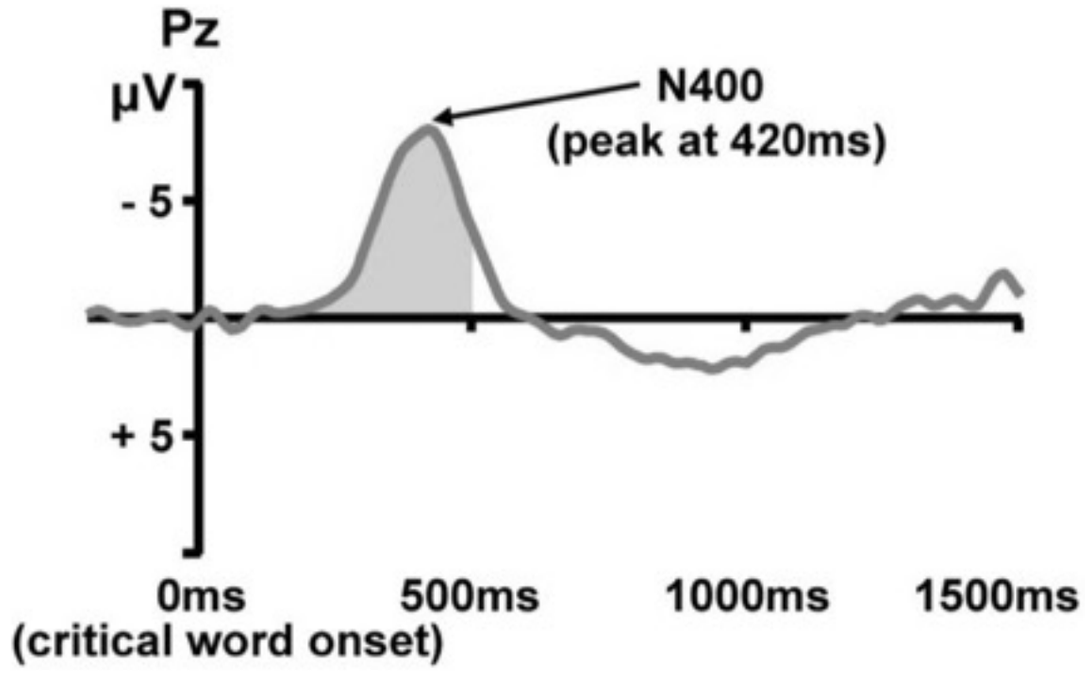
N400 is ~~semantic integration~~ —> lexical retrieval

P600 is ~~syntactic processing~~ —> semantic integration

N400 — semantic integration

He spread his warm bread with socks

He spread his warm bread with butter



Kutas & Hillyard (1980)
Science

P600 — syntactic processing

The spoilt child throw the toys on the floor

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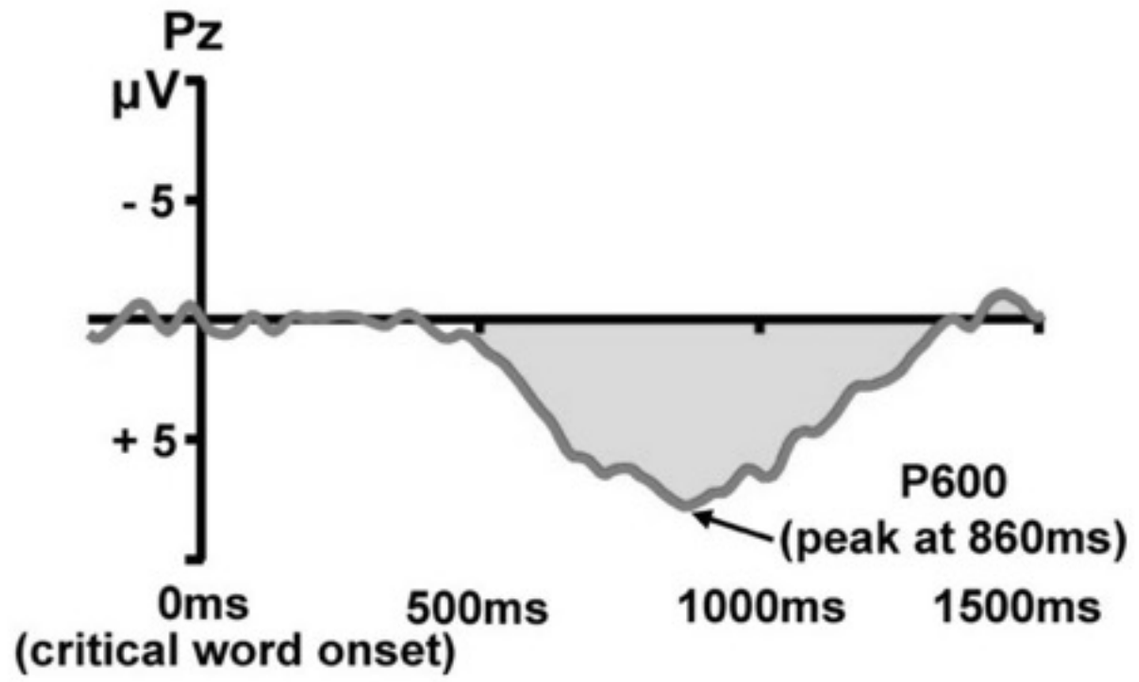

Hagoort et al. (1993)
Lang. Cognitive Proc.

Puzzle — the ‘semantic’-P600

De speer heeft de atleten geworpen
‘The javelin has the athletes thrown’

De speer werd door de atleten geworpen
‘The javelin was by the athletes thrown’

Hoeks et al. (2004)
Cogn. Brain Res.

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Expected: N400-effect, no P600-effect

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Solution: people were tricked into a ‘semantic illusion’

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Implication: independent semantic analysis stream

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Multi-stream models

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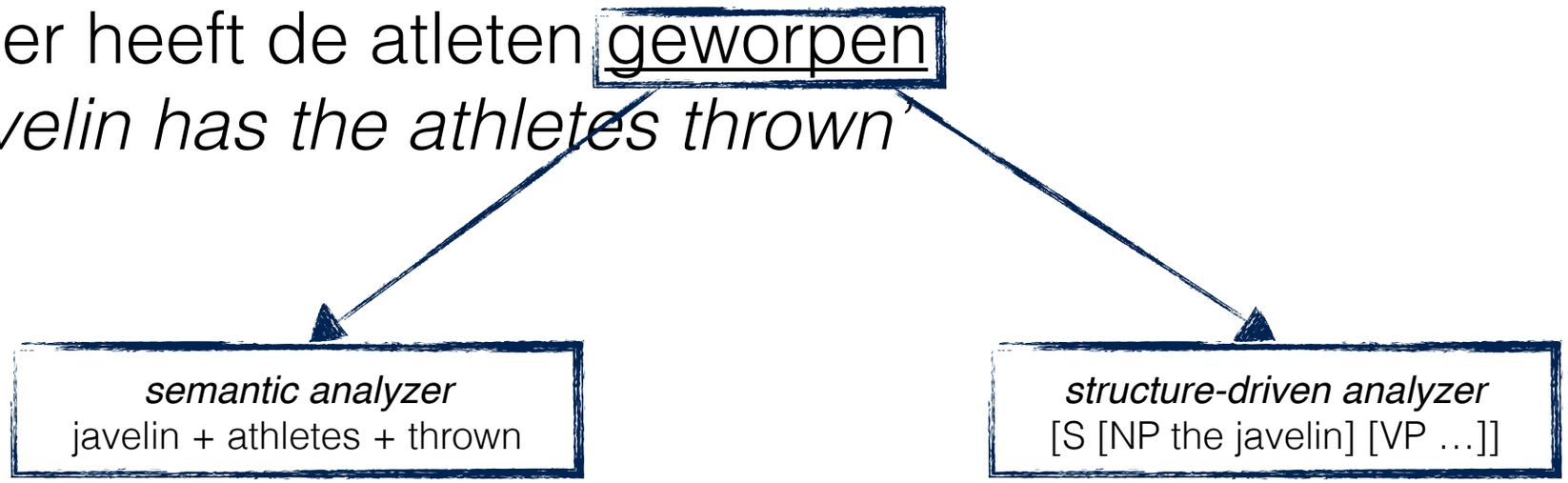

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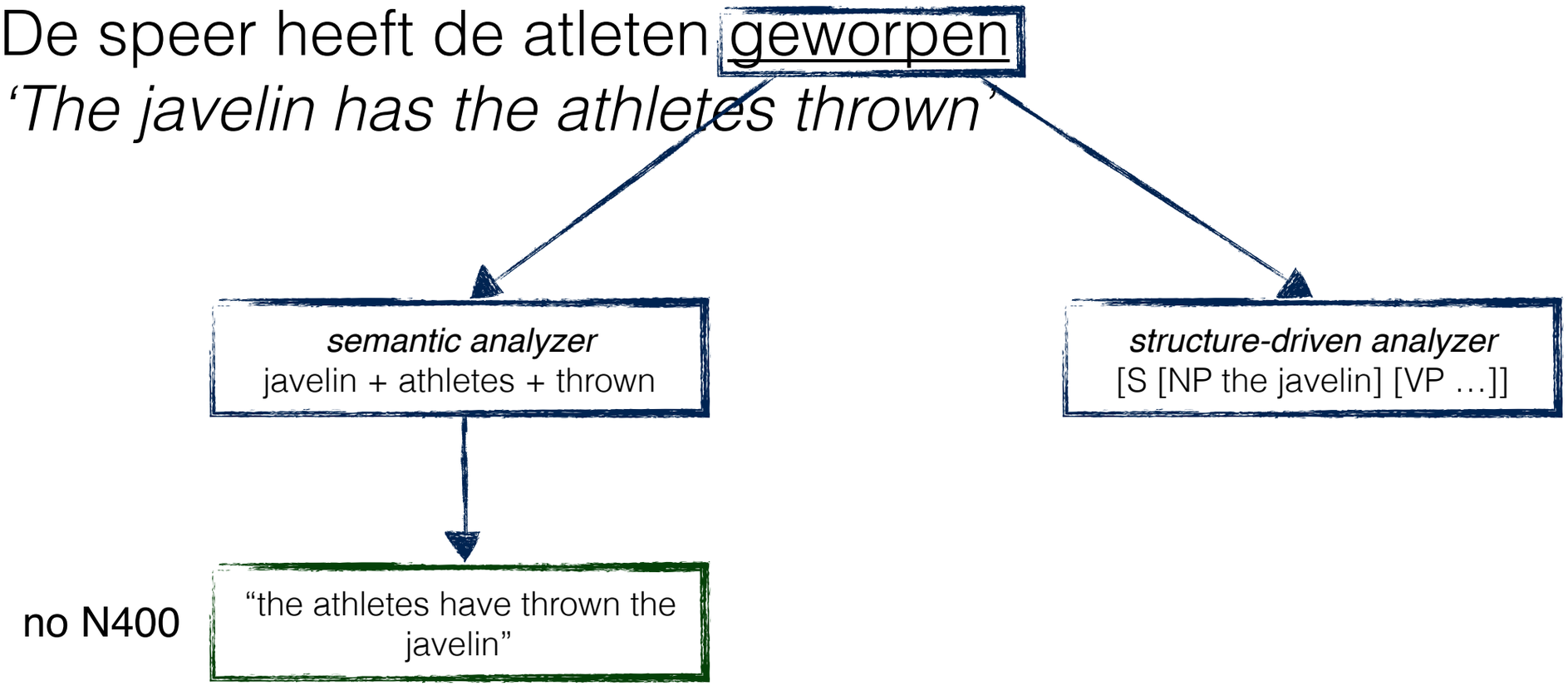

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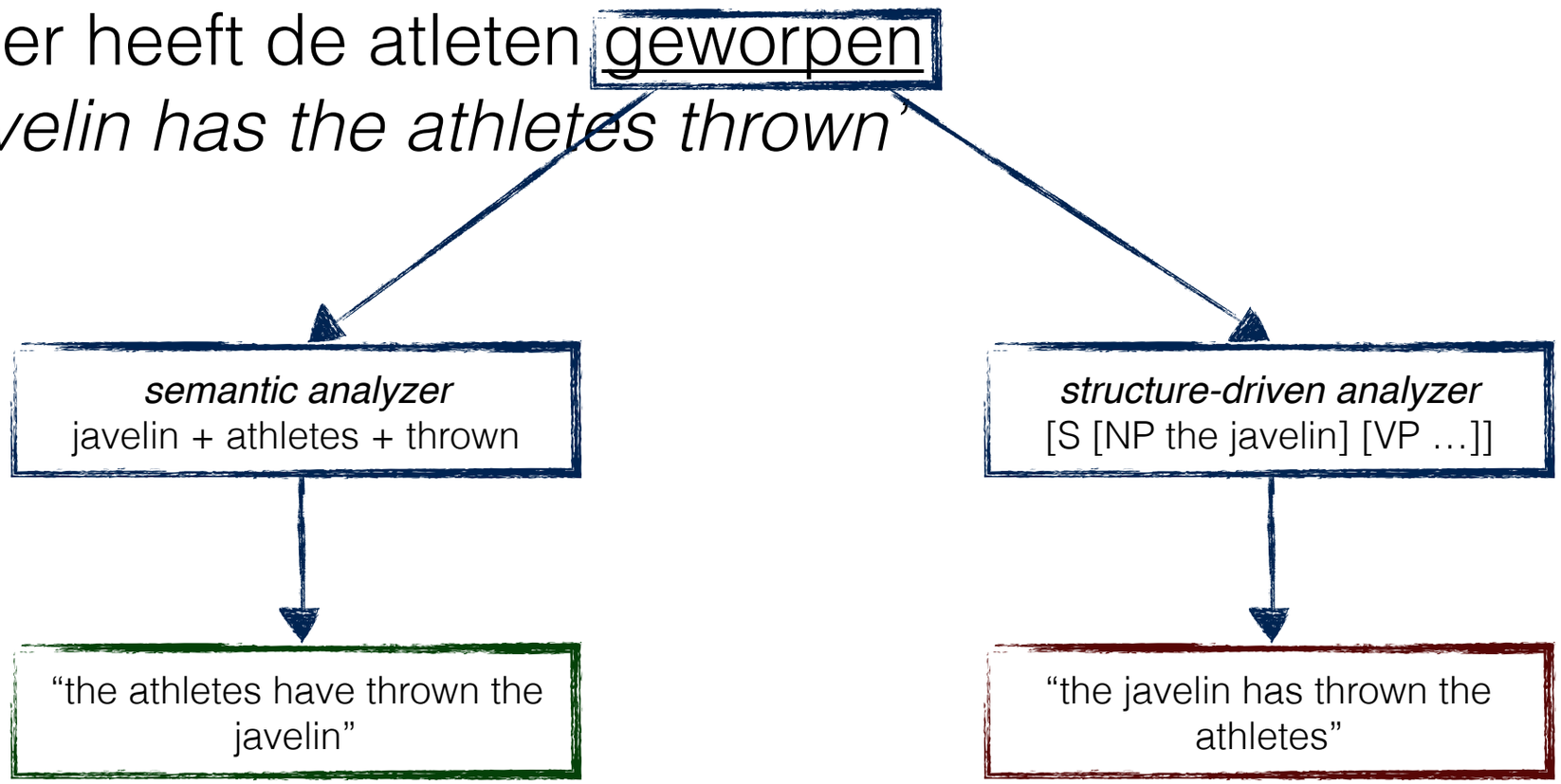

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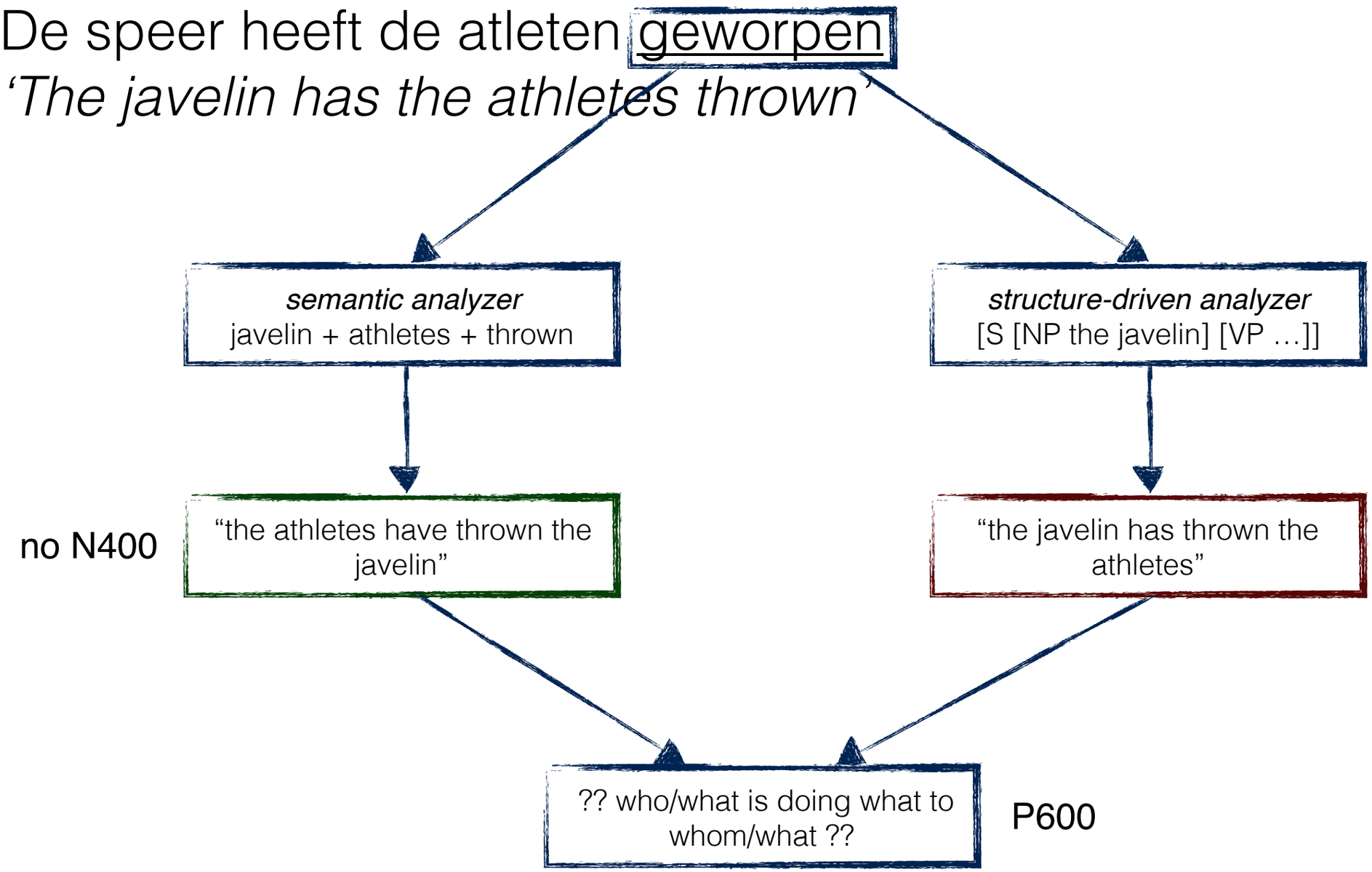

Multi-stream models

Semantic Attraction (SA)
(Kim and Osterhout, 2005)

Monitoring Theory (MT)
(Van Herten et al., 2005, 2006)

Continued Combinatory Analysis (CCA)
(Kuperberg, 2007)

ext. Argument Dependency Model (eADM)
(Bornkessel-Schlesewsky and Schlesewsky, 2008)

Processing Competition (PC)
(Hagoort et al., 2009)

Table 1 – Summary of the different models/accounts, and their explanations of the absence of an N400-effect and the presence of a P600-effect in SIE data (SA = Semantic Attraction; MT = Monitoring Theory; CCA = Continued Combinatory Analysis; eADM = extended Argument Dependency Model, and PC = Processing Competition. Models marked with a "" are fully interactive, meaning that their streams can influence each other during online processing.

Model	Stream(s)	Absence of N400-effect	P600-effect reflects
SA*	Syntax-driven and semantics-driven	Plausible combination of arguments and verb	Syntactic revision
MT	Algorithmic stream and plausibility heuristic	Plausible combination of arguments and verb	Conflict resolution
CCA*	Syntax-driven, thematic-role based, and semantic-memory based	Blocking of semantic integration	Continued Combinatory Analysis
eADM	Thematic-role based and plausibility heuristics	Plausible combination of arguments and verb	Problematic integration of streams
PC*	Syntax-driven and semantics-driven	Strong semantic cues	Syntactic processing

Brouwer et al. (2012)
Brain Res.

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compositional semantic processing

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compositional semantic processing

continued analysis

Brouwer et al. (2012)
Brain Res.

Multi-stream models (cont'd)

Item	Observed	SA	MT	CCA	eADM	PC
Hoeks et al. (2004)						
De speer werd door de atleten geworpen	—	—	—	—	—	—
De speer heeft de atleten geworpen	P6	P6	P6	P6	P6	P6
De speer werd door de atleten opgesomd	N4/P6	N4	N4	P6*	N4/P6	P6
De speer heeft de atleten opgesomd	N4/P6	N4	N4	P6*	N4/P6	P6
Kim and Osterhout (2005)						
The hearty meal was devoured…	—	—	—	—	—	—
The hearty meal was devouring…	P6	P6	P6	P6	P6	N4
The dusty tabletops were devouring…	N4/(P6)[a]	N4	N4	P6	N4/P6	N4
van Herten et al. (2005)						
De stroper die op de vos joeg…	—	—	—	—	—	—
De vos die op de stroper joeg…	P6	—	P6	P6	P6	P6
Kuperberg et al. (2007)						
For breakfast the boys would eat…	—	—	—	—	—	—
For breakfast the boys would watch…	N4	N4	N4	N4	N4	N4
For breakfast the eggs would eat…	P6	P6	P6	P6	P6	P6
For breakfast the eggs would watch…	(N4)/P6	N4	N4	P6	P6	P6
Kos et al. (2010)						
Fred eet een boterham…	—	—	—	—	—	—
Fred eet een restaurant…	N4	N4	N4	N4	P6	N4
Fred eet in een restaurant…	—	—	—	—	—	—
Fred eet in een boterham…	N4	N4	P6	N4	??	N4
Nieuwland and van Berkum (2005)						
Prior context…						
Next, the woman told the tourist…	—	—	—	—	—	—
Next, the woman told the suitcase…	P6	N4	N4	N4	N4/P6	N4

Brouwer et al. (2012)
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Q: Architectural deficit? Or wrong interpretations of N400 and P600?

Brouwer et al. (2012)
Brain Res.

N400 as lexical retrieval

The Retrieval hypothesis

N400 is retrieval of lexical information from memory, which is facilitated through lexical and contextual priming

Kutas and Federmeier (2000, 2011)
Trends Cogn. Sci.; Annu. Rev. of Psychol.

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N400-effect

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Q: Now what about semantic integration?

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P600 as semantic integration

The MRC hypothesis

P600 is a family of late positivities that reflect the *word-by-word* construction, reorganization, or updating of a mental representation of what is being communicated (and MRC)

Brouwer et al. (2012)
Brain Res.

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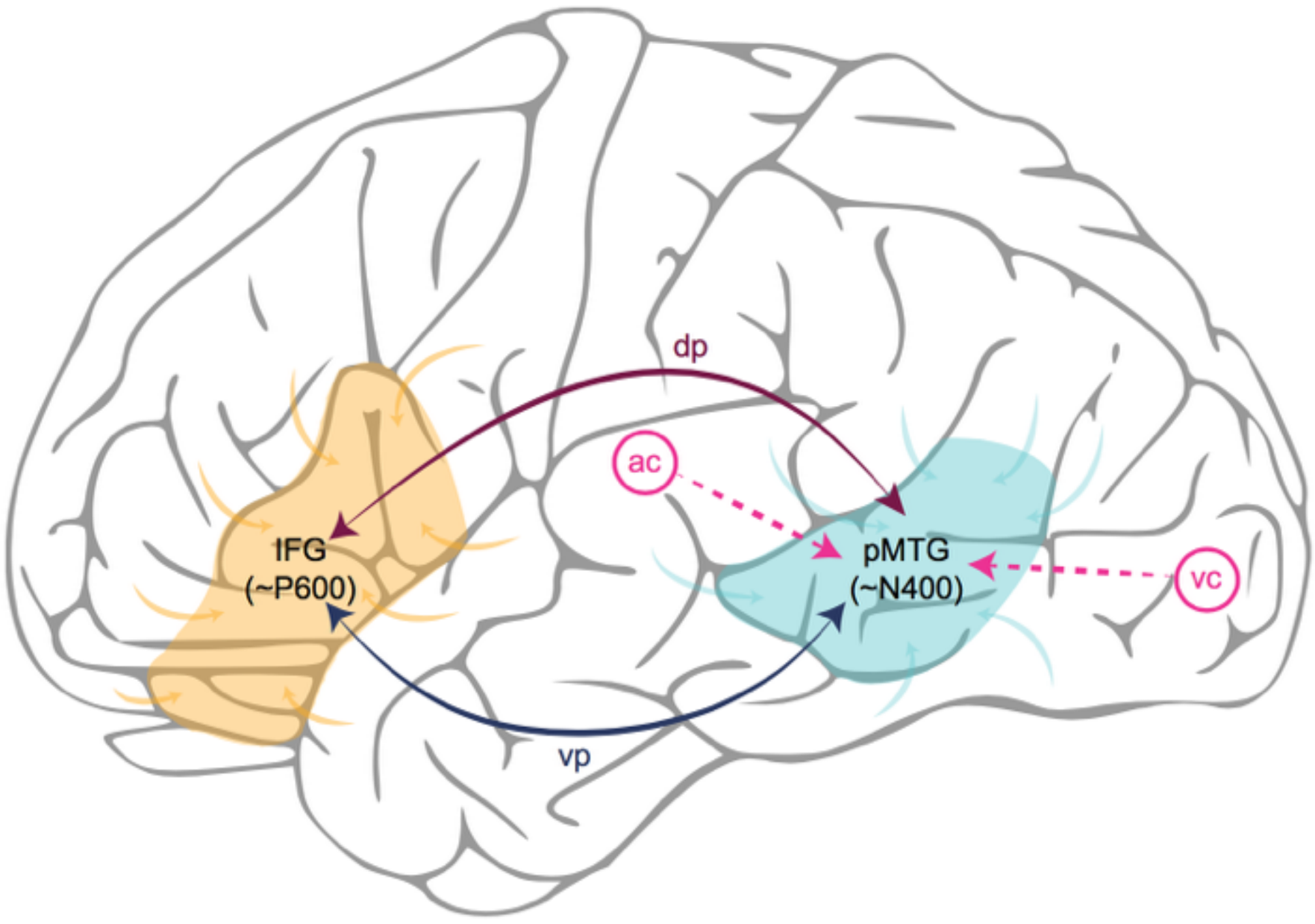
Implication: biphasic N400/P600 "Retrieval-Integration" cycles

Brouwer et al. (2012)
Brain Res.

Aligning Time and Place



Brouwer and Hoeks (2013)
Front. Hum. Neurosci.

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> A **single-stream** account of the N400 and the P600 in language comprehension

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> **Solution:** Implement mathematically **explicit (neuro)computational models** that generate quantitative predictions

What makes a good computational model?

> **Model comprehension** and not just word prediction or syntactic parsing

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> **Model the right level of granularity**: index scalp-recorded summations of post-synaptic potentials in large neural populations

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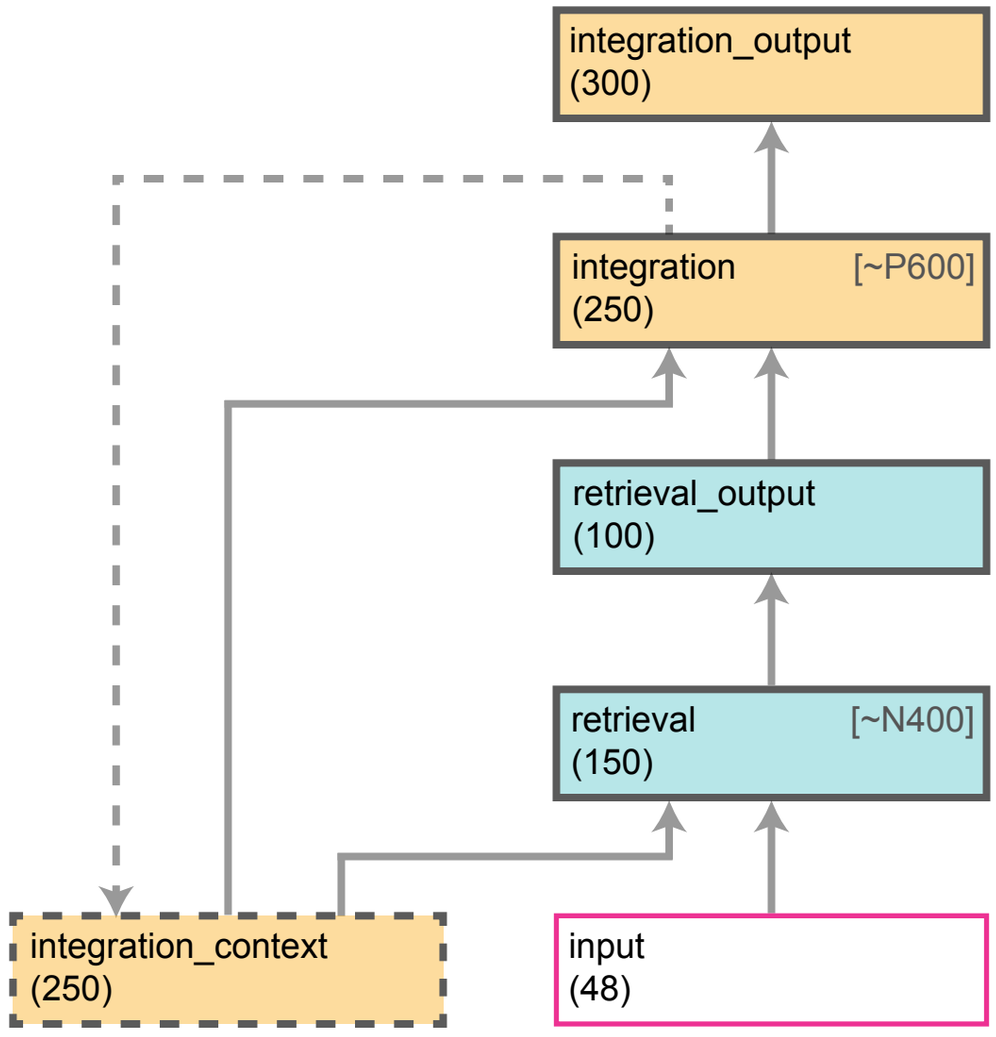
We present such a computational model that implements the **Retrieval** view on the N400, and the **Integration** view on the P600 (cf. Brouwer et al., 2012)

Model Architecture



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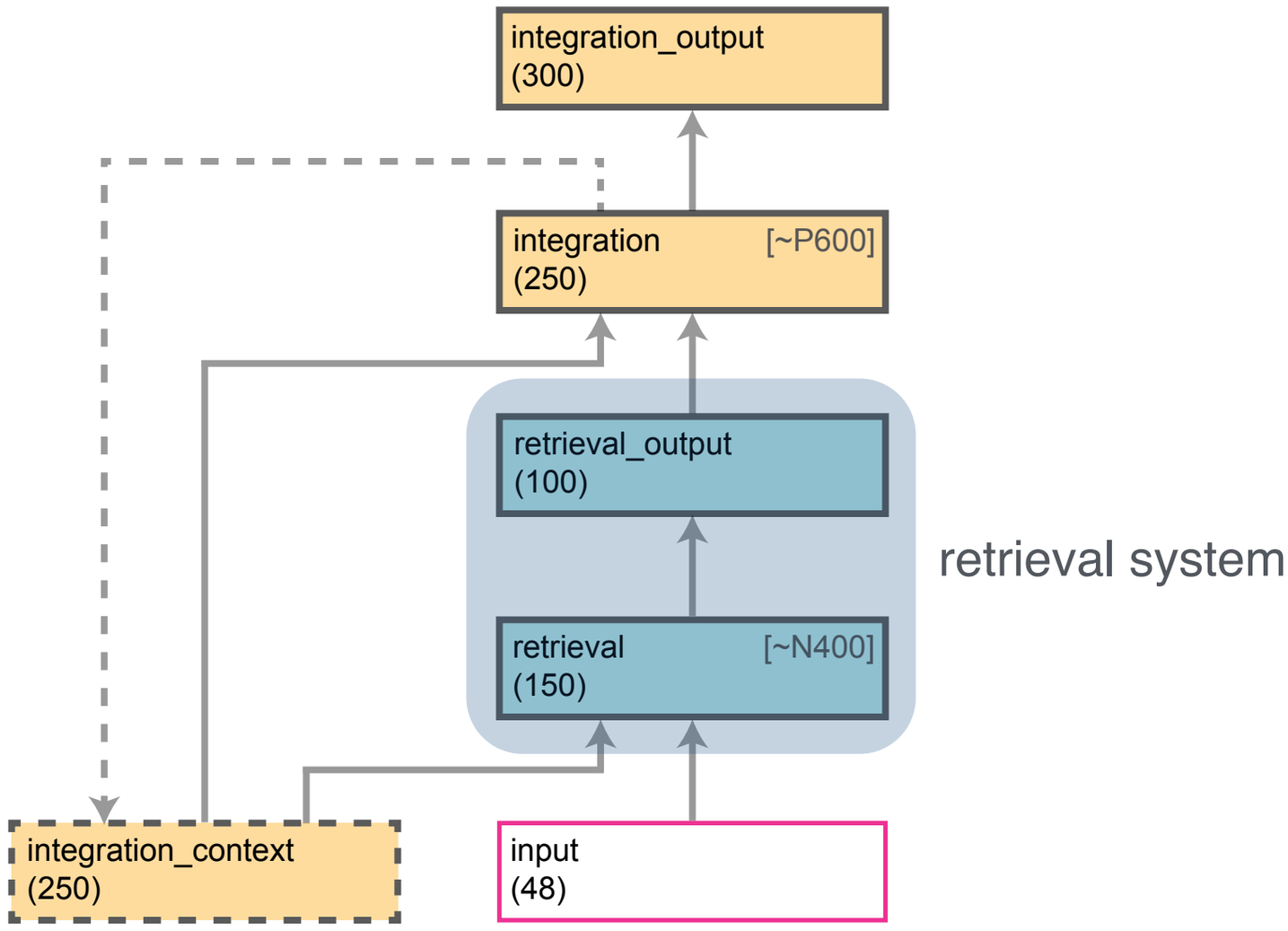

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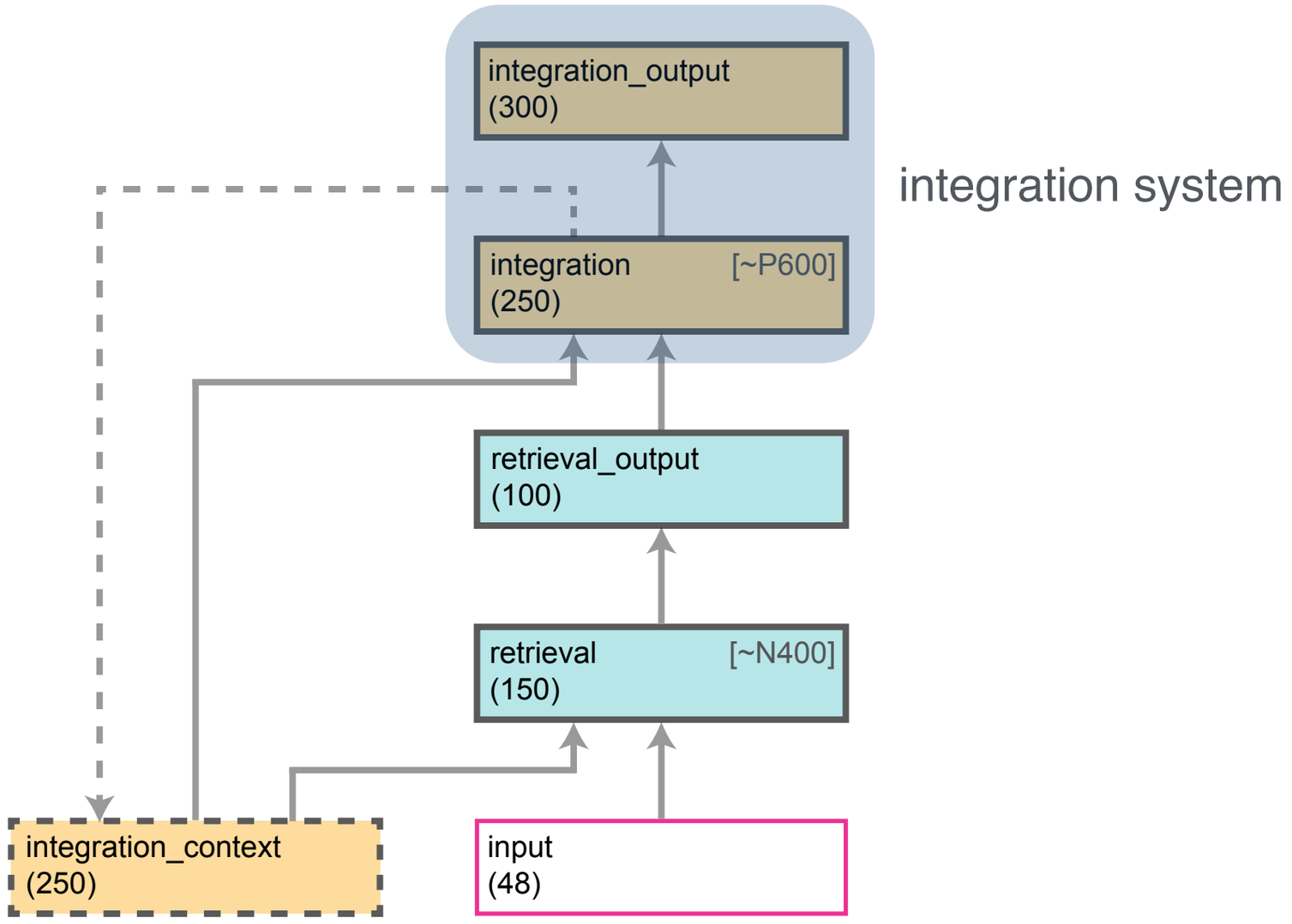

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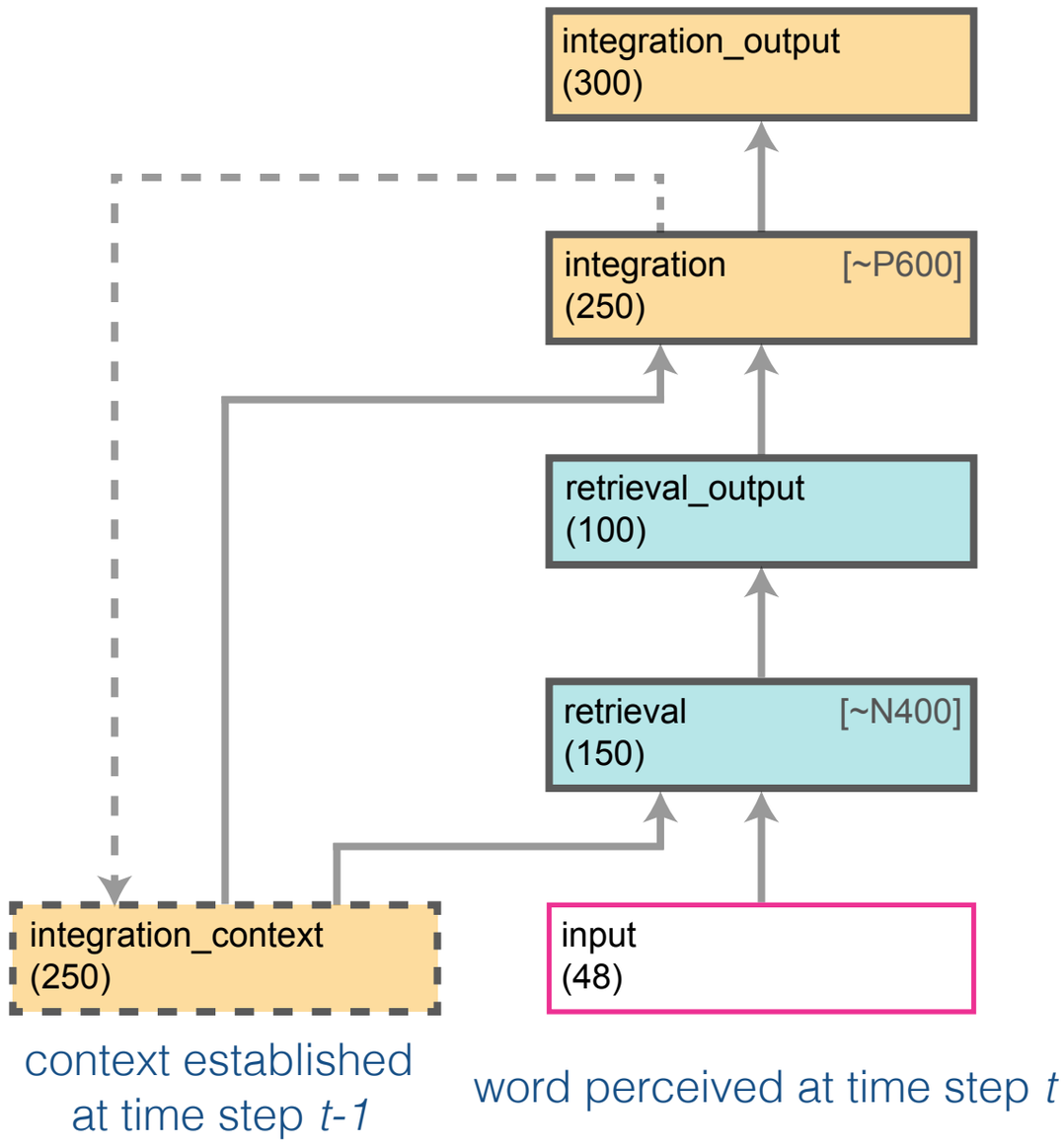

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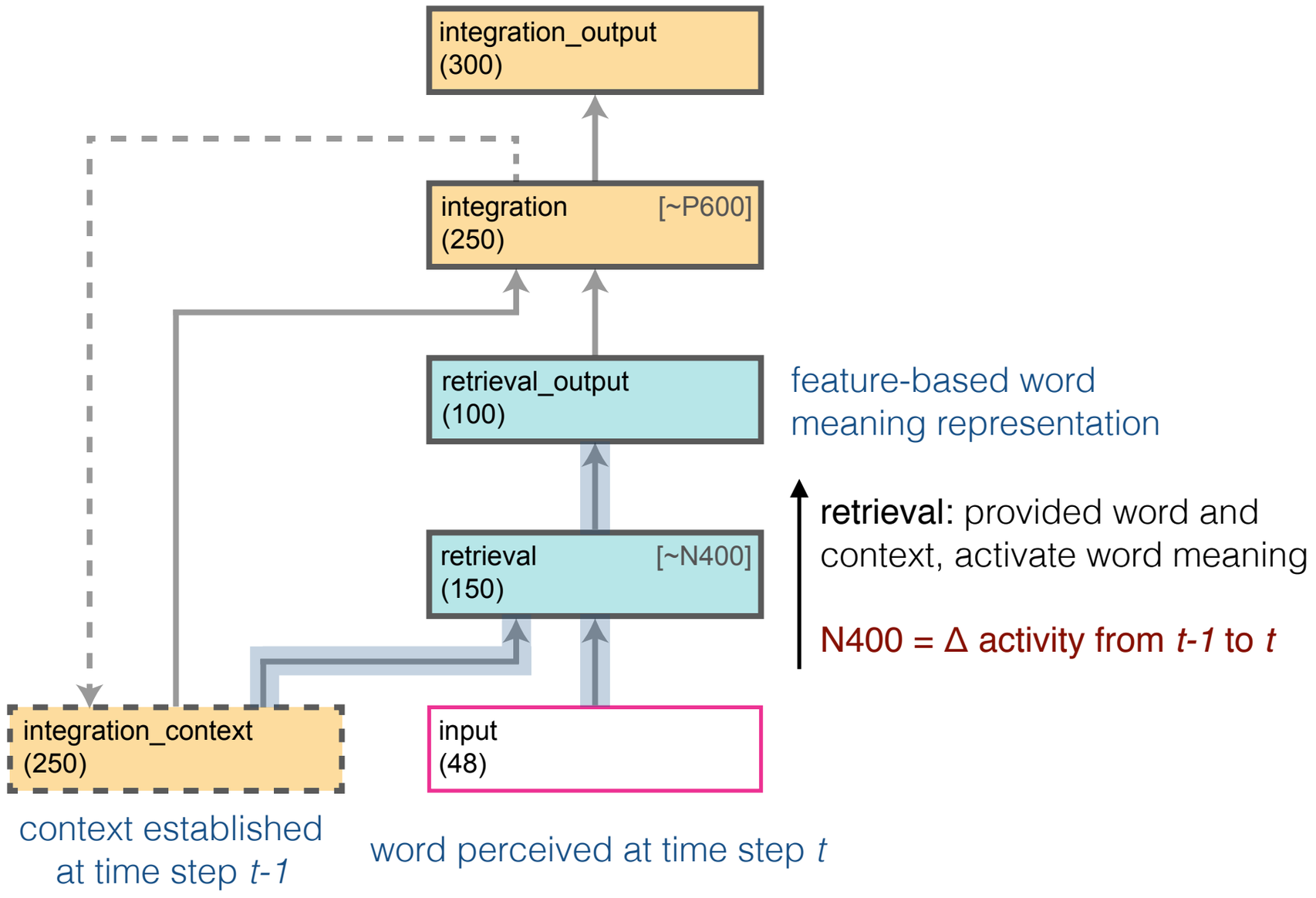

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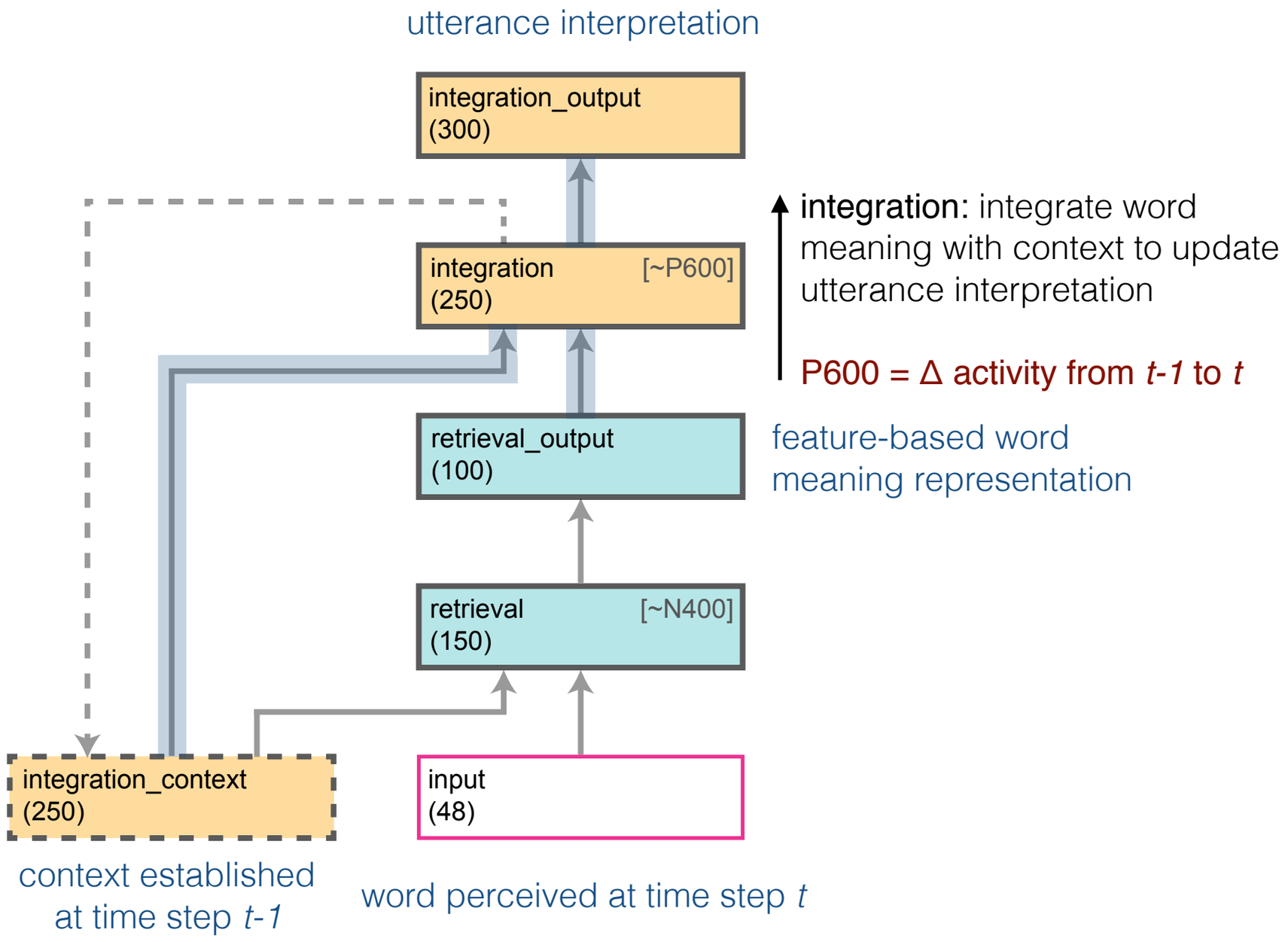

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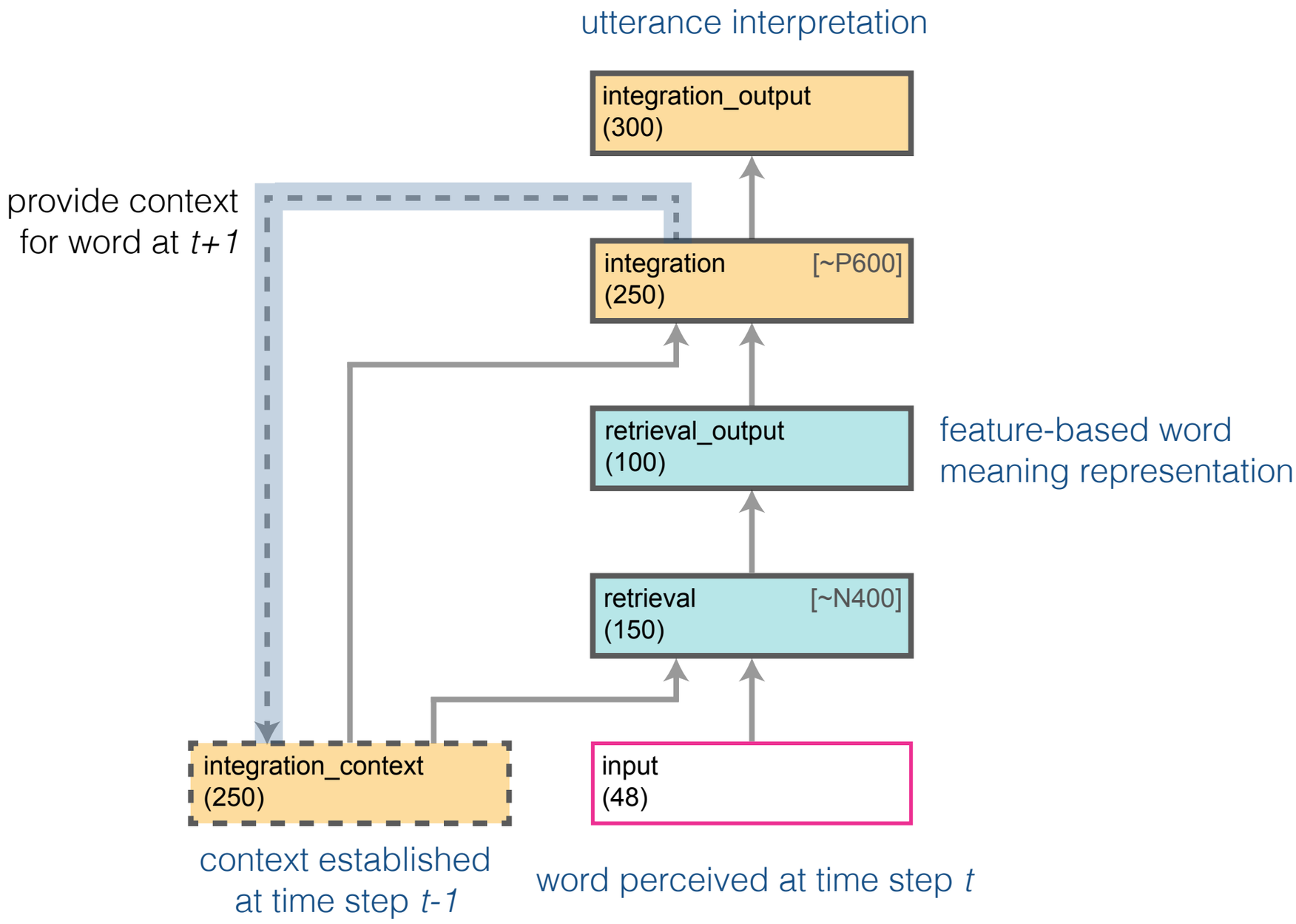

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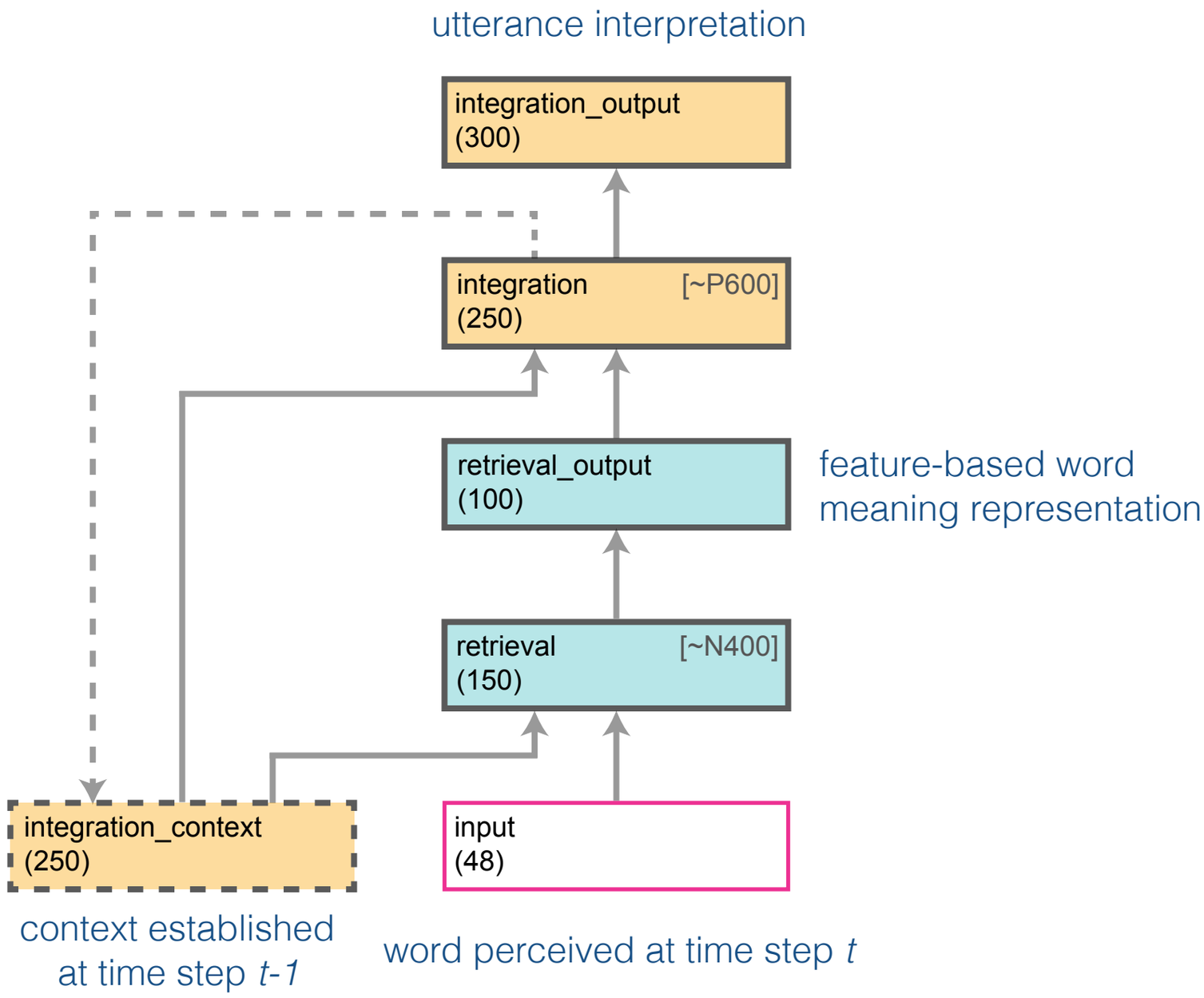

> Taught to comprehend a wide range of structures, allowing us to test it on a range of contrasts **analogous** to signature processing phenomena and their related ERP findings

N400 to Semantic Anomaly

a man drinks rugby / beer

(N400: rugby > beer)

cf. Kutas & Hillyard (1980), *Science*

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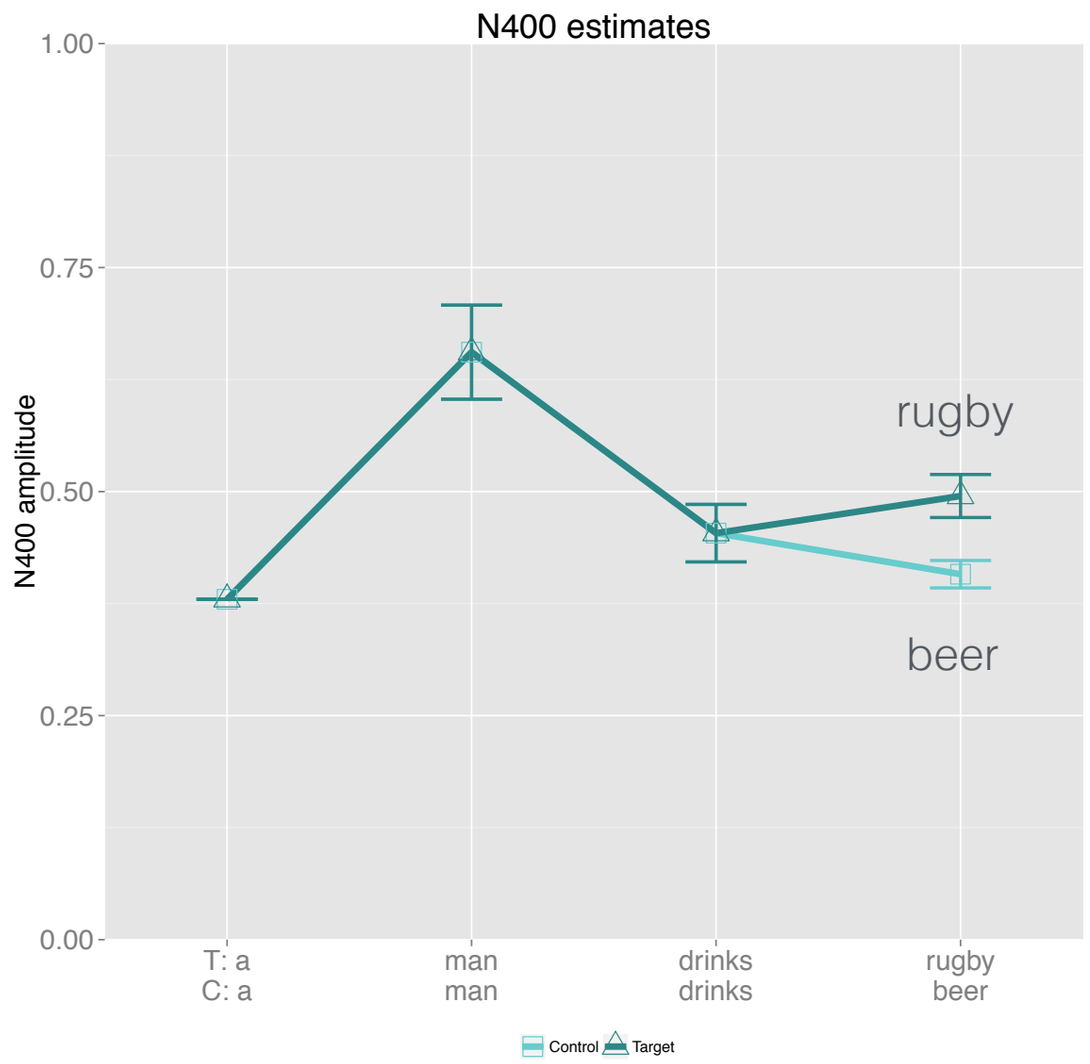

* Error bars show standard errors

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men eat an/a automobile / salad / steak

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(* in the model's world, men prefer steak over salad)

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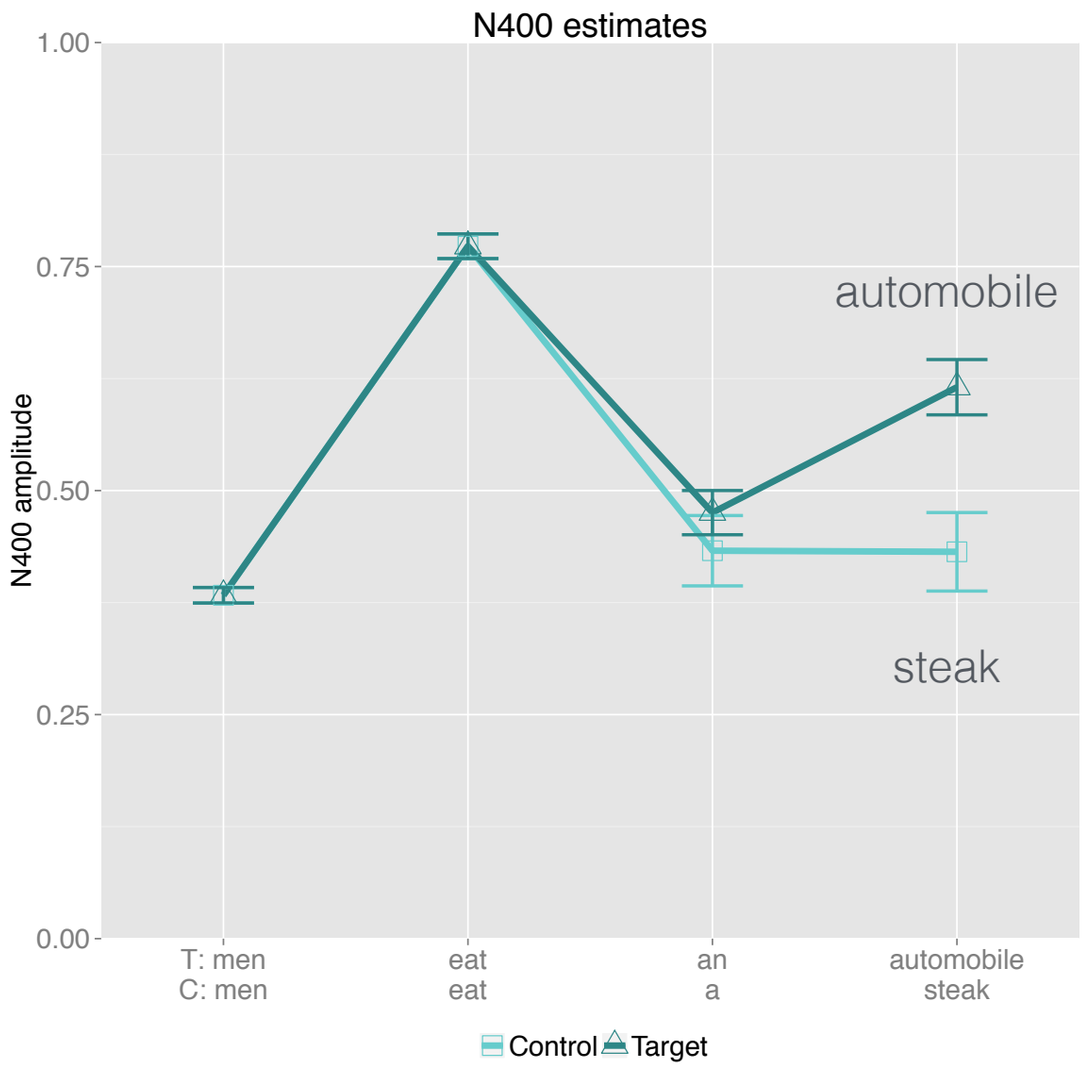

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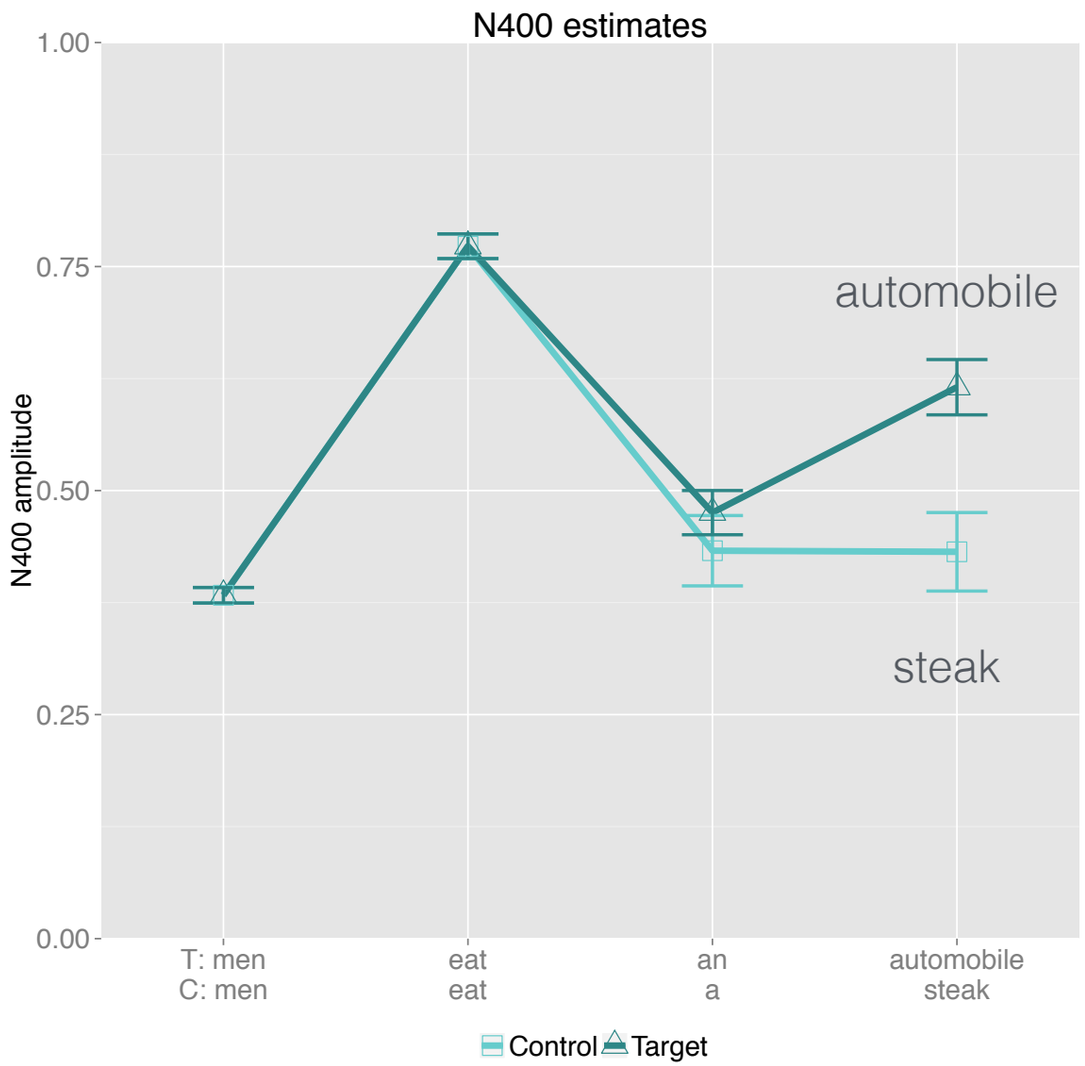

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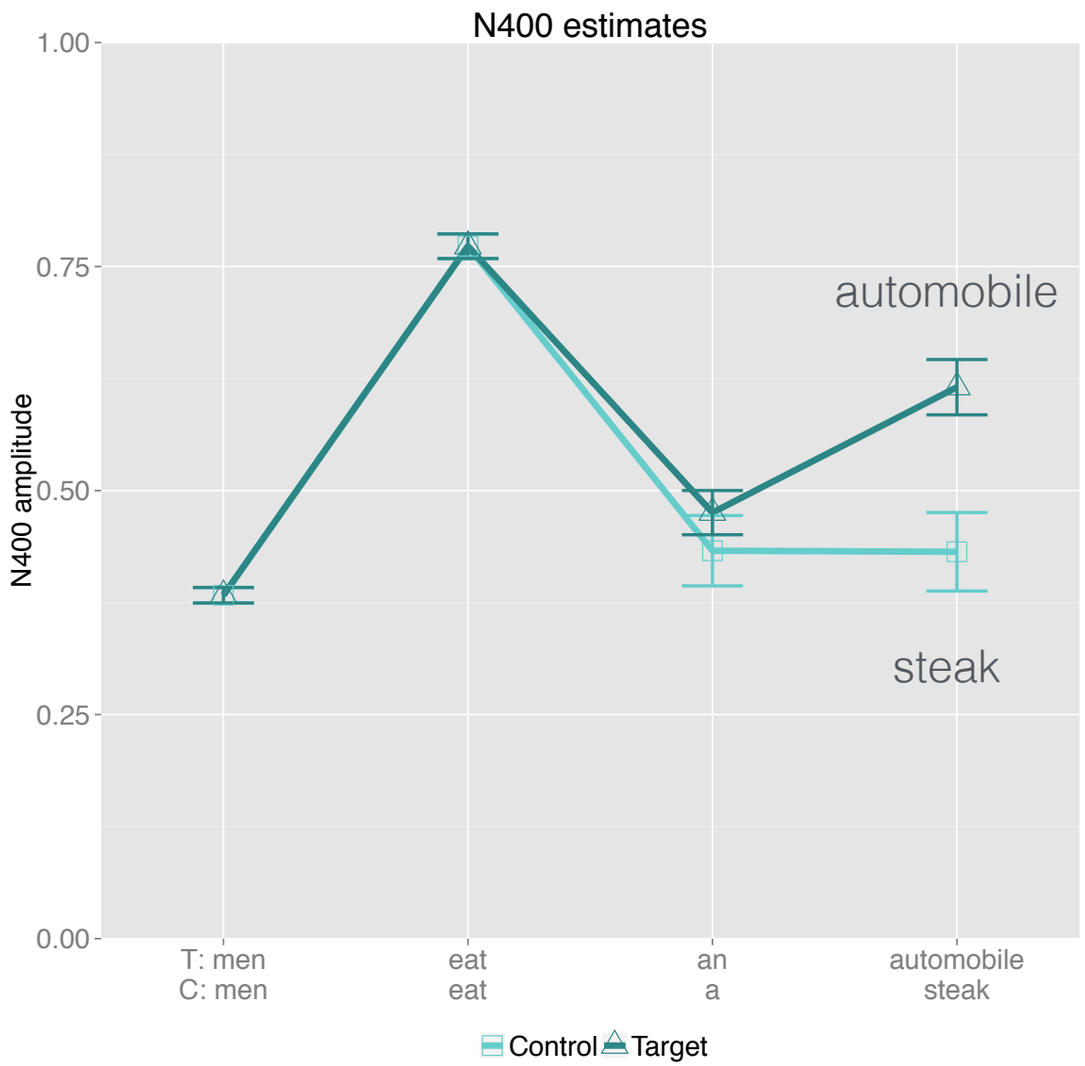

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Q: But what about signature P600 modulations?

Connectionist Language Processing — Crocker & Brouwer

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Syntactic Violations

a man were / was […]

(N400: were = was | P600: were > was)

cf. Molinaro et al. (2008), *Cognition*
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a man <u>were</u> / <u>was</u> […]

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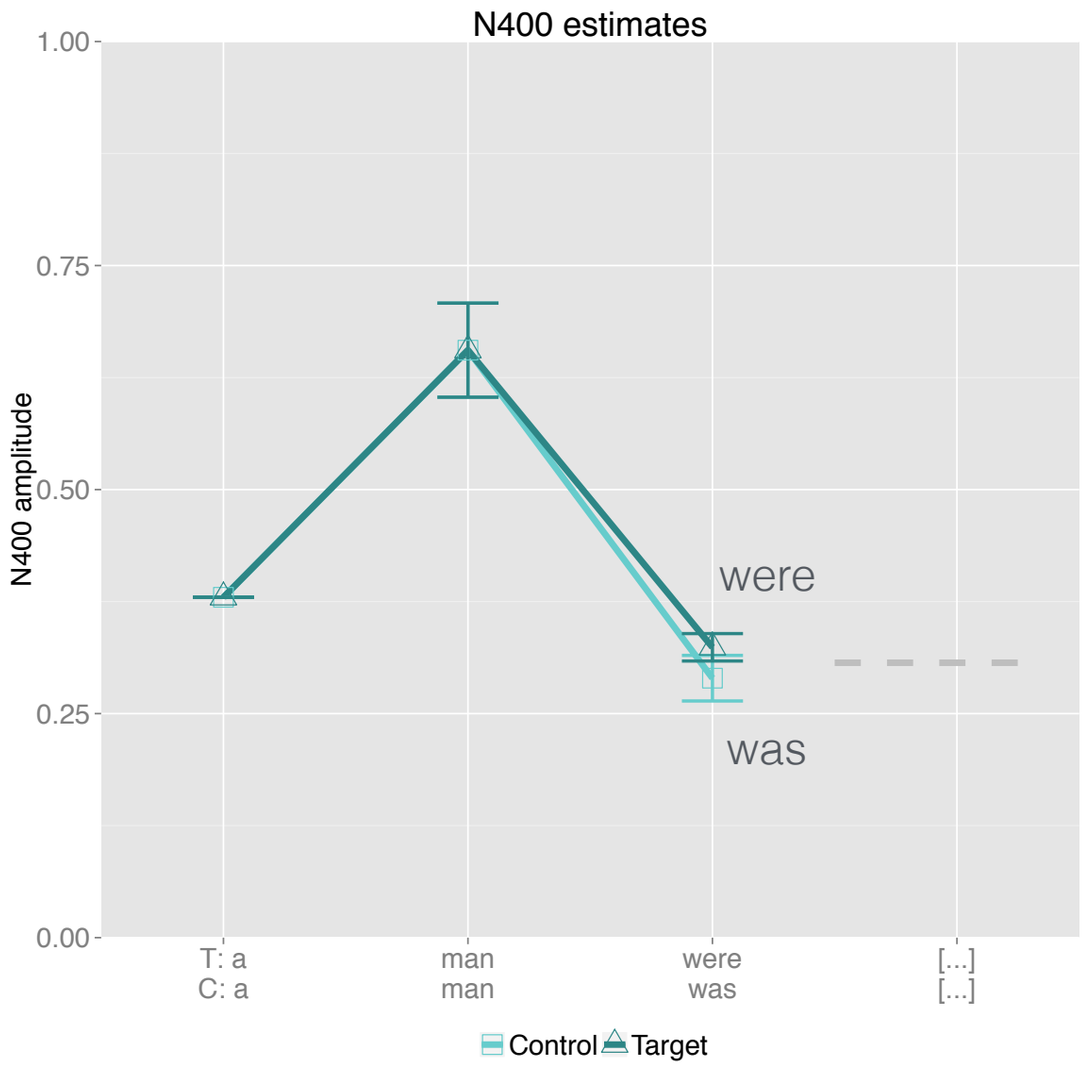

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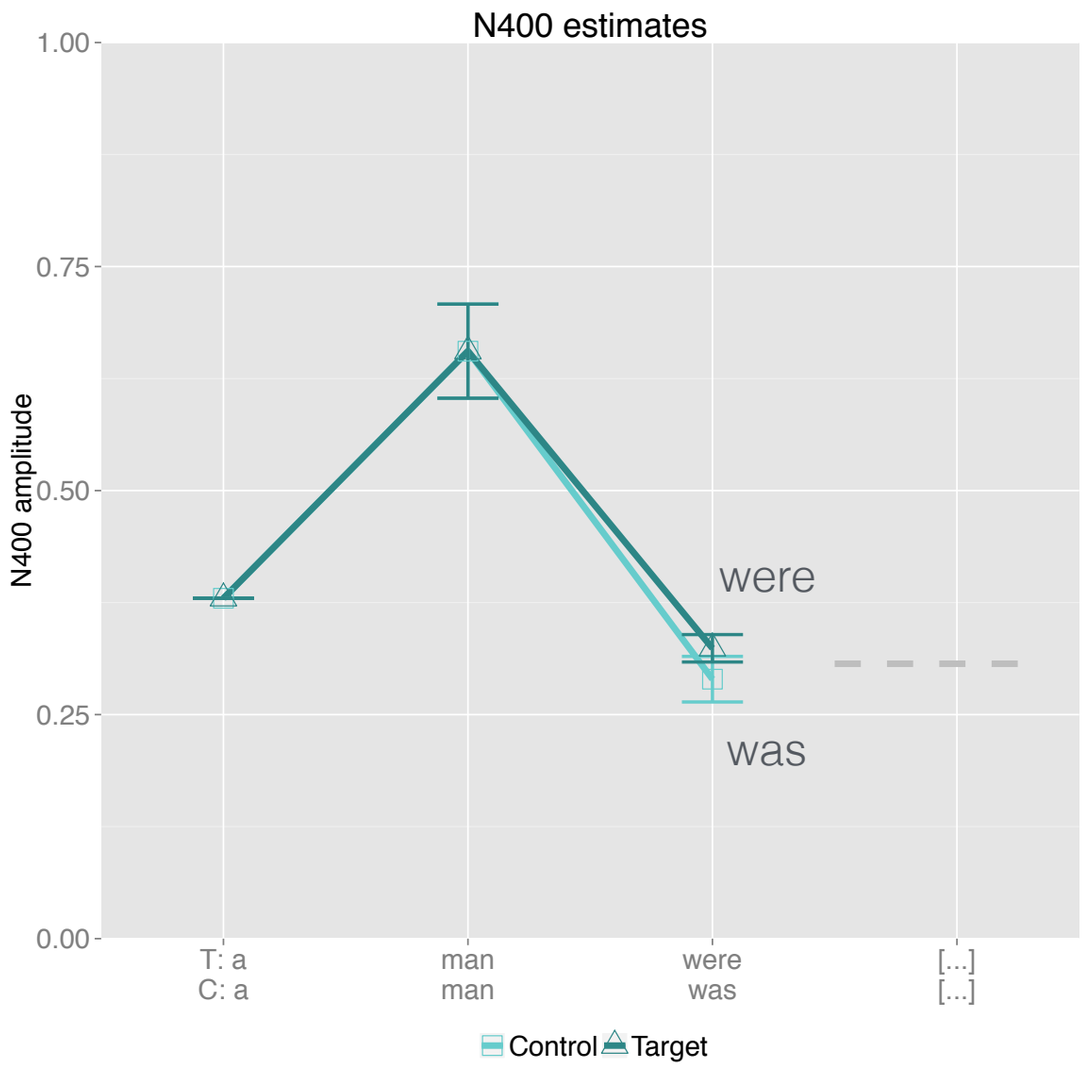

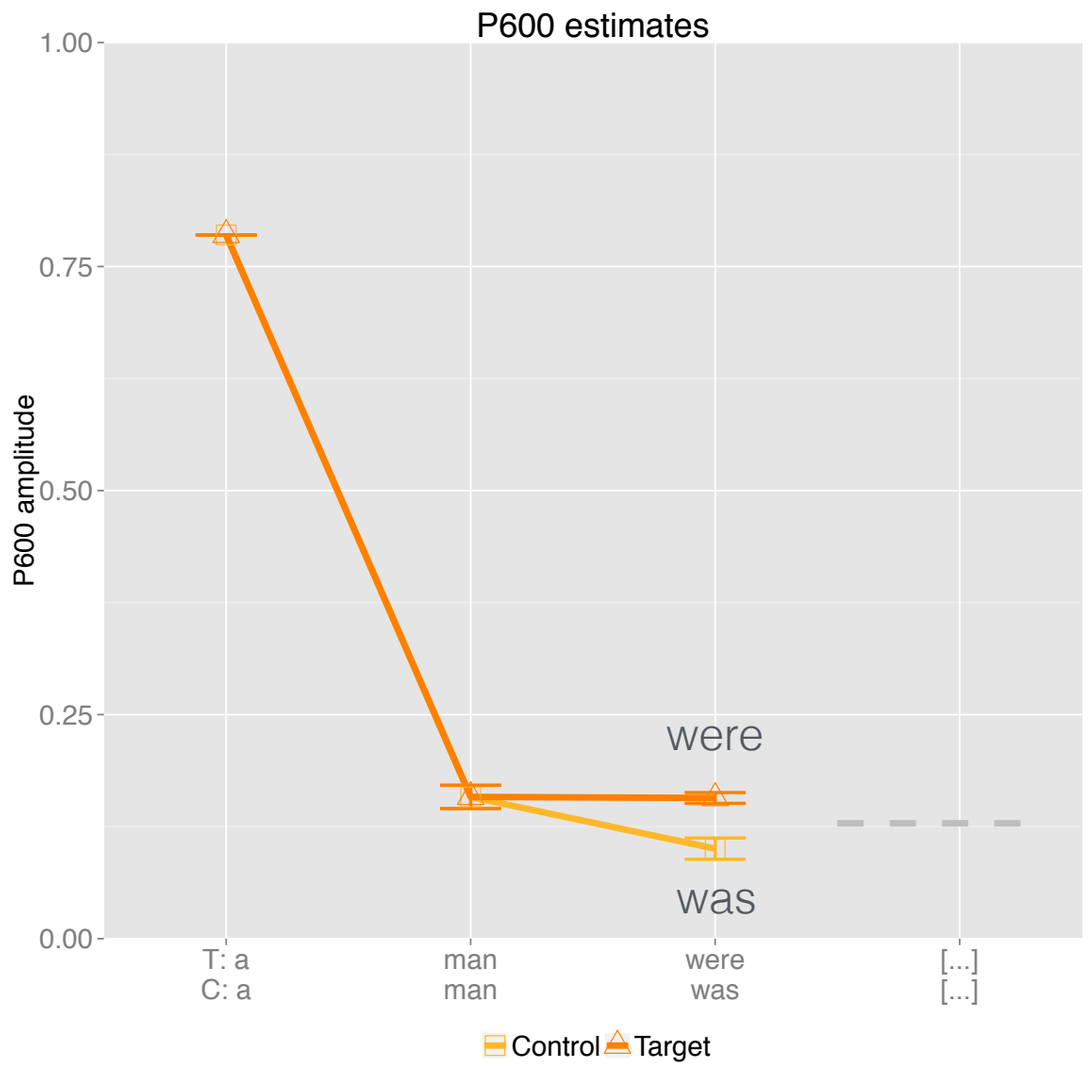

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Garden-paths

a man admired eats […]
a man **that was** admired eats […]

(N400: *red.* = *unred.* | P600: *red.* > *unred.*)

cf. Osterhout & Holcomb (1992), *JML*
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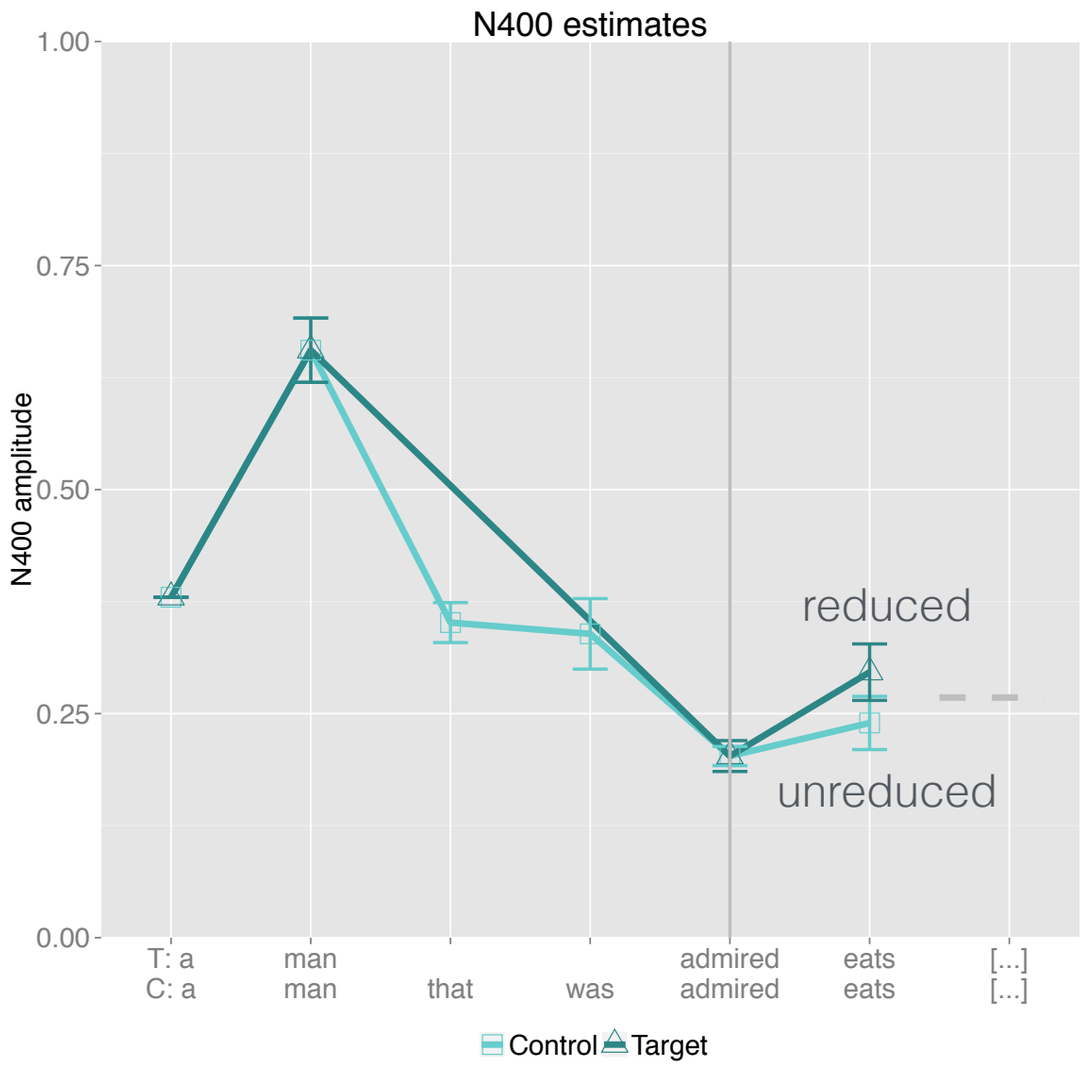

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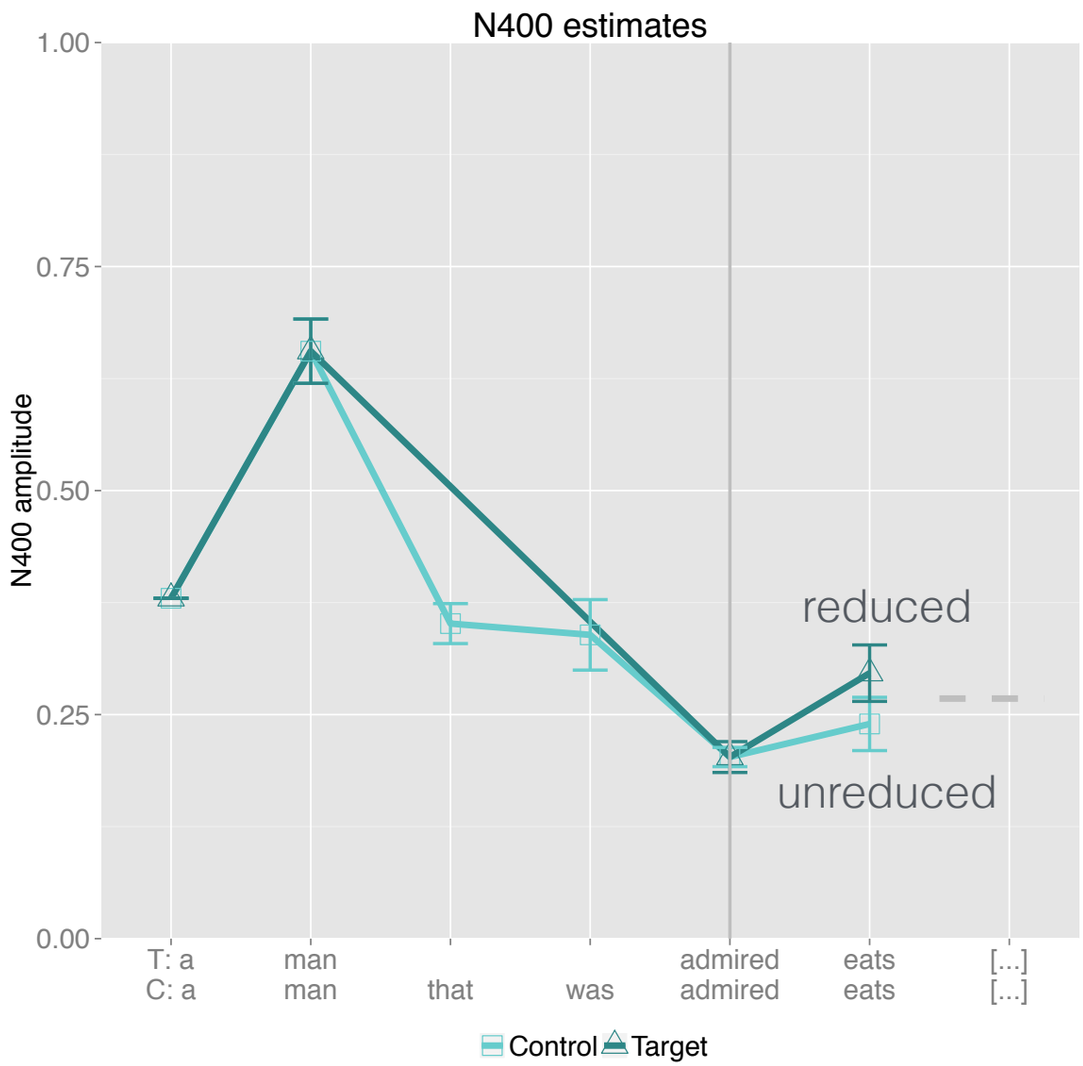

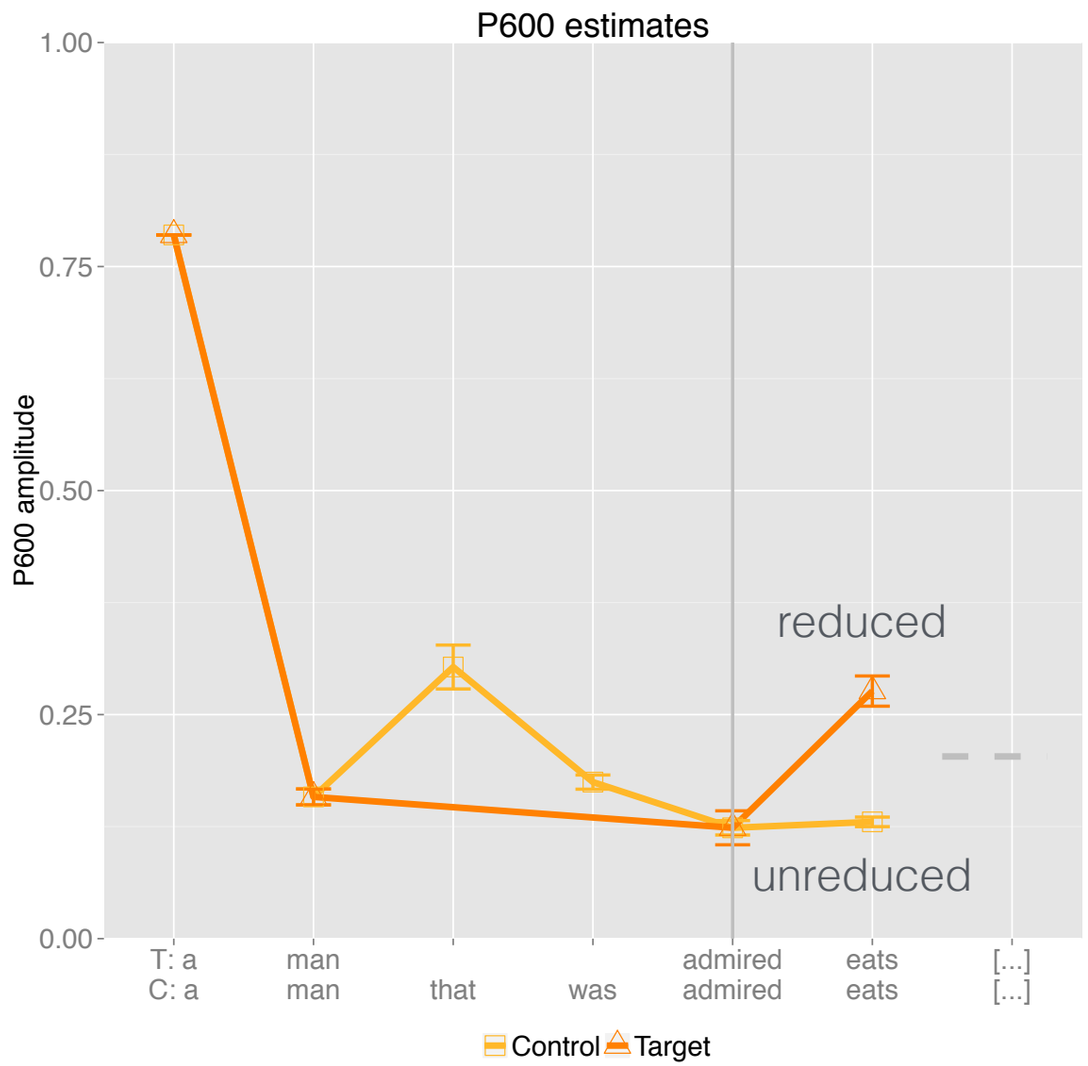

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Semantic Anomalies revisited

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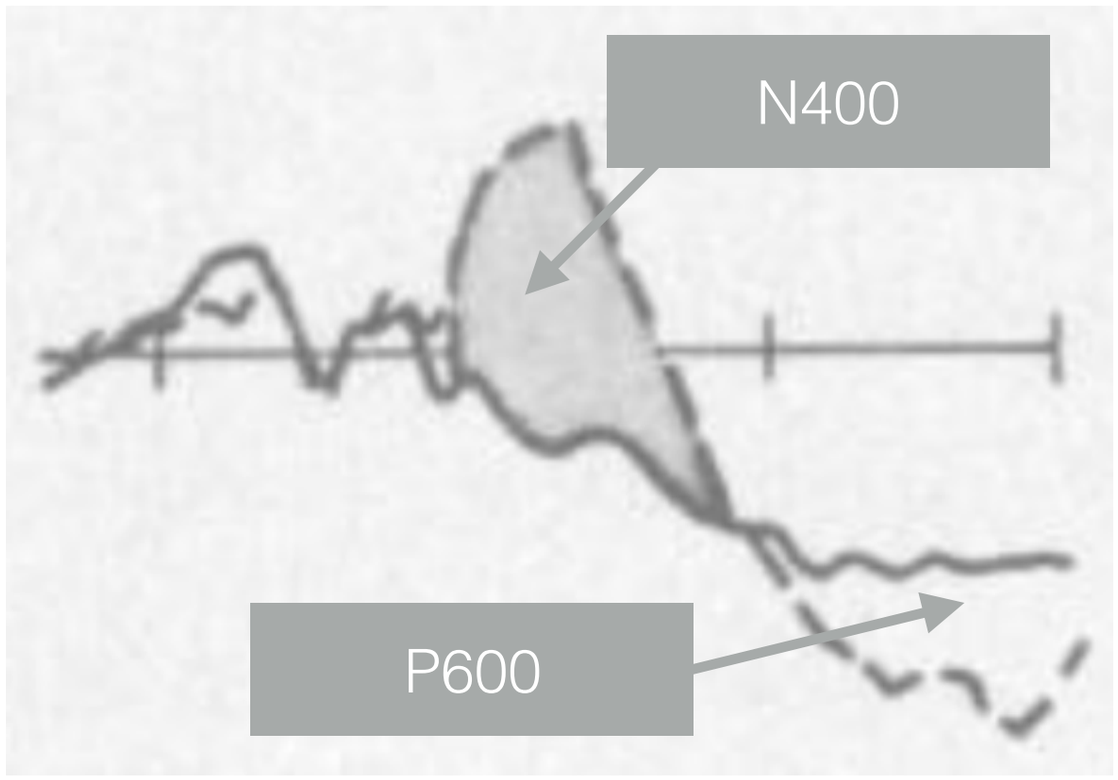
(P600: rugby > beer)



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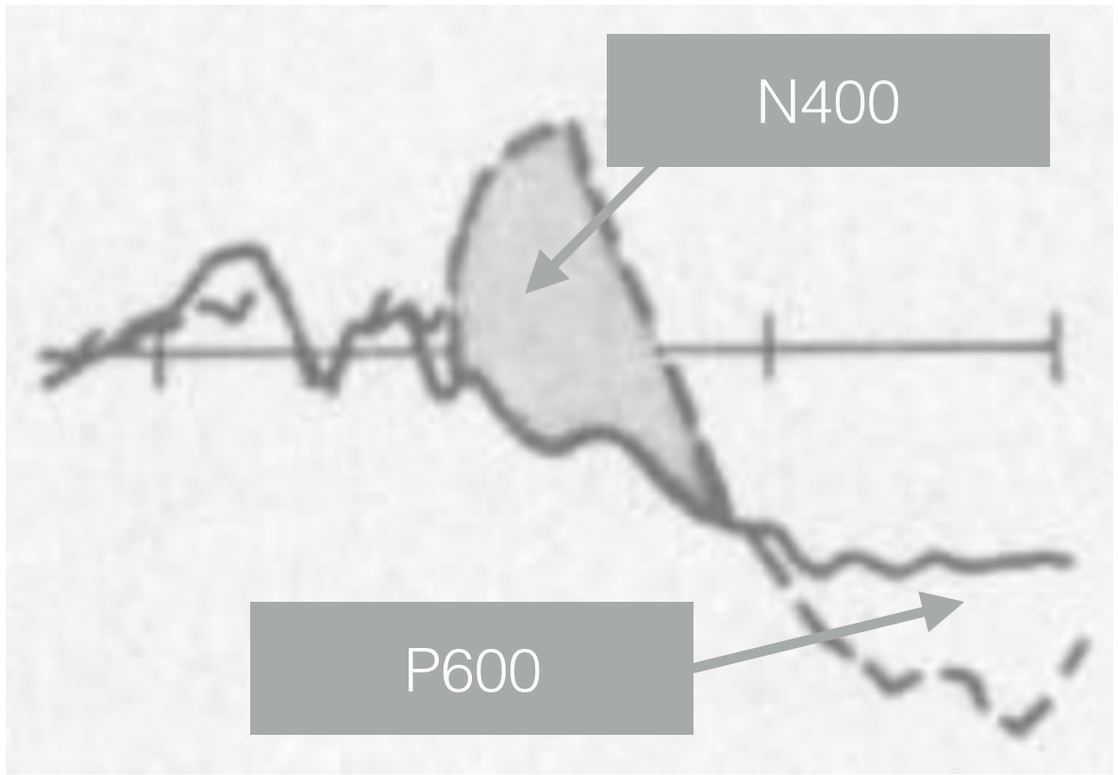

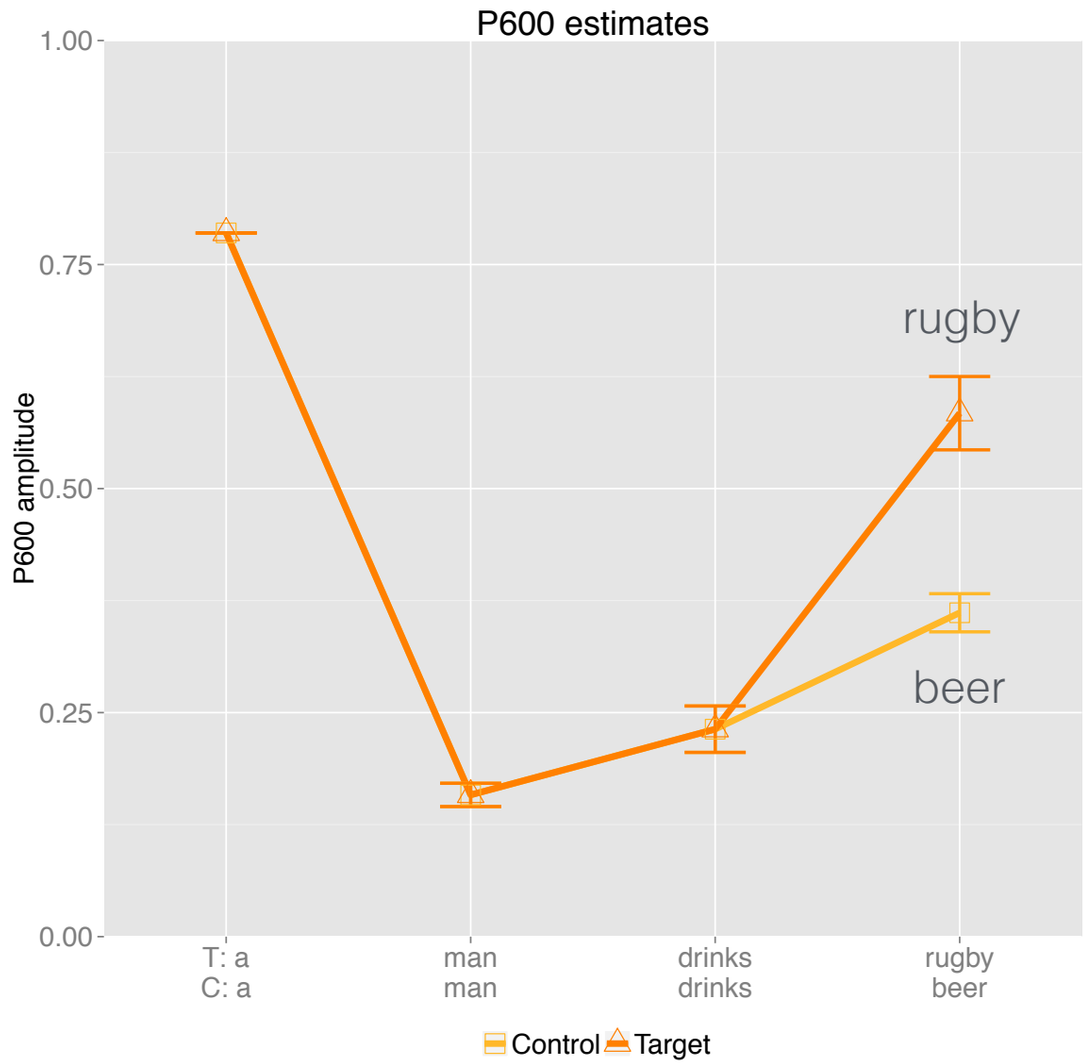

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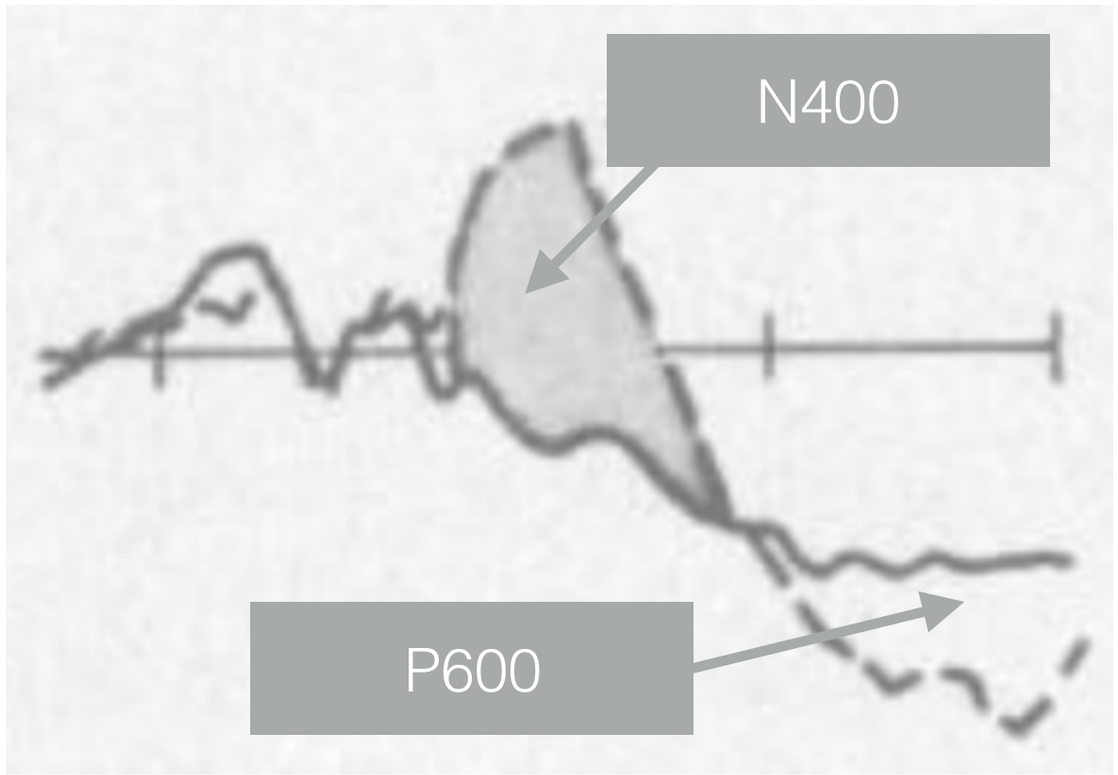

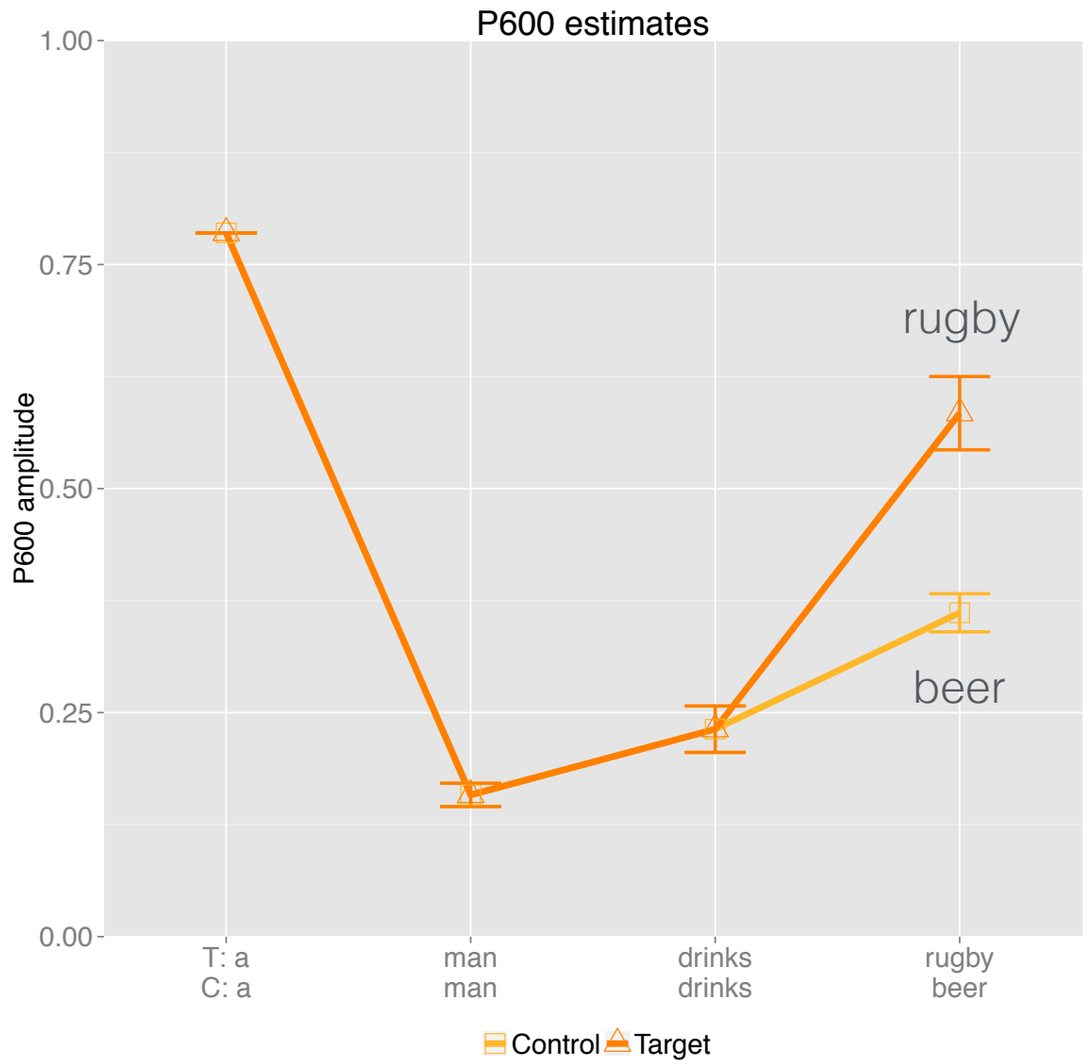

Q: What about reversal anomalies (i.e., the “Semantic P600”-effect)?

cf. Kutas & Hillyard (1980), *Science*

Reversal Anomalies

a steak was eating / eaten […] (N400: eating = eaten | P600: eating > eaten)

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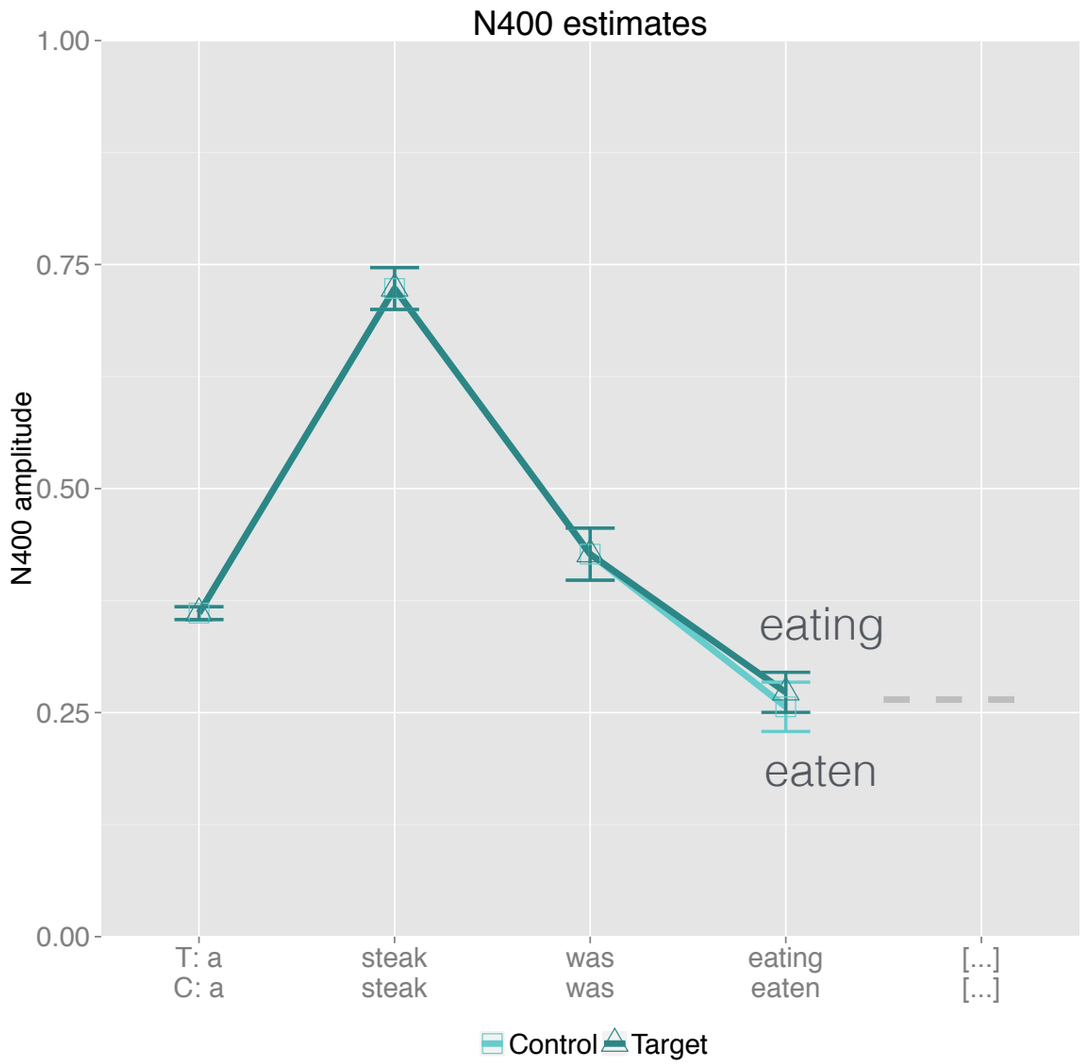

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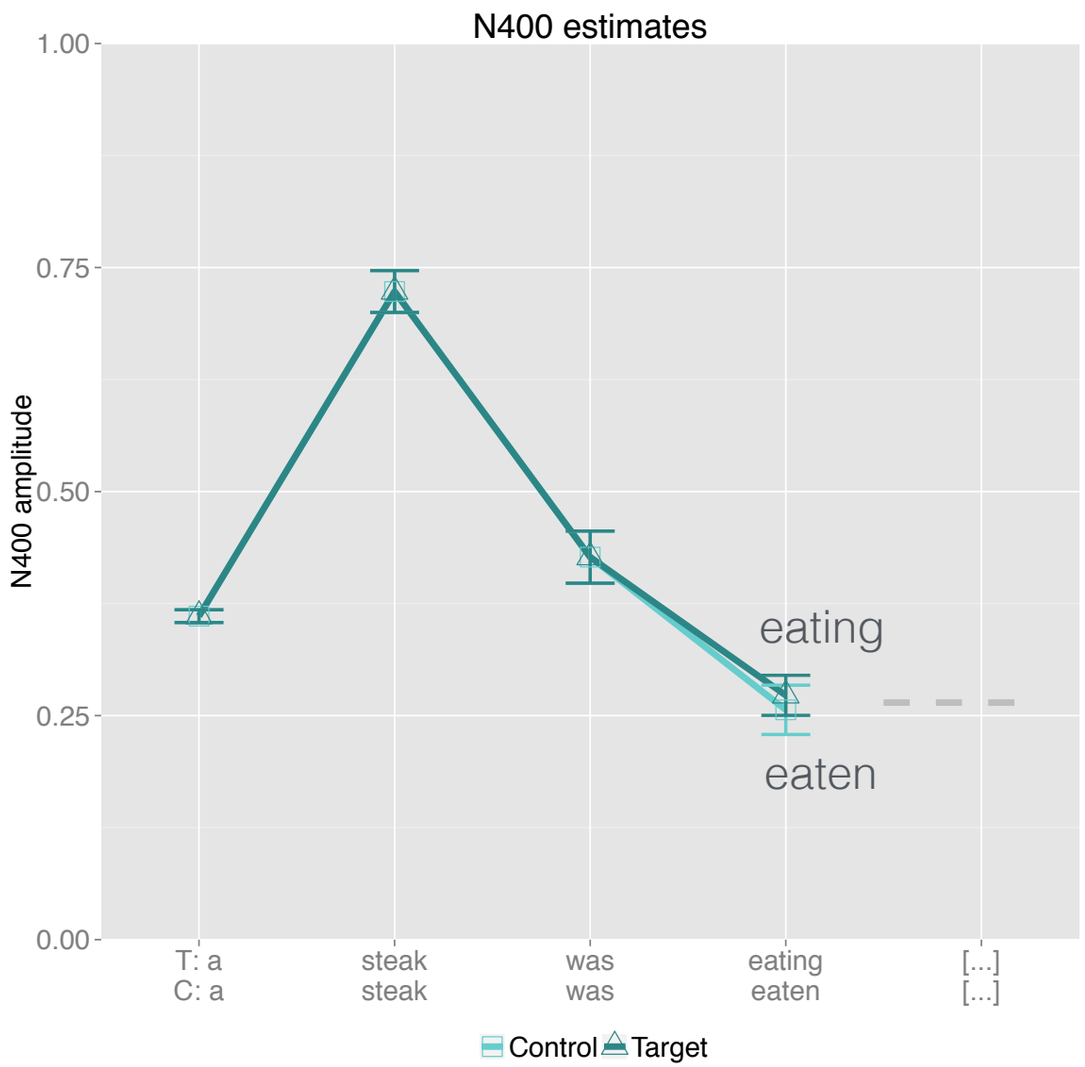

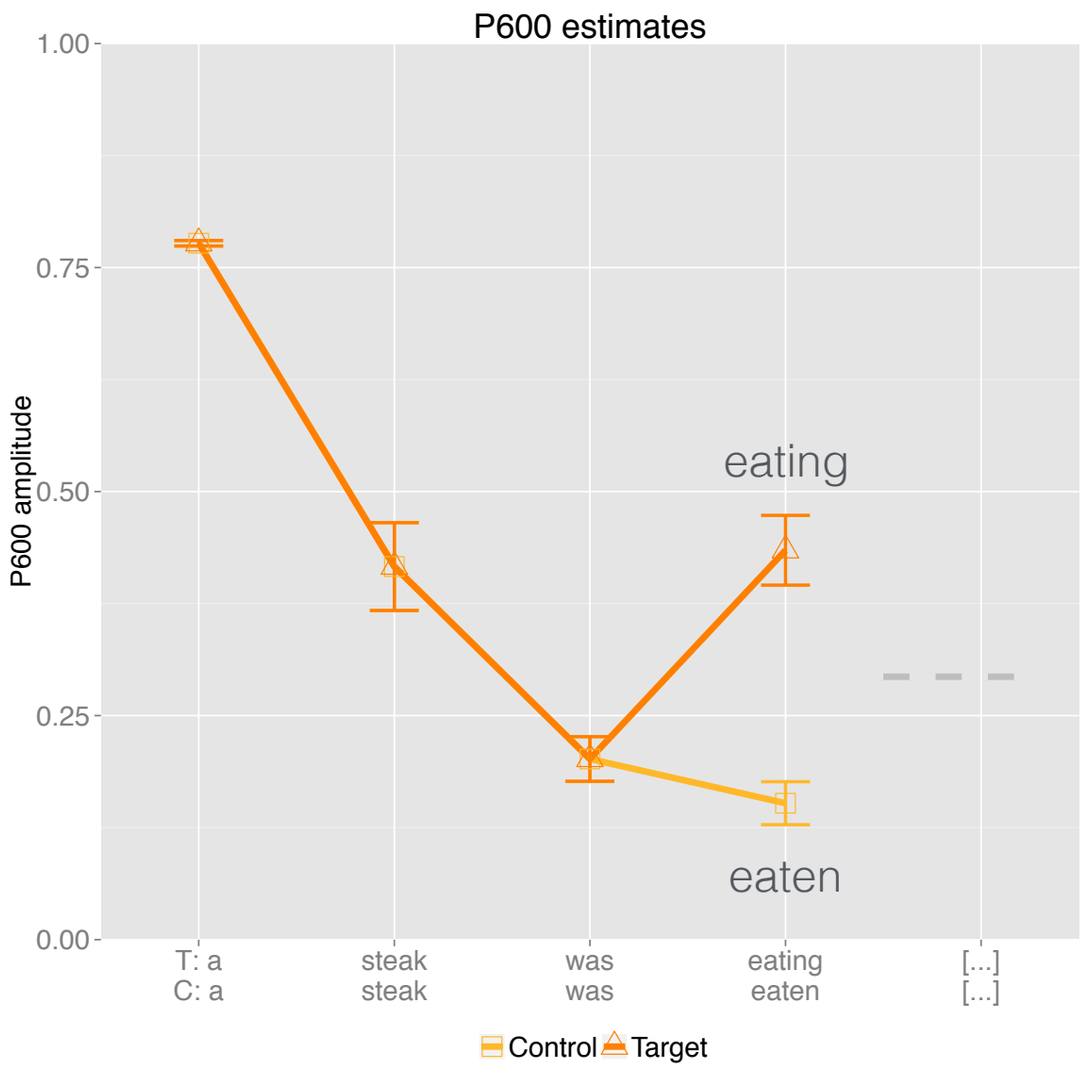

Connectionist Language Processing — Crocker & Brouwer

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> A comprehensive computational model that can be scaled to more phenomena

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