Better than expected: The dynamics of prediction-based processing in younger and older adults' language comprehension

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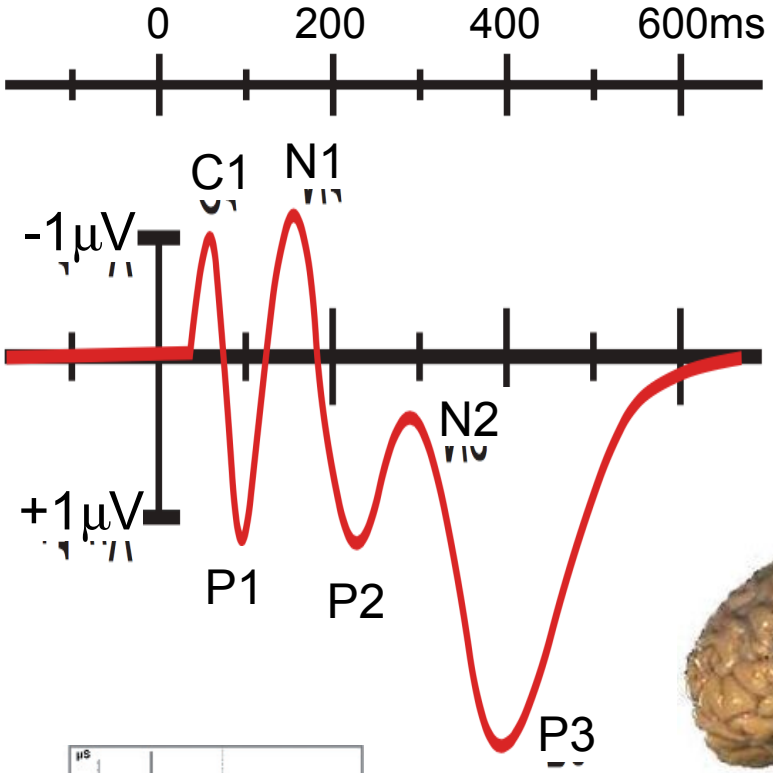
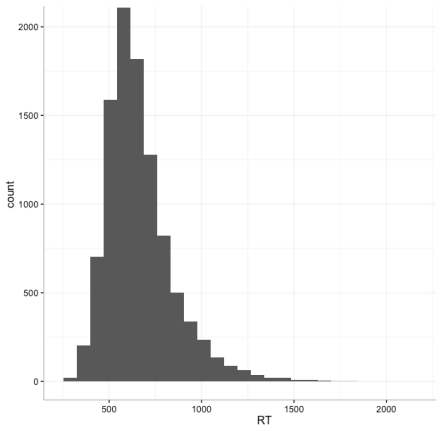
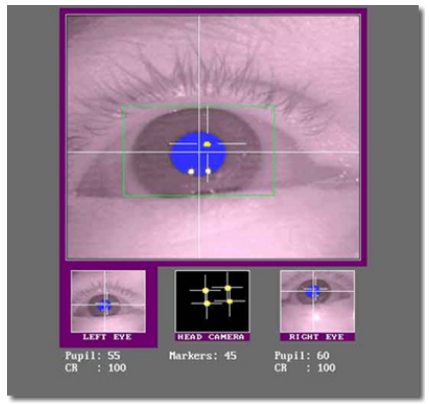
Beckman Institute for Advanced Science and Technology
University of Illinois

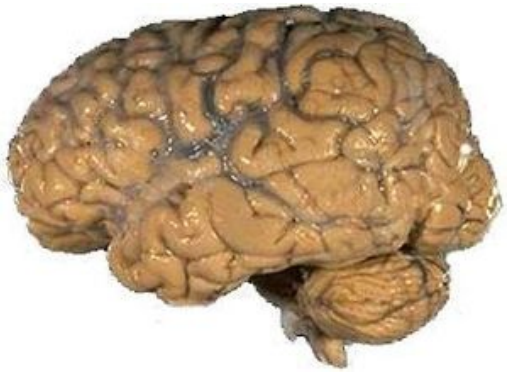

TELLS IT LIKE IT WAS $5.
TELLS IT LIKE IT IS $10.
TELLS IT LIKE IT WILL BE $20.

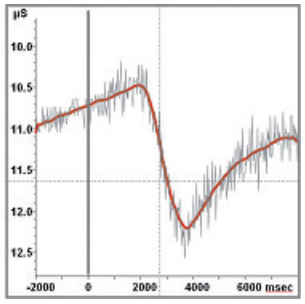
Methods


0
200
400
600ms
C1
N1
-1μV
+1μV
N2
P1
P2
P3

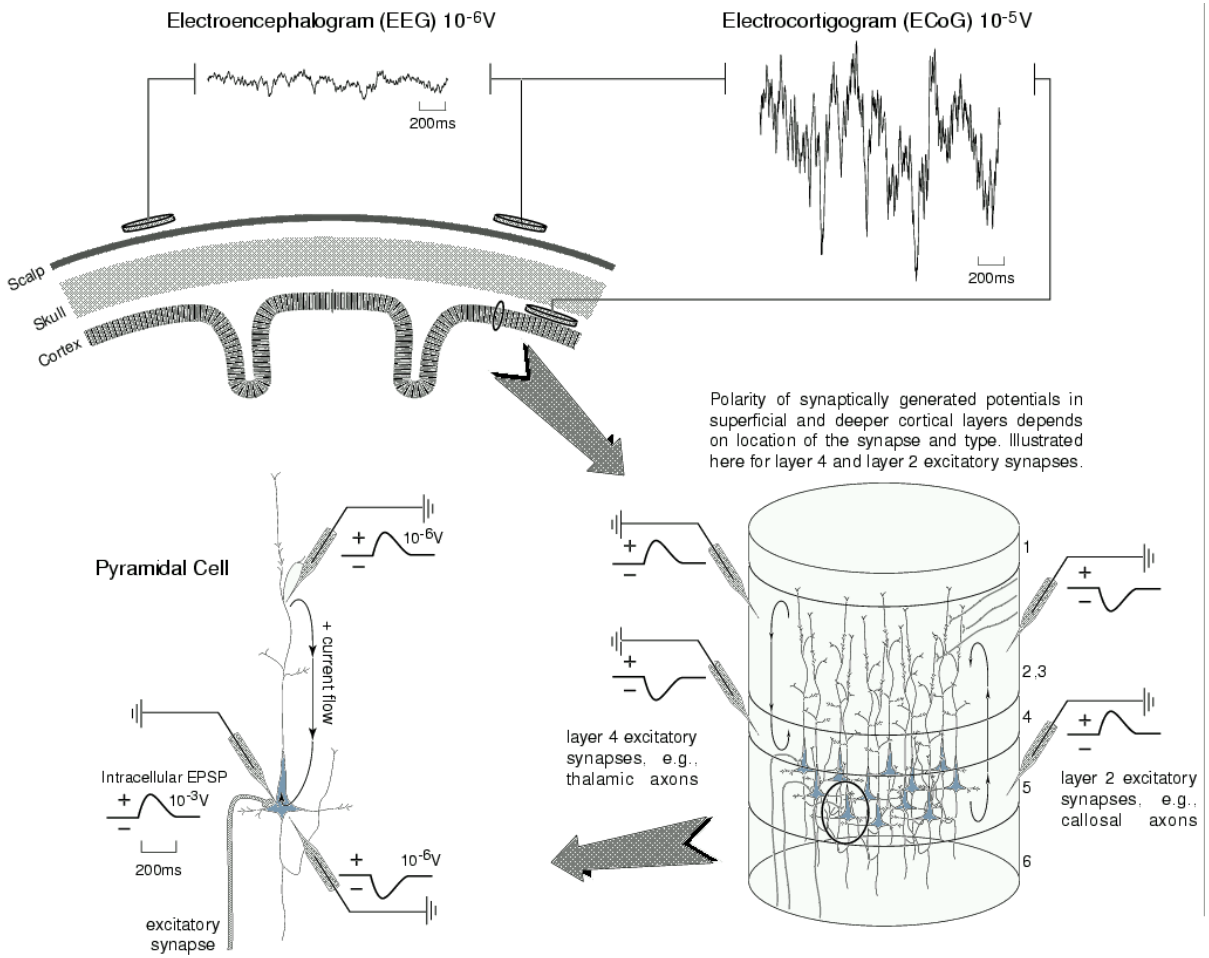

count
RT
500
1000
1500
2000


LEFT EYE
HEAD CAMERA
RIGHT EYE
Pupil: 55
CR : 100
Markers: 45
Pupil: 60
CR : 100

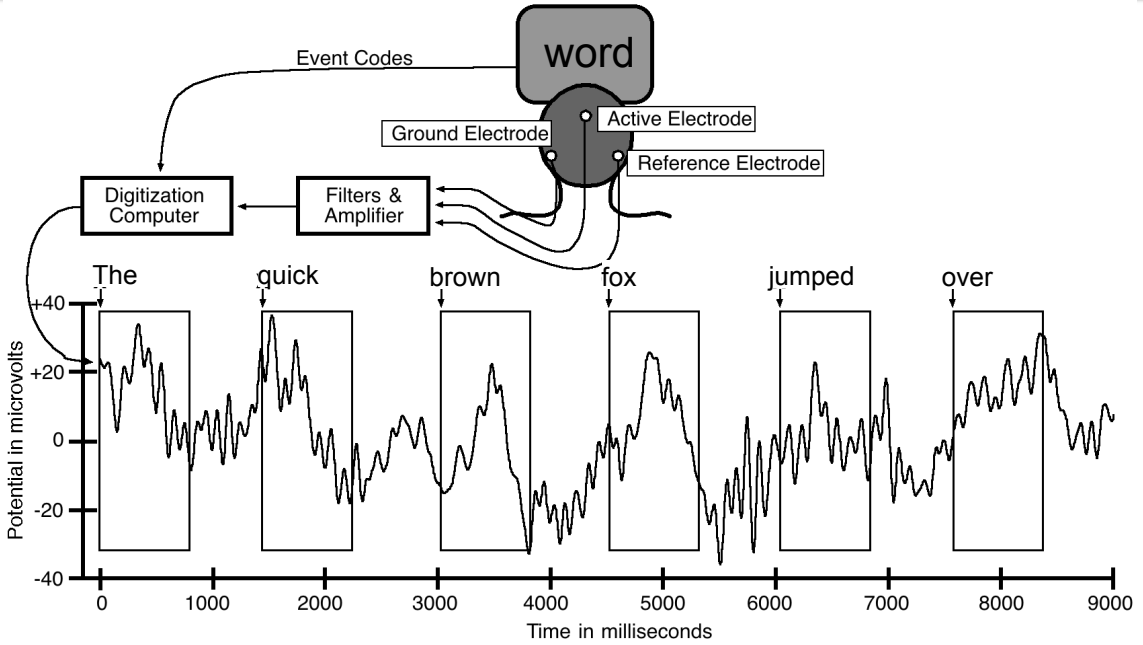



μS
10.0
10.5
11.0
11.5
12.0
12.5
-2000
0
2000
4000
6000 msec

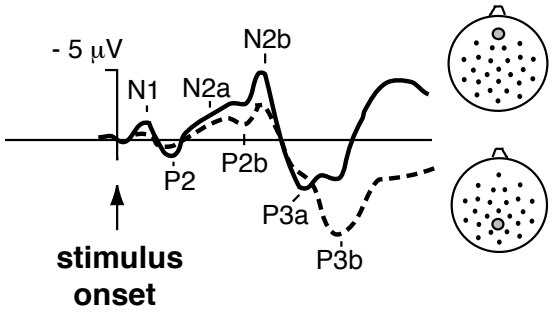
Biological basis of the EEG

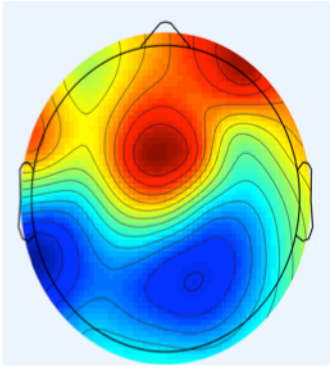


Derivation of the ERP



Event related potential (ERP)





Visual processing timeline

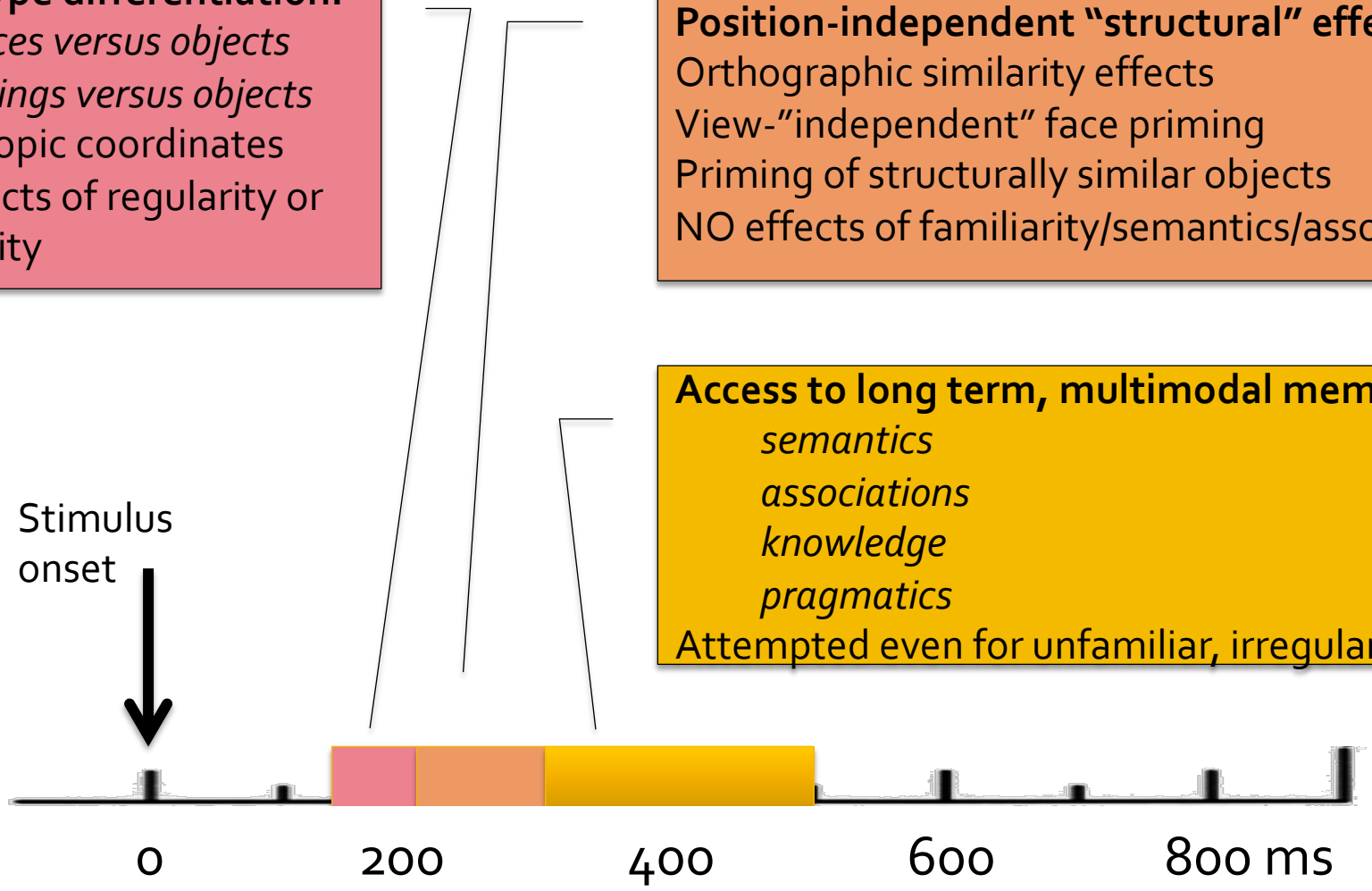
Input type differentiation:
- *Faces versus objects*
- *Strings versus objects*

Retinotopic coordinates
NO effects of regularity or familiarity

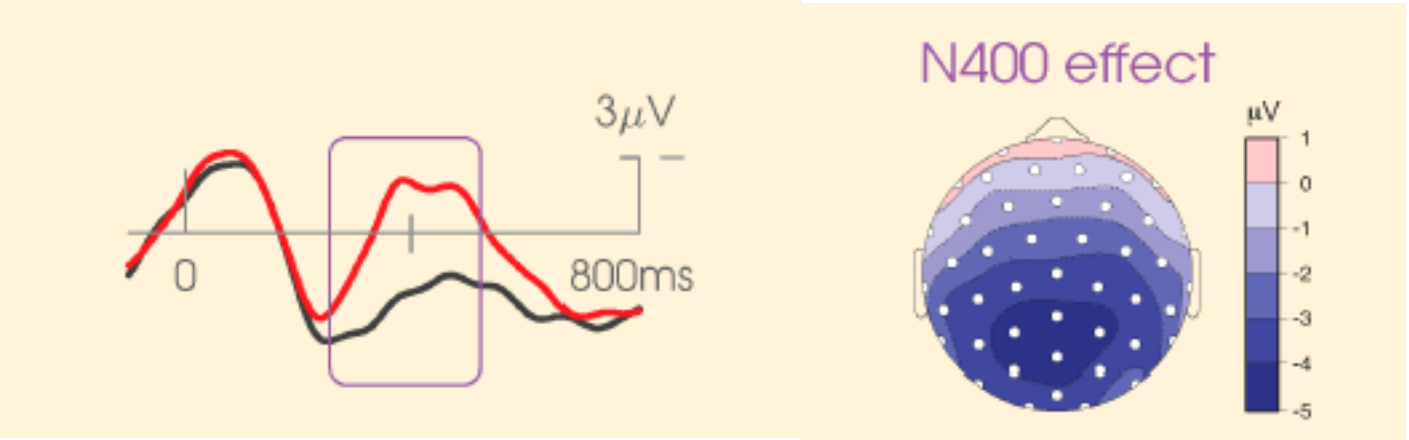
Position-independent "structural" effects:
Orthographic similarity effects
View-"independent" face priming
Priming of structurally similar objects
NO effects of familiarity/semantics/association

Access to long term, multimodal memory:
- *semantics*
- *associations*
- *knowledge*
- *pragmatics*

Attempted even for unfamiliar, irregular stimuli

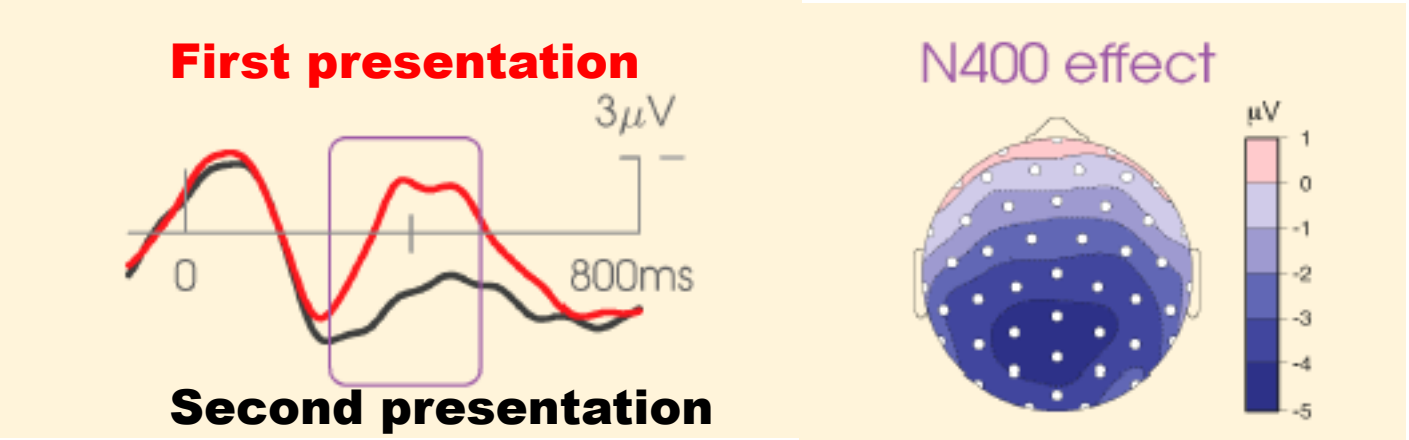


The N400



- negative-going voltage deflection; part of the normal response to meaningful stimuli of all types in a wide variety of tasks
- 250-550 ms (peak ~400 ms); stable latency
- amplitude reduced by factors that ease semantic access

The N400



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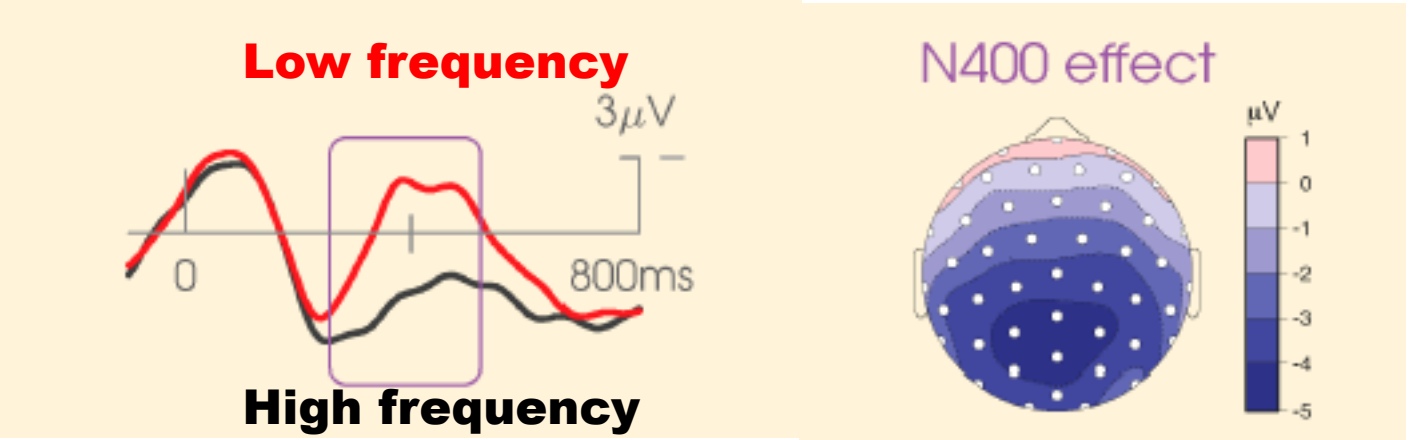

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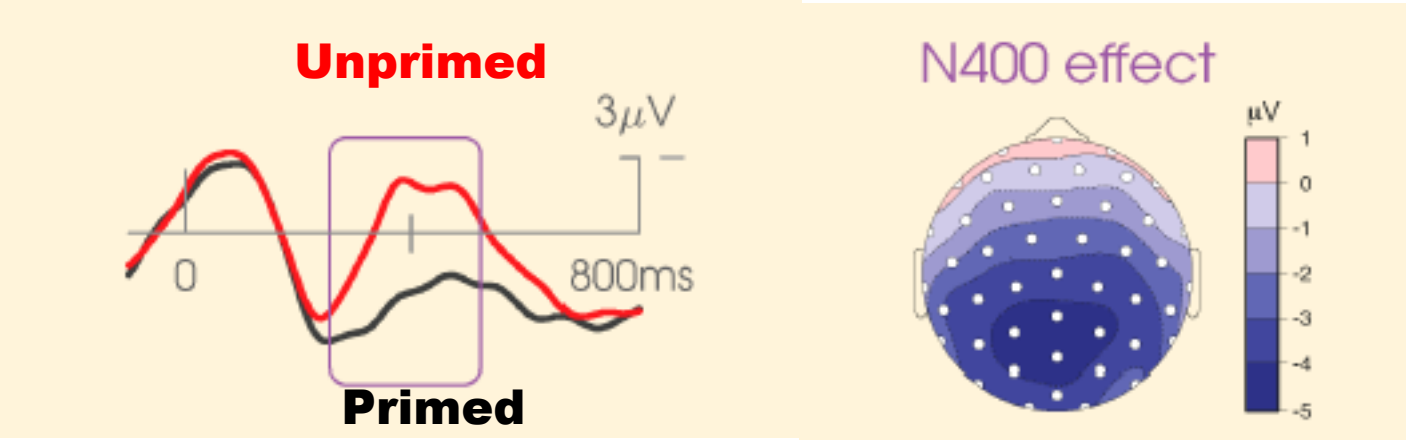

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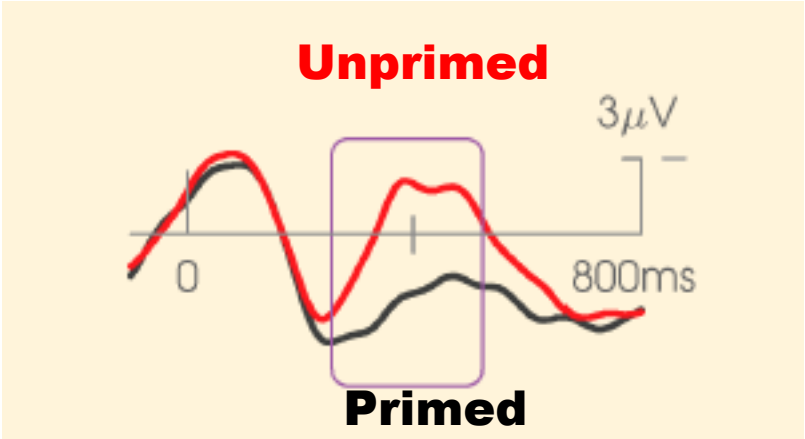
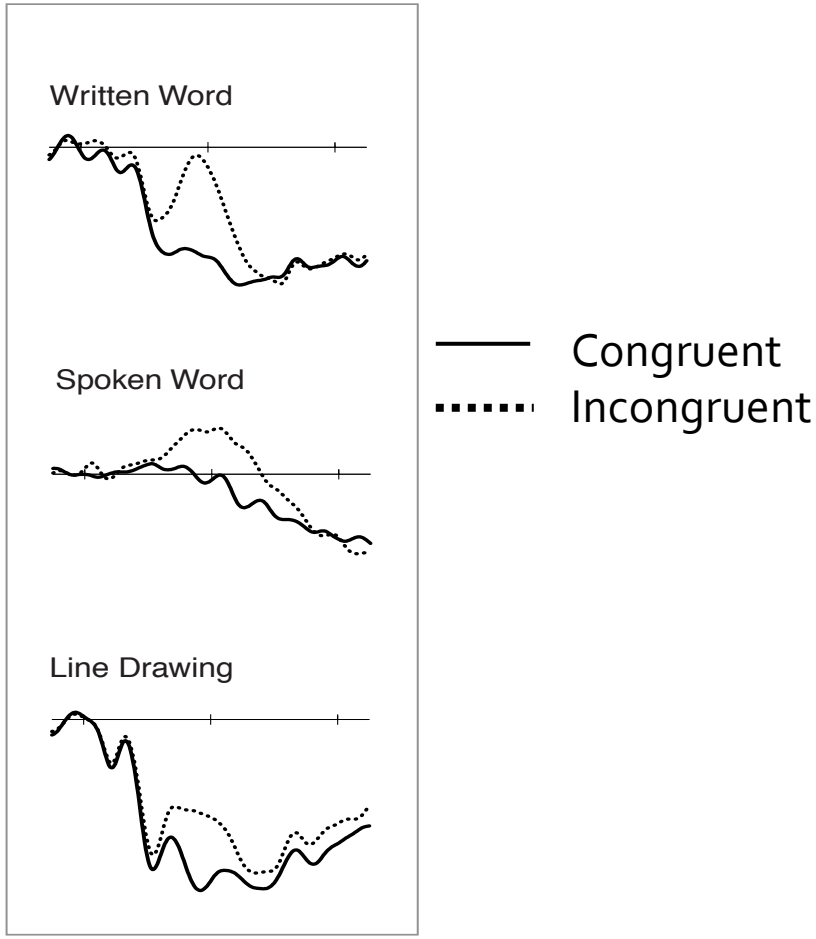
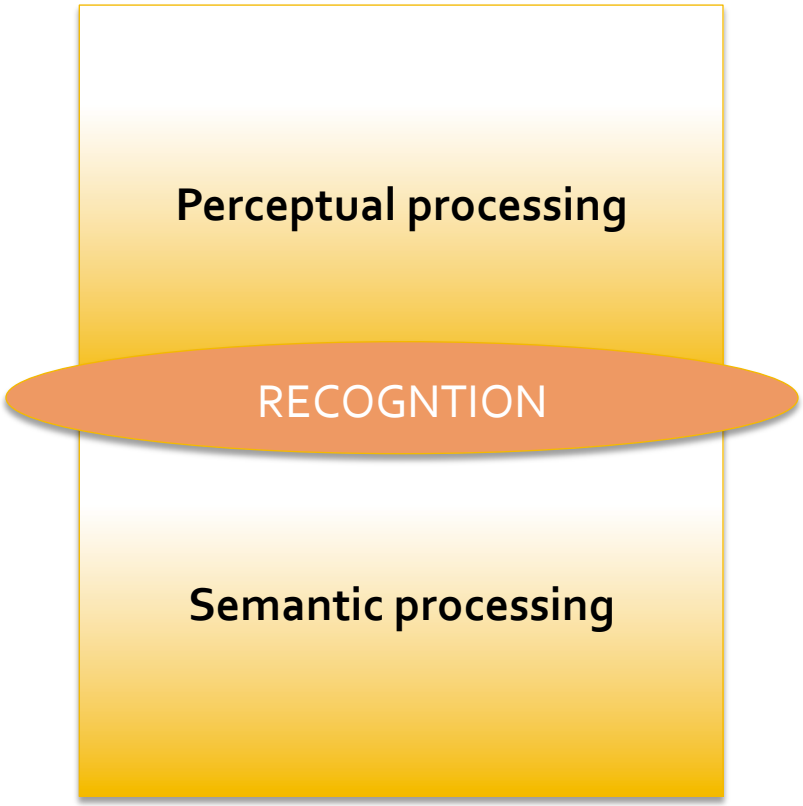

Unprimed
3μV
0
800ms
Primed


Sentence Final
Three Modalities
Written Word
Spoken Word
Line Drawing
Congruent
Incongruent

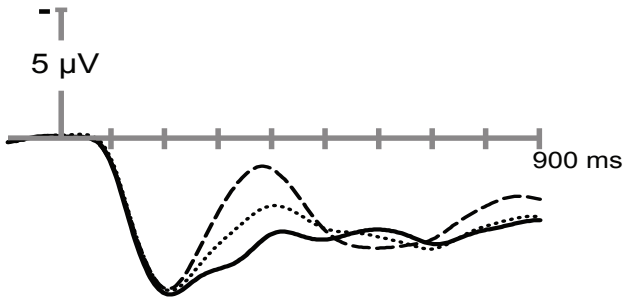
Meaning access out of context



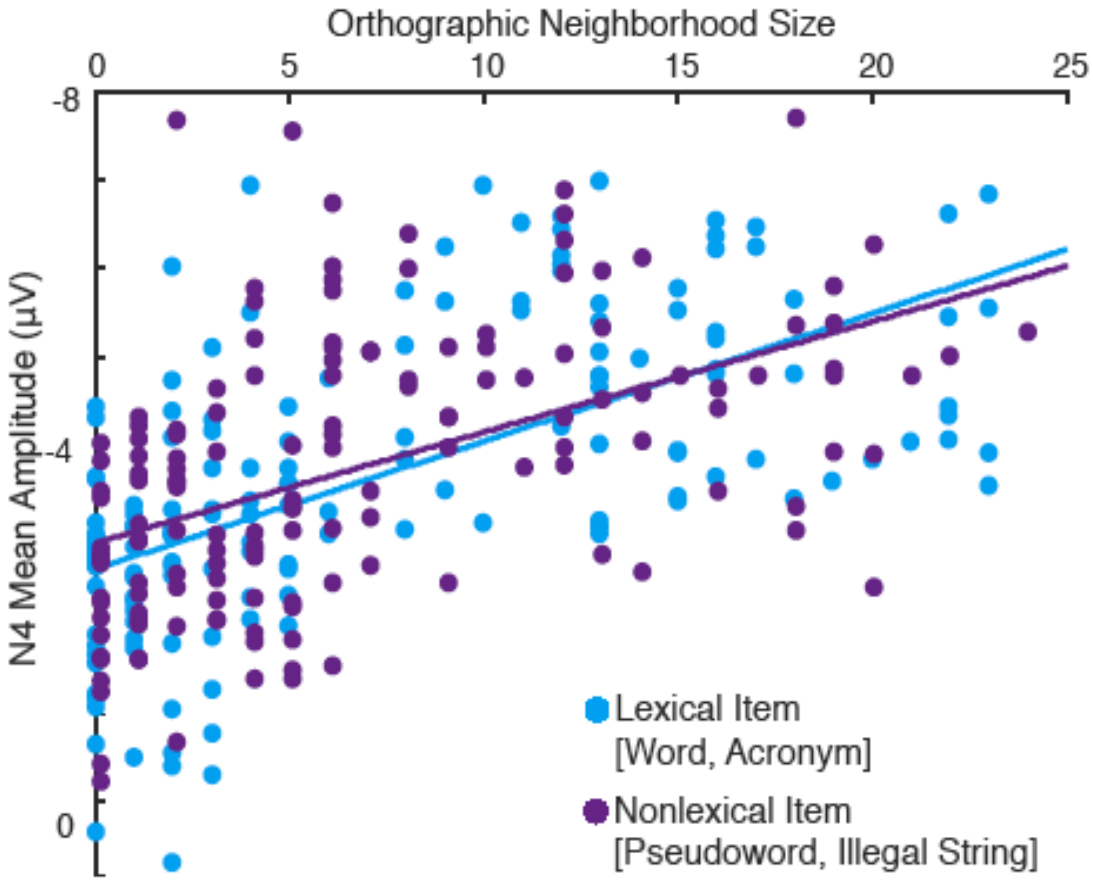
N400 latency is highly stable

- The N400 does not change its timing as a function of repetition, priming, frequency, familiarity, noise level, task demands, goals, attentional states, etc.
- Primary determiner of N400 latency is age.
  - Latency decreases across childhood
  - Latency increases across adulthood (1-2 ms/year)
- Semantic access is yoked to *time*, not to recognition.

Neighborhood density and meaningfulness

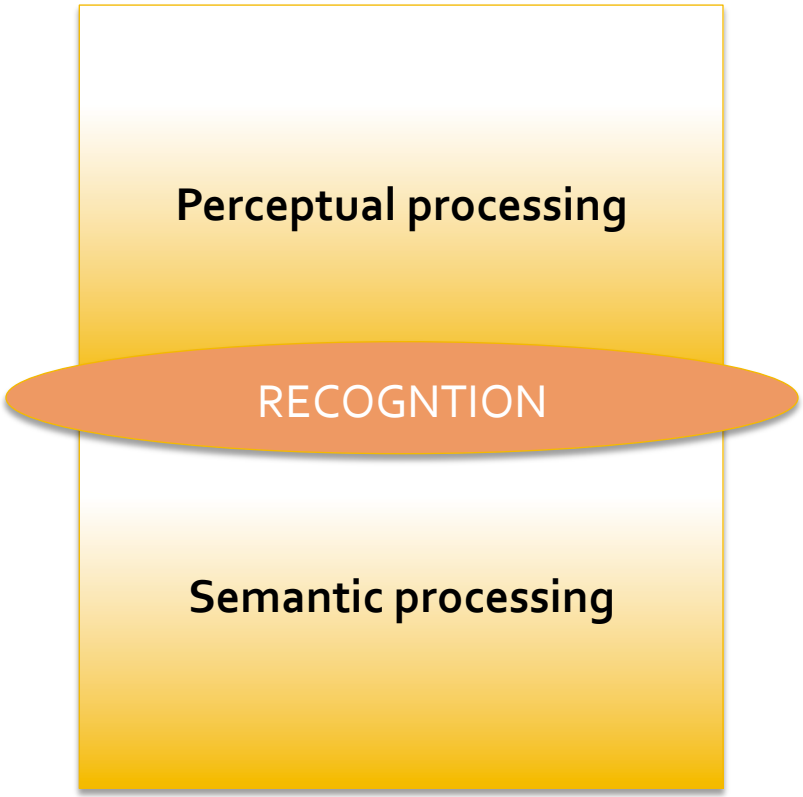


High N *(MAP, LAR)*
Mid N *(FAN)*
Low N *(SKI, BBQ, NGR)*

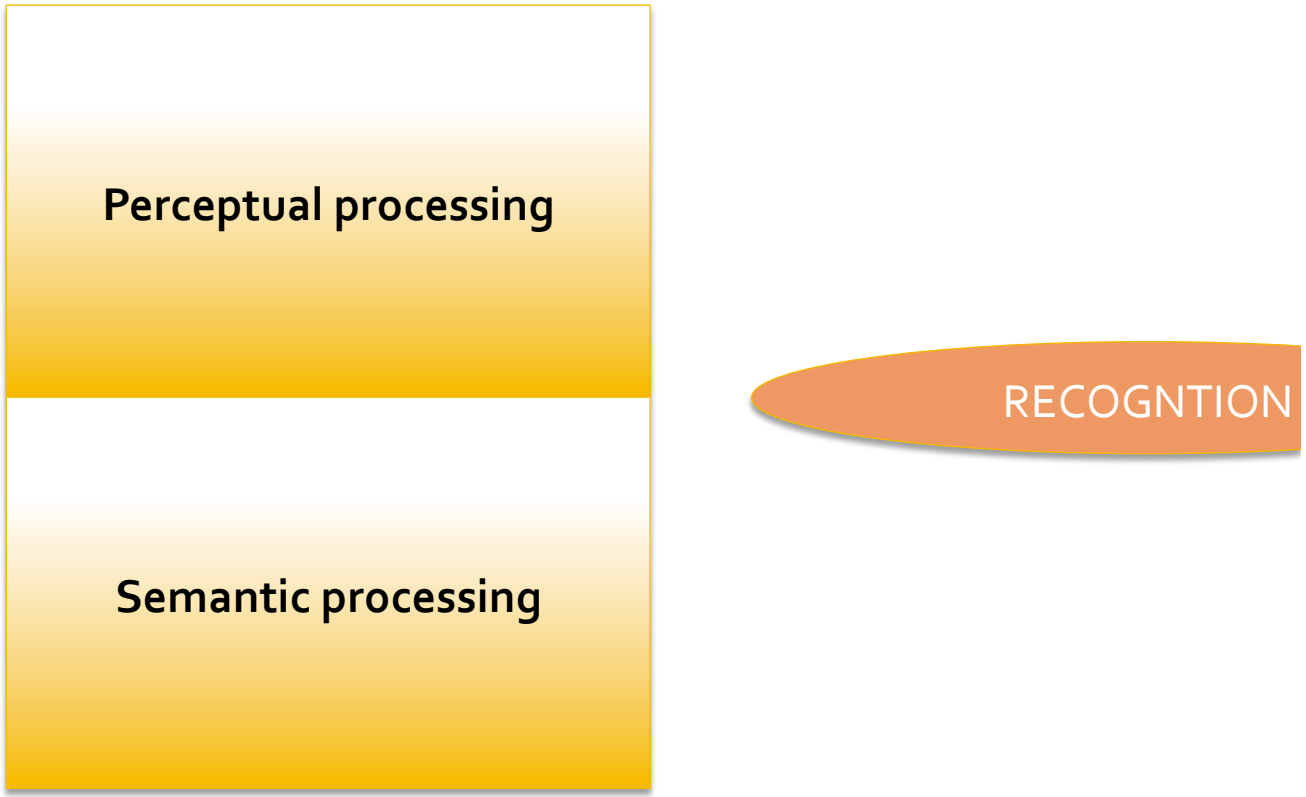


Laszlo & Federmeier 2011

Revisiting meaning access out of context



Revisiting meaning access out of context



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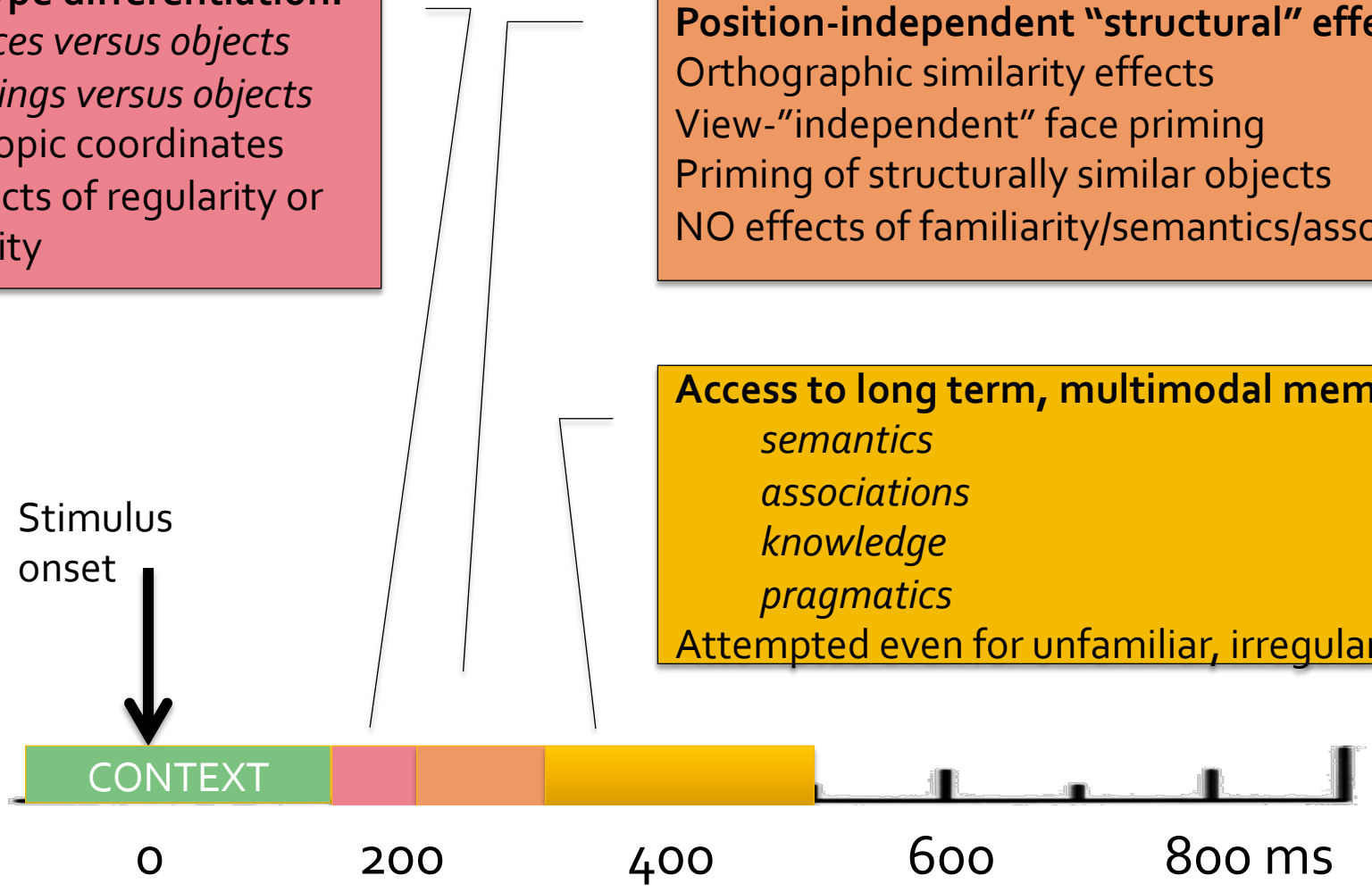


Building a message over time

The N400, an index of semantic processing, decreases in amplitude across a congruent sentence.

13th+ word
10th–12th word
4th–6th word
2nd–3rd word

Congruent: *She **kept checking** the **oven** because the **cake seemed** to be **taking** an awfully **long time** to **bake**.*

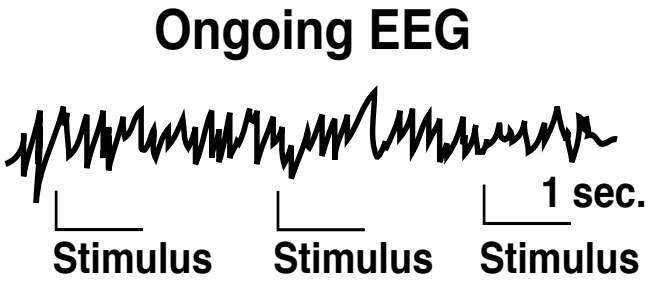
Van Petten & Kutas, 1990, 1991; Van Petten, 1993

Psychophysiology, 00 (2015), 00–00. Wiley Periodicals, Inc. Printed in the USA.

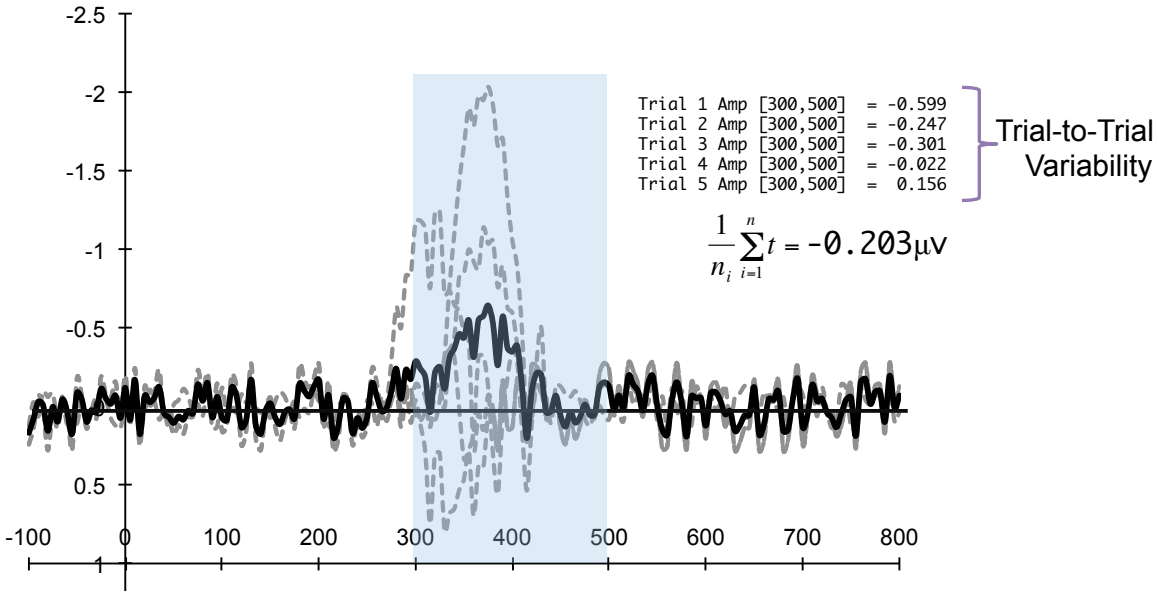
DOI: 10.1111/psyp.12515

Revisiting the incremental effects of context on word processing: Evidence from single-word event-related brain potentials

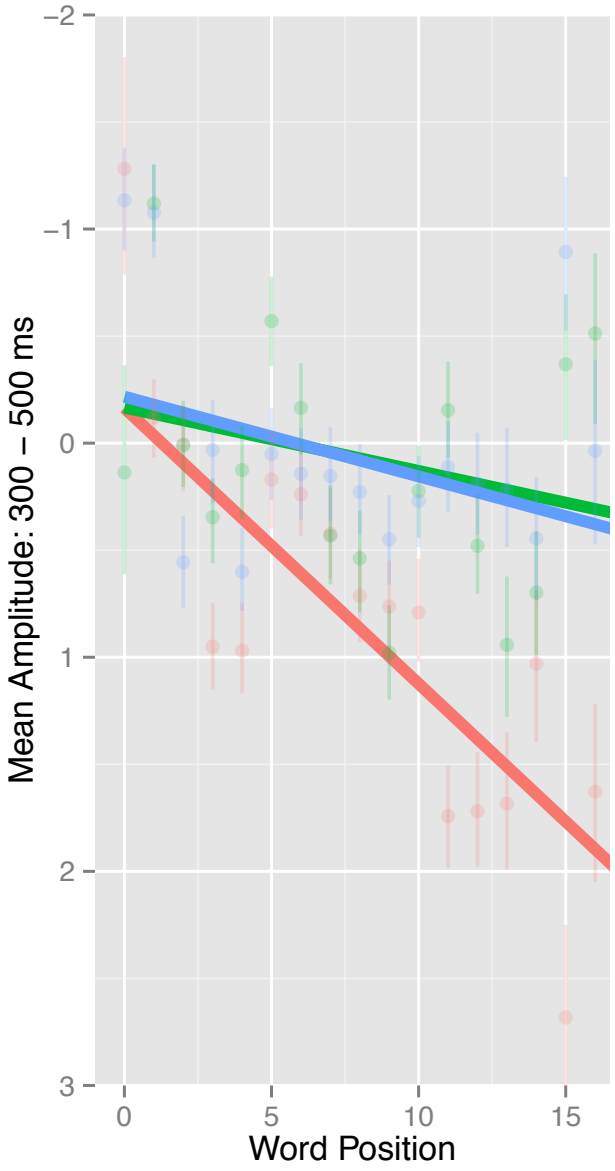
BRENNAN R. PAYNE,[a,b] CHIA-LIN LEE,[d] AND KARA D. FEDERMEIER[a,b,c]

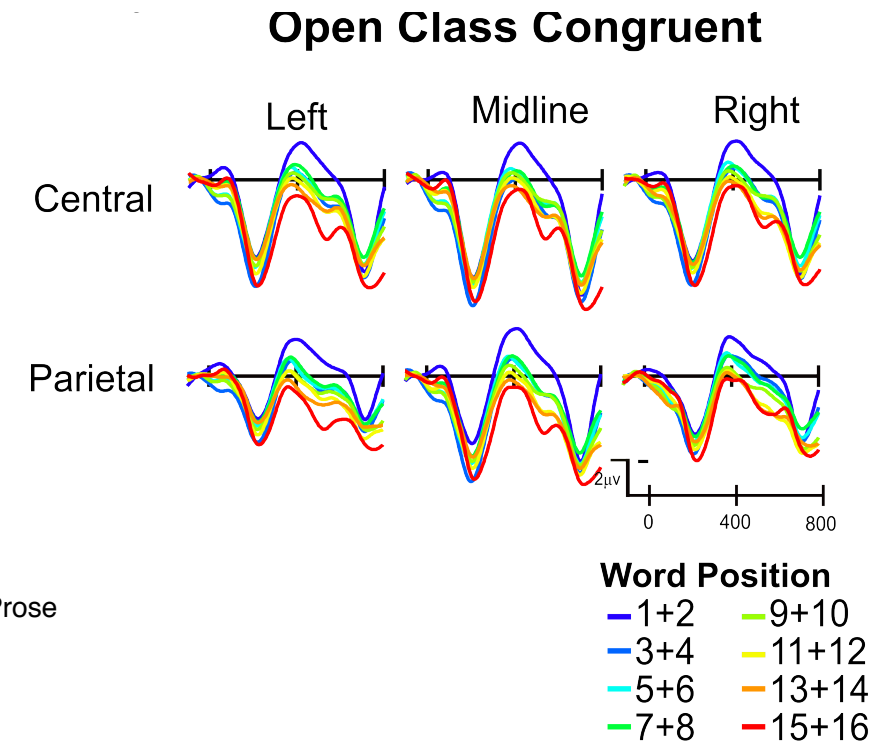


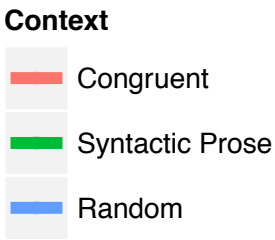
Traditional ERP: Average time-series over multiple trials (to create ERP), then measure mean amplitude within a latency band.



Item-Level: Measure mean amplitude within a latency band on each trial. Use statistical model to average across trials. Mean information is identical, but this approach recovers *item-to-item variability* in mean amplitudes





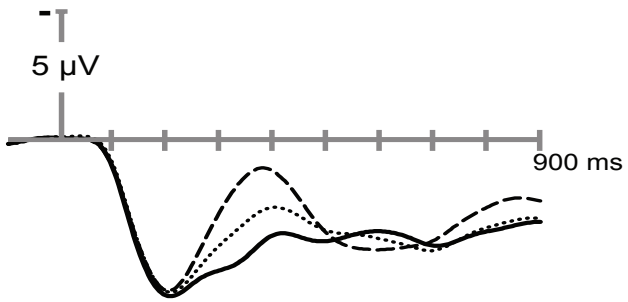


Random: *The court the she spring making missing awfully art poor to because an to be went began bake.*

Syntactic Prose: *She went missing the spring because the court began to be making an awfully poor art to bake.*

Congruent: *She **kept checking** the **oven** because the **cake seemed** to be **taking** an awfully **long time** to **bake**.*

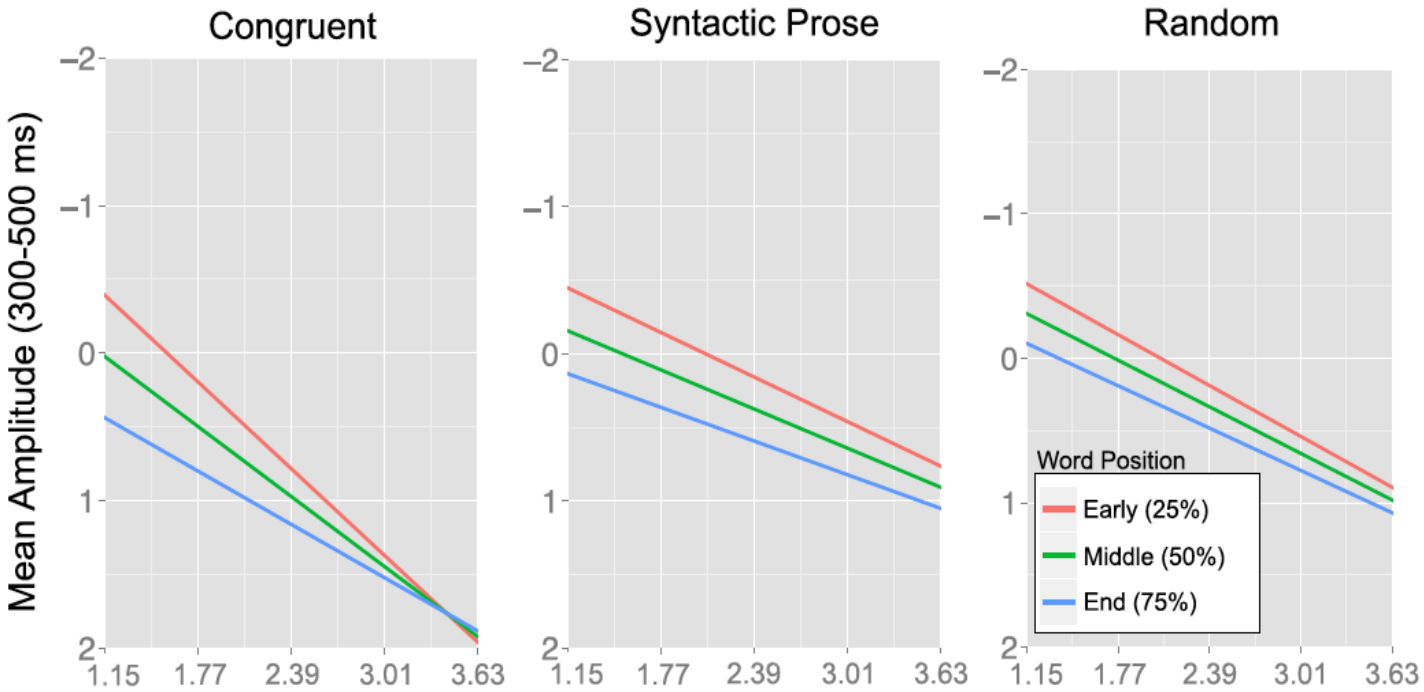
Payne et al., 2015



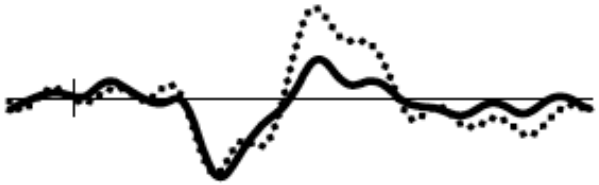
N400 orthographic neighborhood effect

High N
Mid N
Low N

… remains constant across word position in all contexts



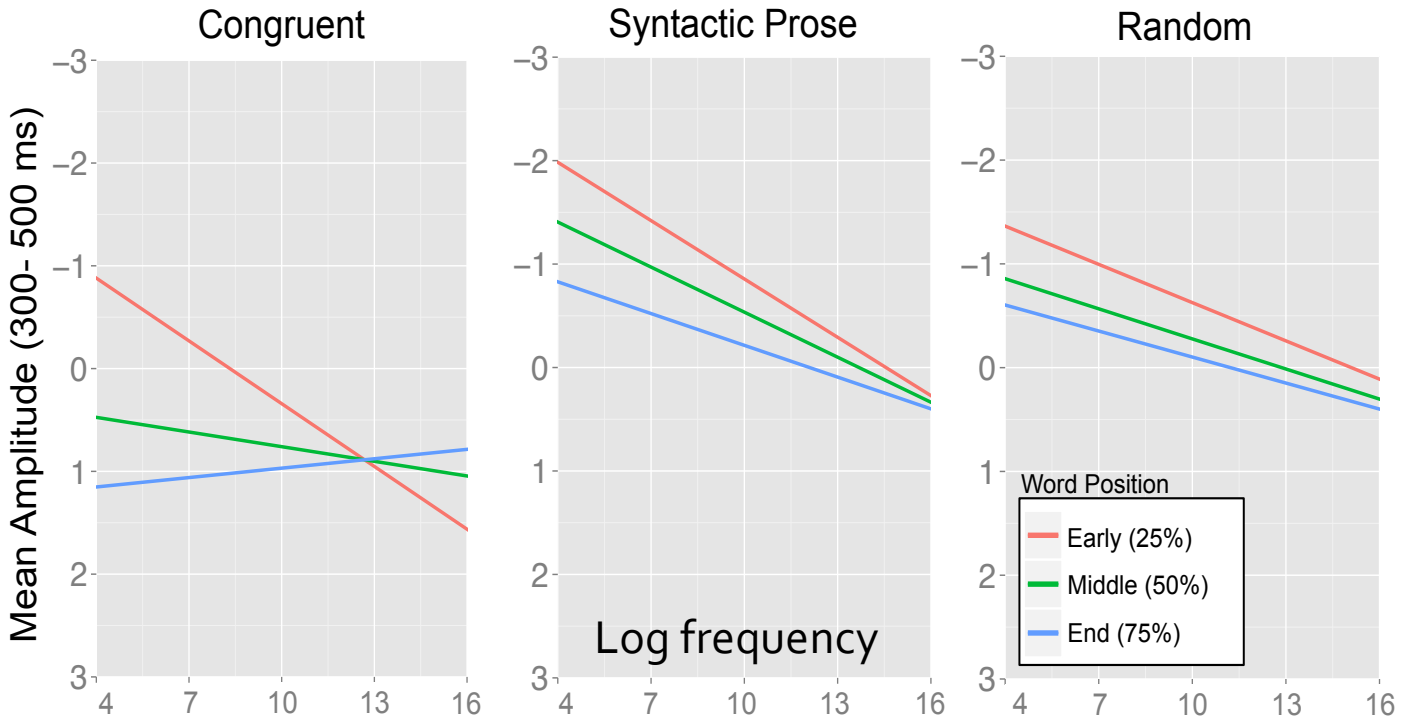
OLD 20: Mean distance to 20 nearest neighbors



Frequent
Less frequent

N400 frequency effect

… is eliminated as contextual constraint builds



Payne et al., 2015

Prediction of semantics (reading)

High Constraint:
He caught the pass and scored another touchdown.
There was nothing he enjoyed more than a good game of . . .

Federmeier & Kutas 1999

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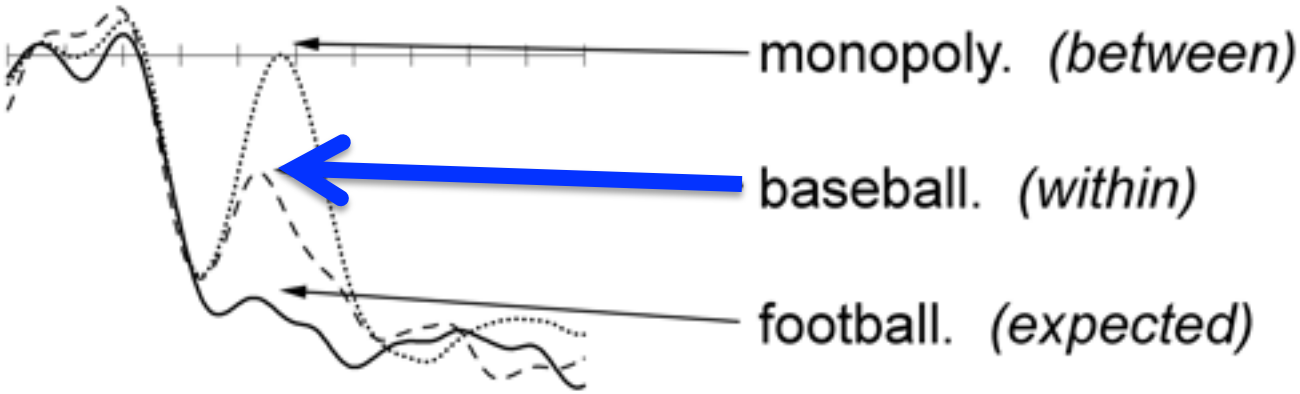

High Constraint:
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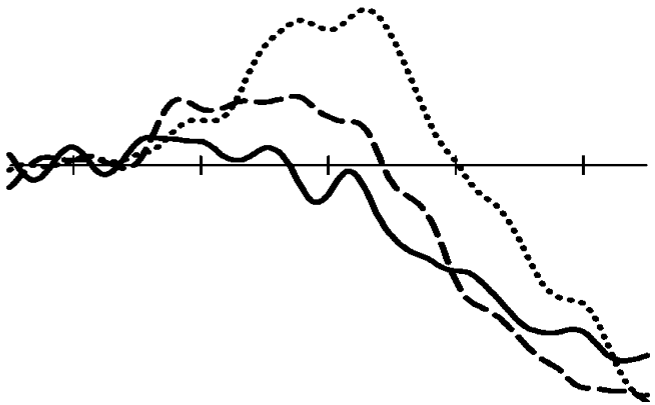
Federmeier & Kutas 1999

Prediction of semantics (listening)



monopoly. *(between)*

baseball. *(within)*

football. *(expected)*

High Constraint:
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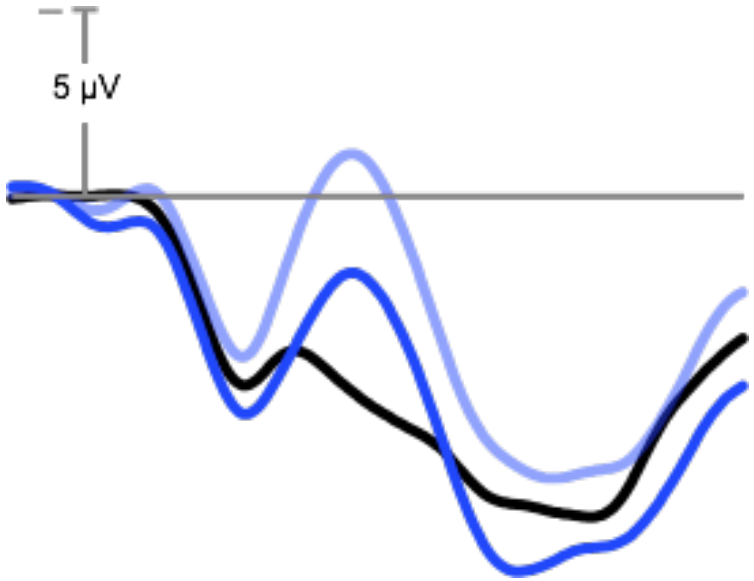
Federmeier et al., 2002

Orthographic effects of prediction



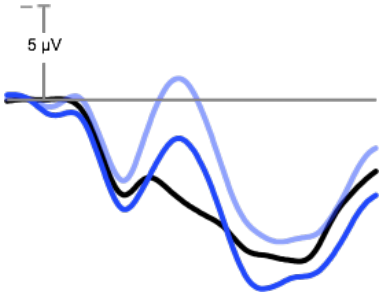
CLAM

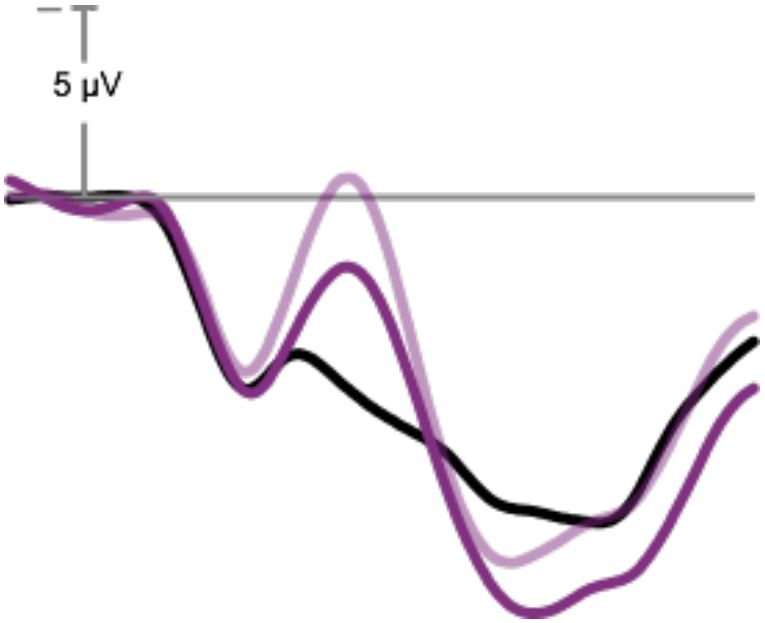
The genie was ready to grant his third and final WISH

DISH

Laszlo & Federmeier 2009

Orthographic effects of prediction





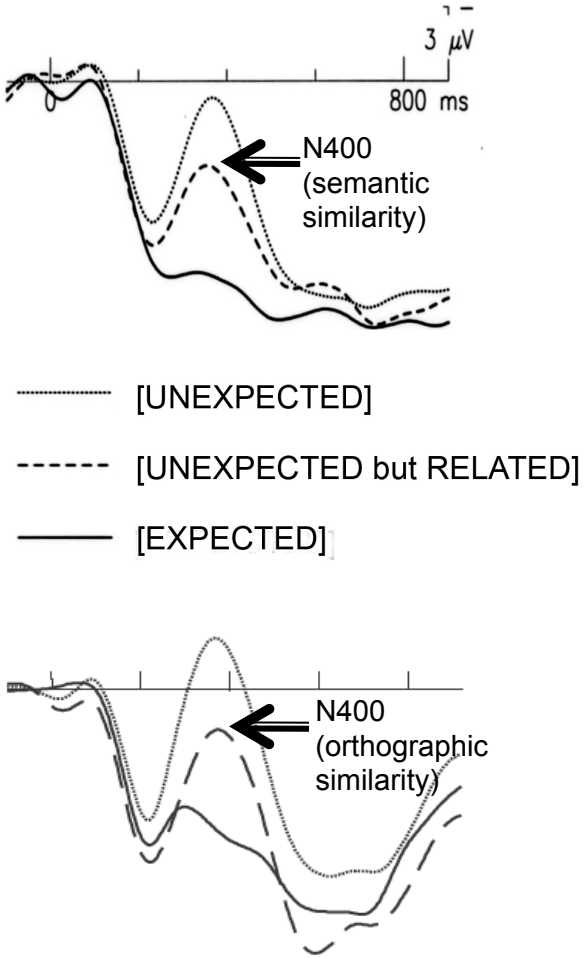
HORM
CLAM

The genie was ready to grant his third and final WISH

DISH
WUSH

Laszlo & Federmeier 2009

ERP correlates of prediction



Federmeier & Kutas, 1999; Laszlo & Federmeier, 2009

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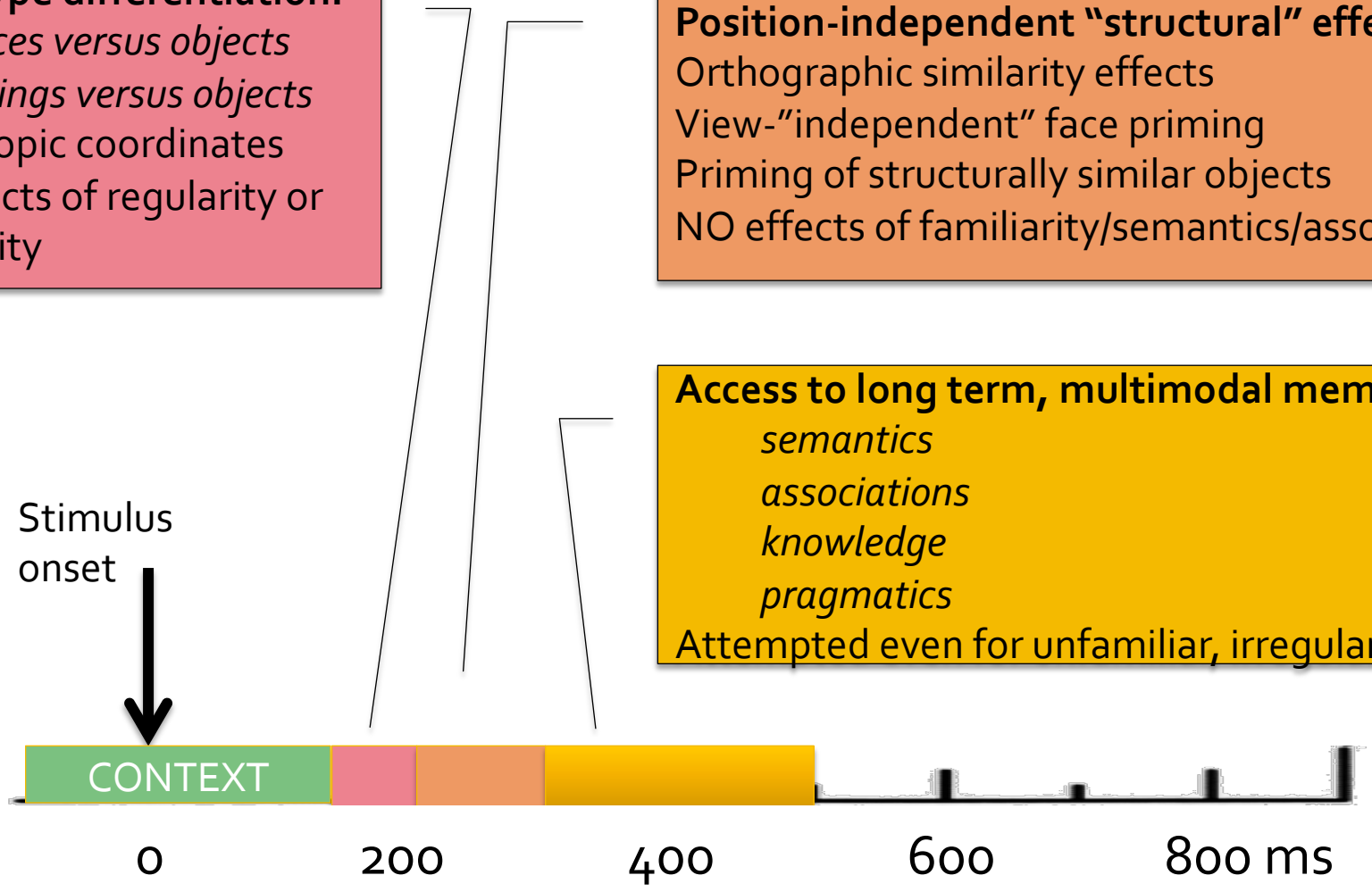

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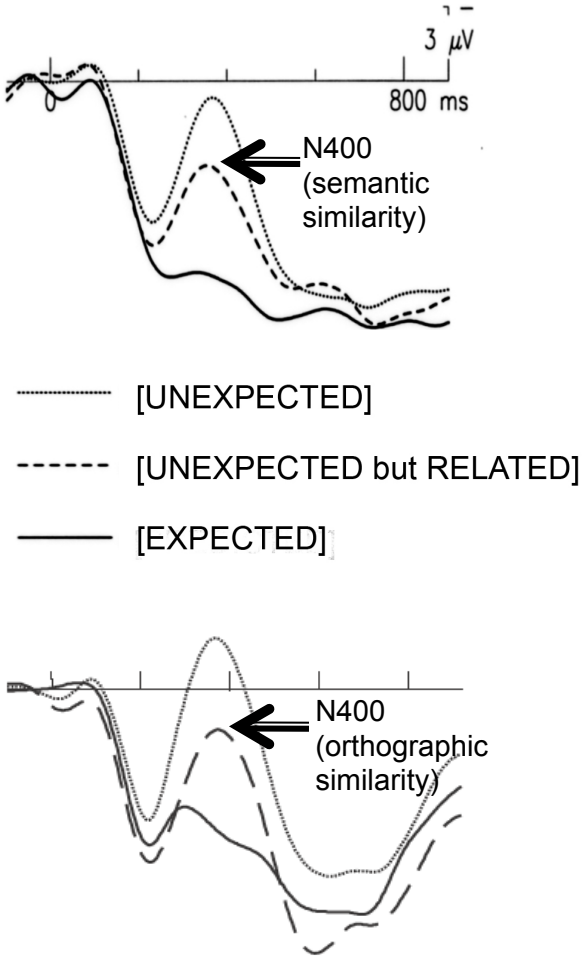

Federmeier & Kutas, 1999; Laszlo & Federmeier, 2009

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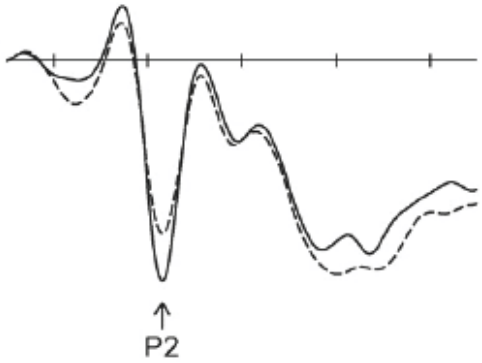
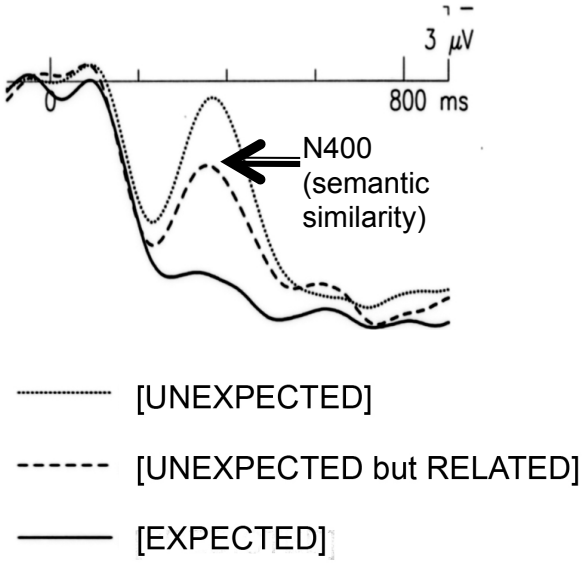
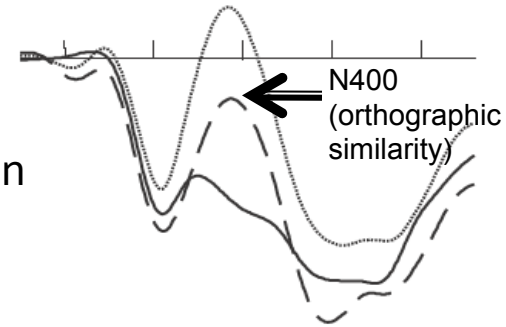






(Also can see effects of prediction on the N1, the N300, the PMN, etc.)

Wlotko & Federmeier, 2007; Federmeier & Kutas, 1999; Laszlo & Federmeier, 2009

When predictions go wrong …

When the two met, one of them held out his

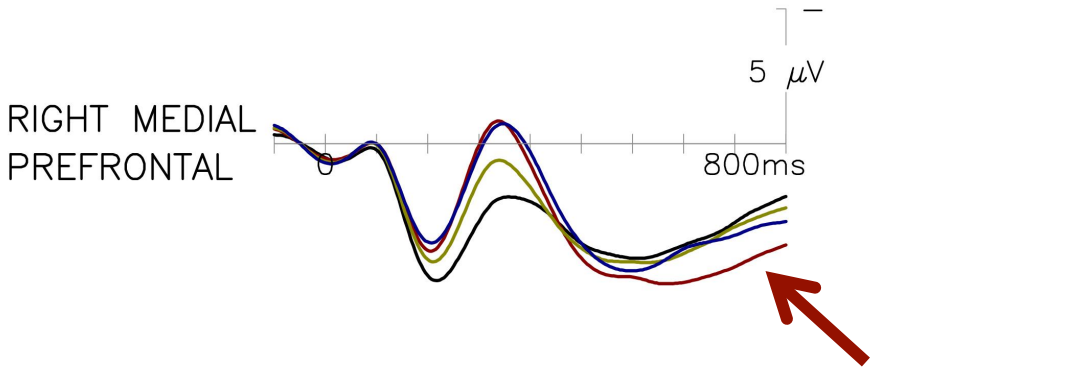
HAND	BADGE.	**Strongly Constrained**
Strongly expected	*Unexpected*	

Sandy always wished she'd had a

DOG	BADGE.	**Weakly Constrained**
Weakly expected	*Unexpected*	

Consequences of prediction violation: frontal positivity

"When the two met, one of them held out his badge. *(hand)*"



Strongly Constrained, Expected

Strongly Constrained, Unexpected

Weakly Constrained, Expected

Weakly Constrained, Unexpected

Federmeier et al 2007

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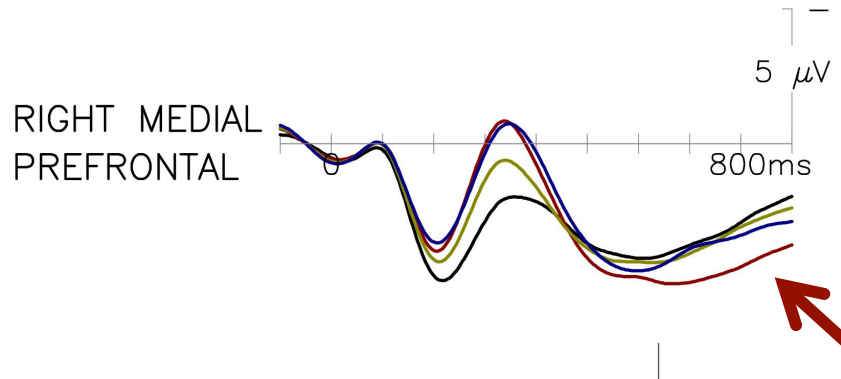
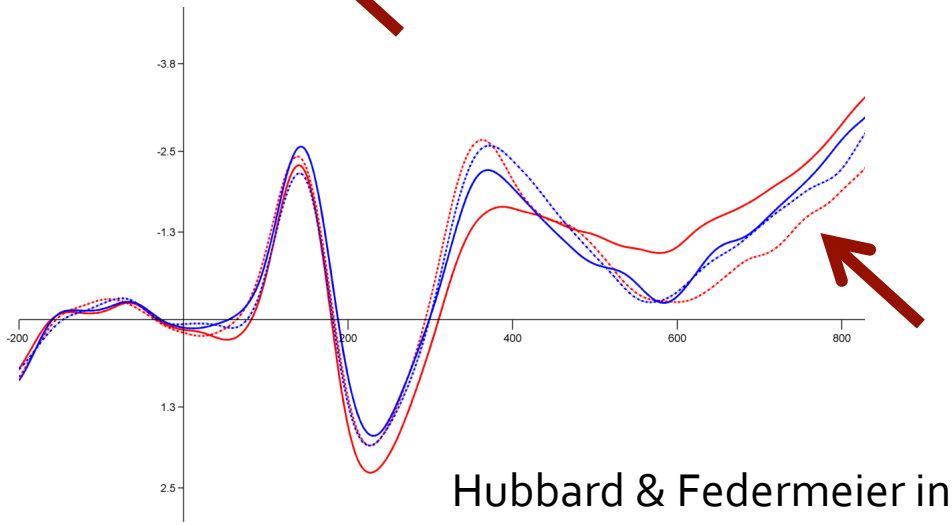


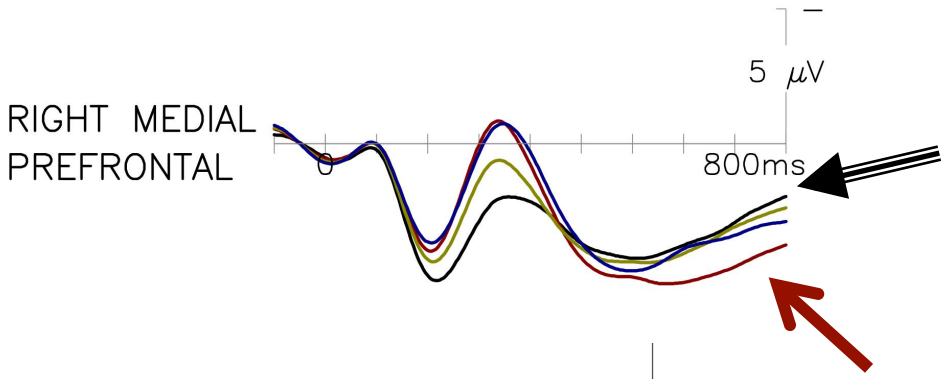


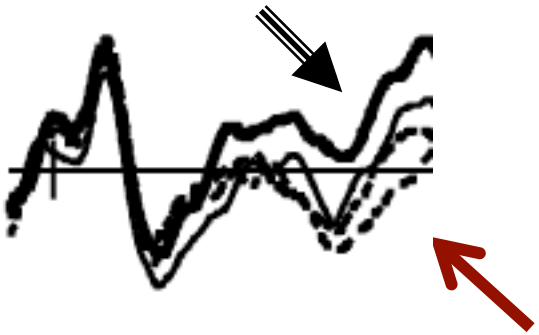
Payne & Federmeier 2017

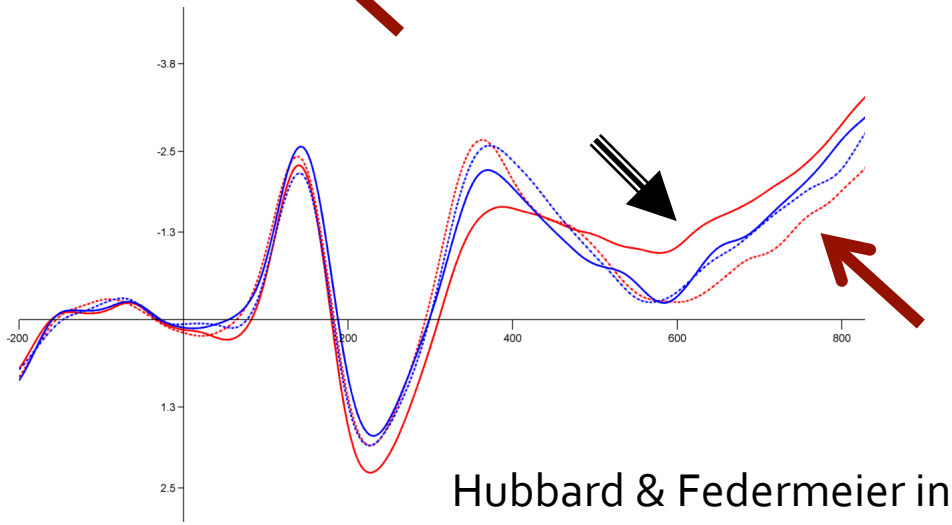
Hubbard & Federmeier in prep

Two effects: also a frontal negativity to strongly constrained expected items …

"When the two met, one of them held out his badge. *(hand)*"



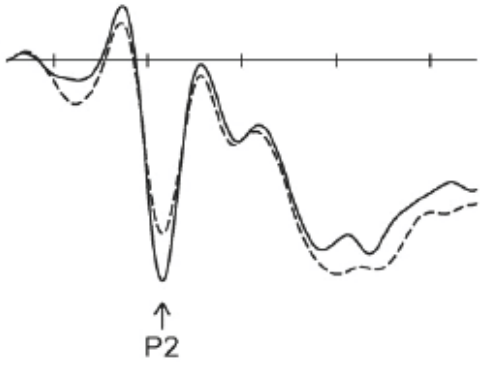




Payne & Federmeier 2017

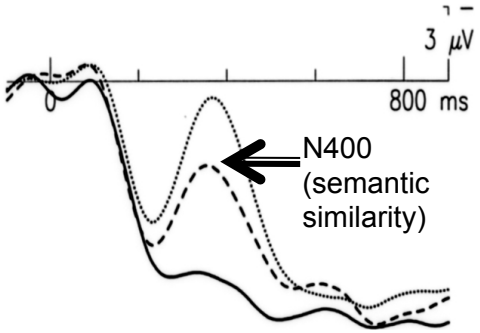
Hubbard & Federmeier in prep

ERP correlates of prediction



Strongly Constrained

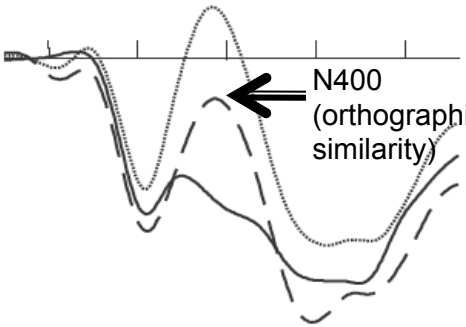
Weakly Constrained



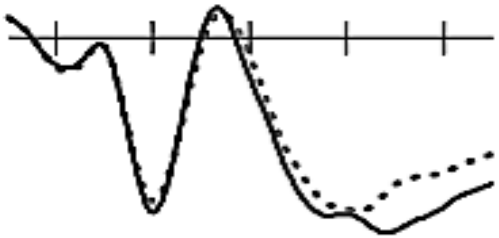
[UNEXPECTED]

[UNEXPECTED but RELATED]

[EXPECTED]



Plausible but
unexpected words



Strongly Constrained

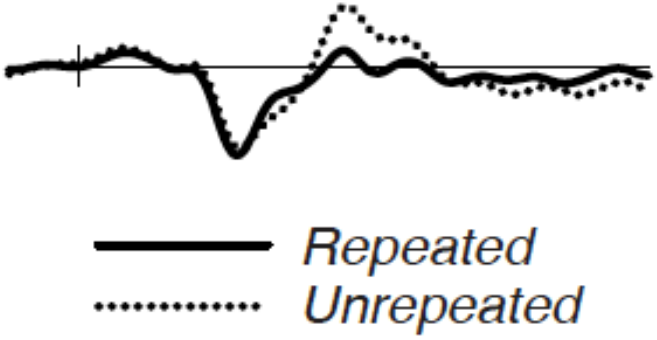
Weakly Constrained

Wlotko & Federmeier, 2007; Federmeier & Kutas, 1999; Laszlo & Federmeier, 2009; Federmeier et al., 2007

Downstream effects of predicting

The jeweler was asked if he would examine the ring's huge …

N400 repetition effect



diamond?

crack.

Design

Seen in strong constraint

The jeweler was asked if he would examine the ring's huge crack.
The mother of the tall guard had the same accent.
There were a lot of old boxes stored in the attic.
He started looking for the diamond.

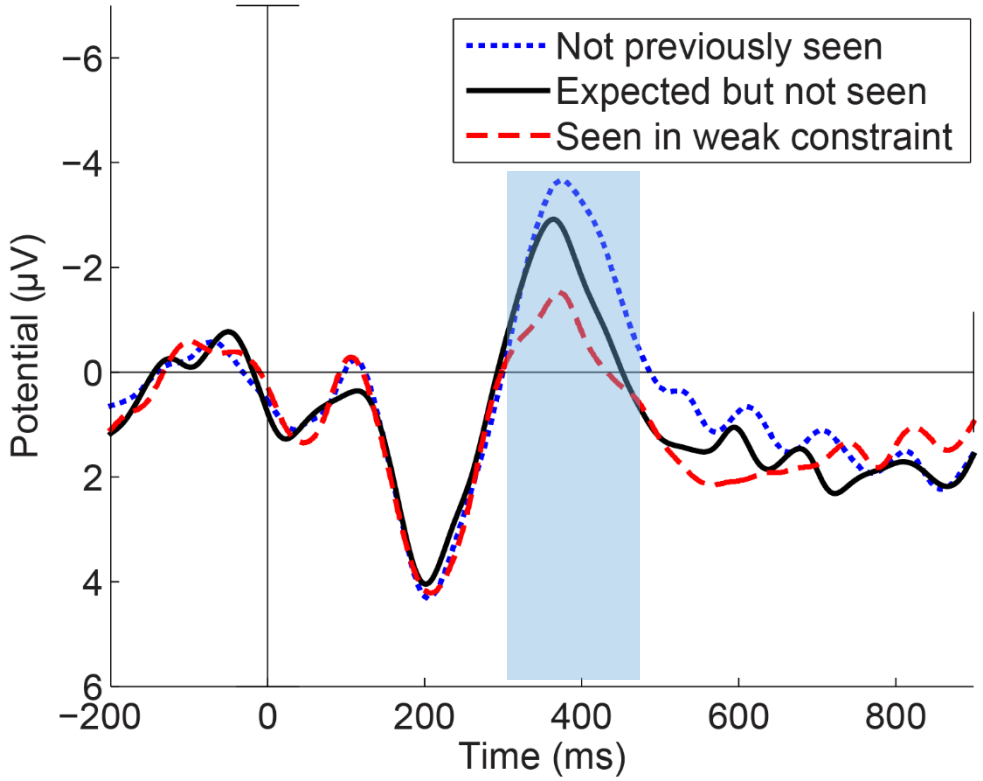
Seen in weak constraint

The guy was still wondering if anyone had noticed the big diamond.
The mother of the tall guard had the same accent.
There were a lot of old boxes stored in the attic.
He started looking for the diamond.

Not previously seen

The mother of the tall guard had the same accent.
There were a lot of old boxes stored in the attic.
He started looking for the diamond.

Predictions elicit repetition effects



Rommers & Federmeier in prep

Design

Seen in strong constraint

The jeweler was asked if he would examine the ring's huge diamond.
The mother of the tall guard had the same accent.
There were a lot of old boxes stored in the attic.
He started looking for the diamond.

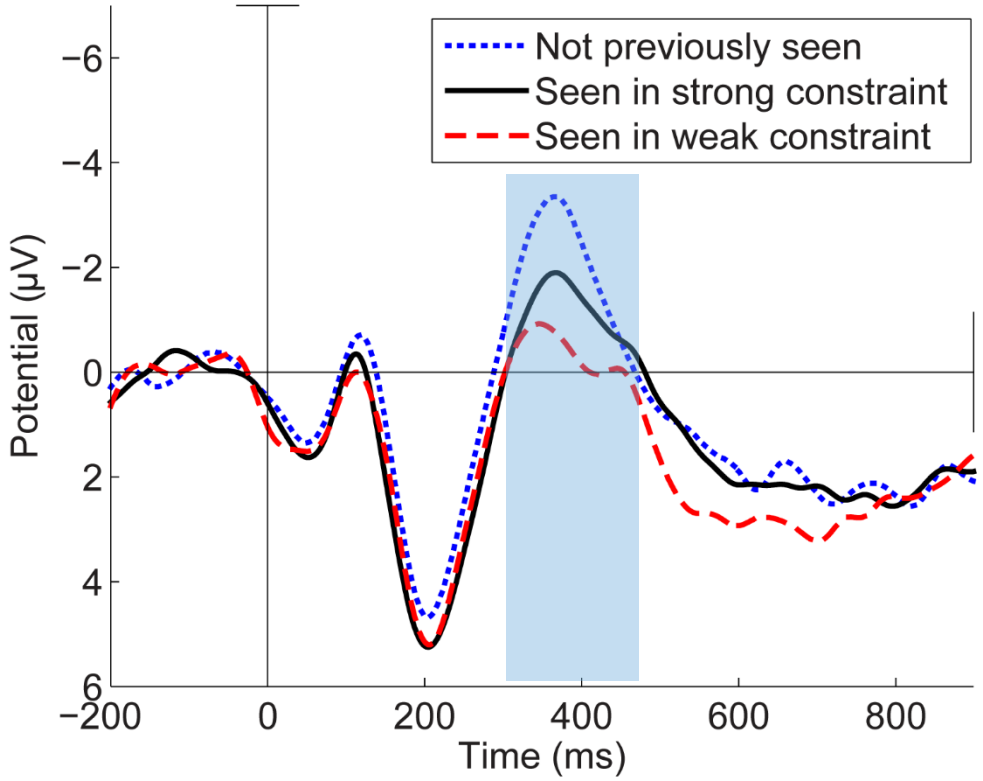
Seen in weak constraint

The guy was still wondering if anyone had noticed the big diamond.
The mother of the tall guard had the same accent.
There were a lot of old boxes stored in the attic.
He started looking for the diamond.

Not previously seen

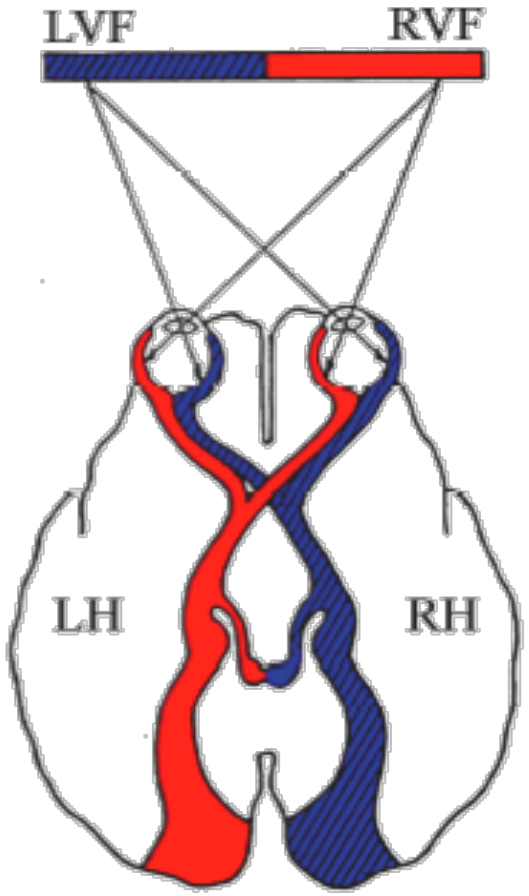
The mother of the tall guard had the same accent.
There were a lot of old boxes stored in the attic.
He started looking for the diamond.

Predictions diminish stimulus encoding

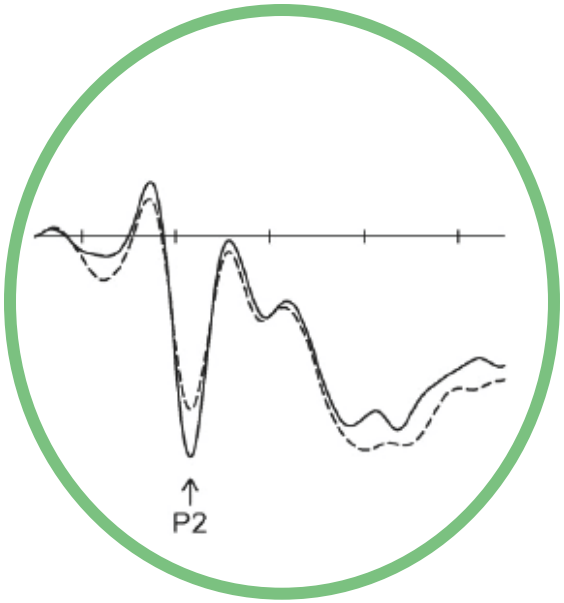


Rommers & Federmeier in prep

Hemispheric differences

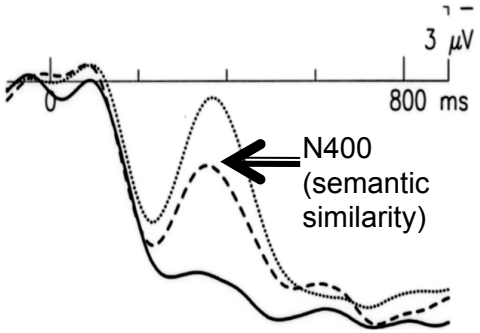


ERP correlates of prediction



Strongly Constrained

Weakly Constrained



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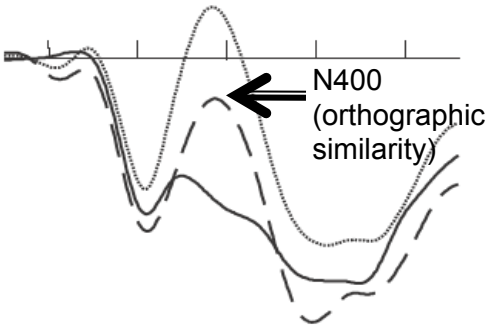
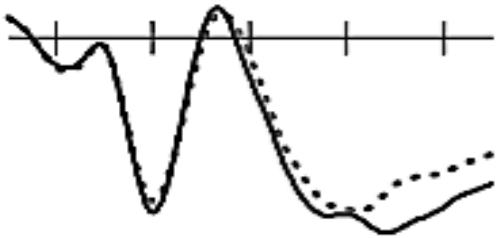


Plausible but
unexpected words

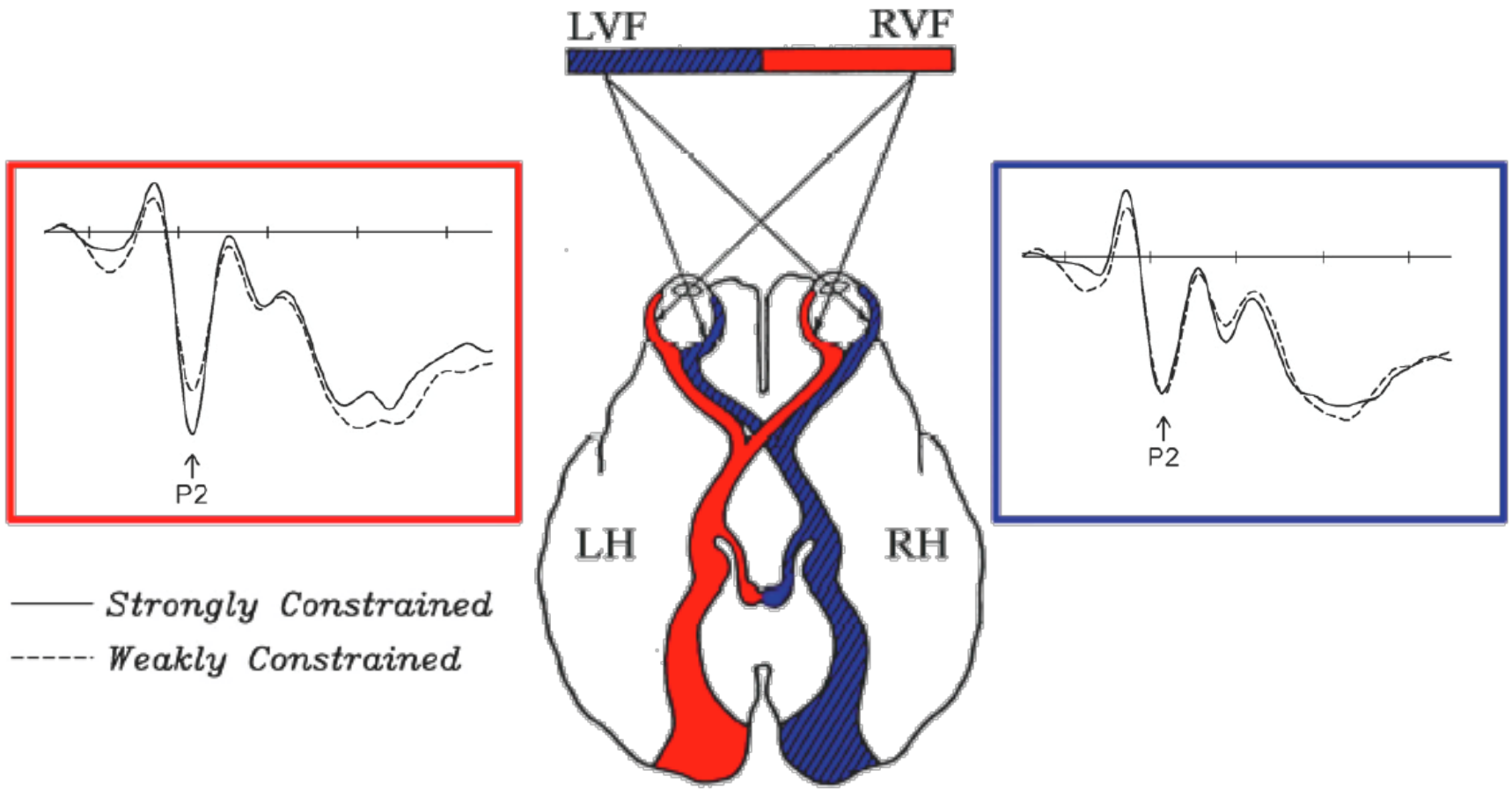


Strongly Constrained

Weakly Constrained

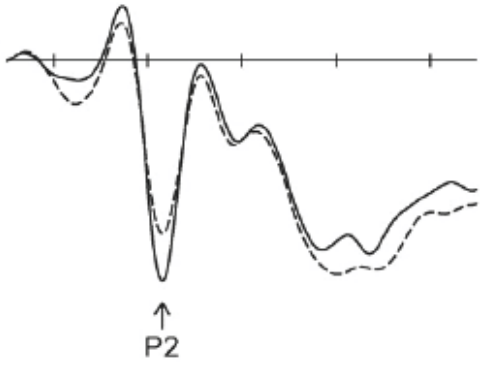
Wlotko & Federmeier, 2007; Federmeier & Kutas, 1999; Laszlo & Federmeier, 2009; Federmeier et al., 2007

Hemispheric differences in prediction



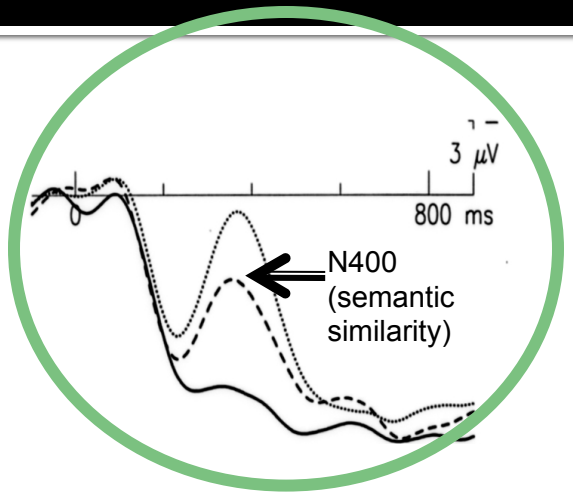
Wlotko & Federmeier, 2007

ERP correlates of prediction



Strongly Constrained

Weakly Constrained



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[UNEXPECTED but RELATED]

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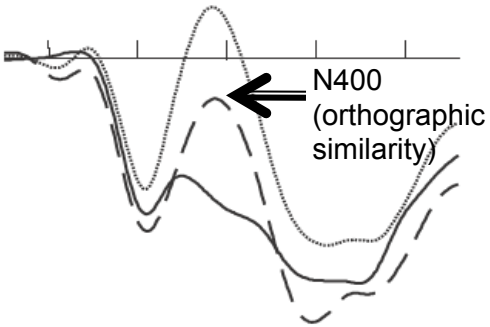
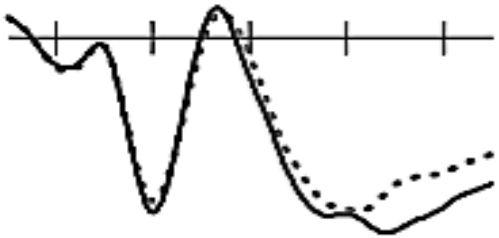


Plausible but unexpected words



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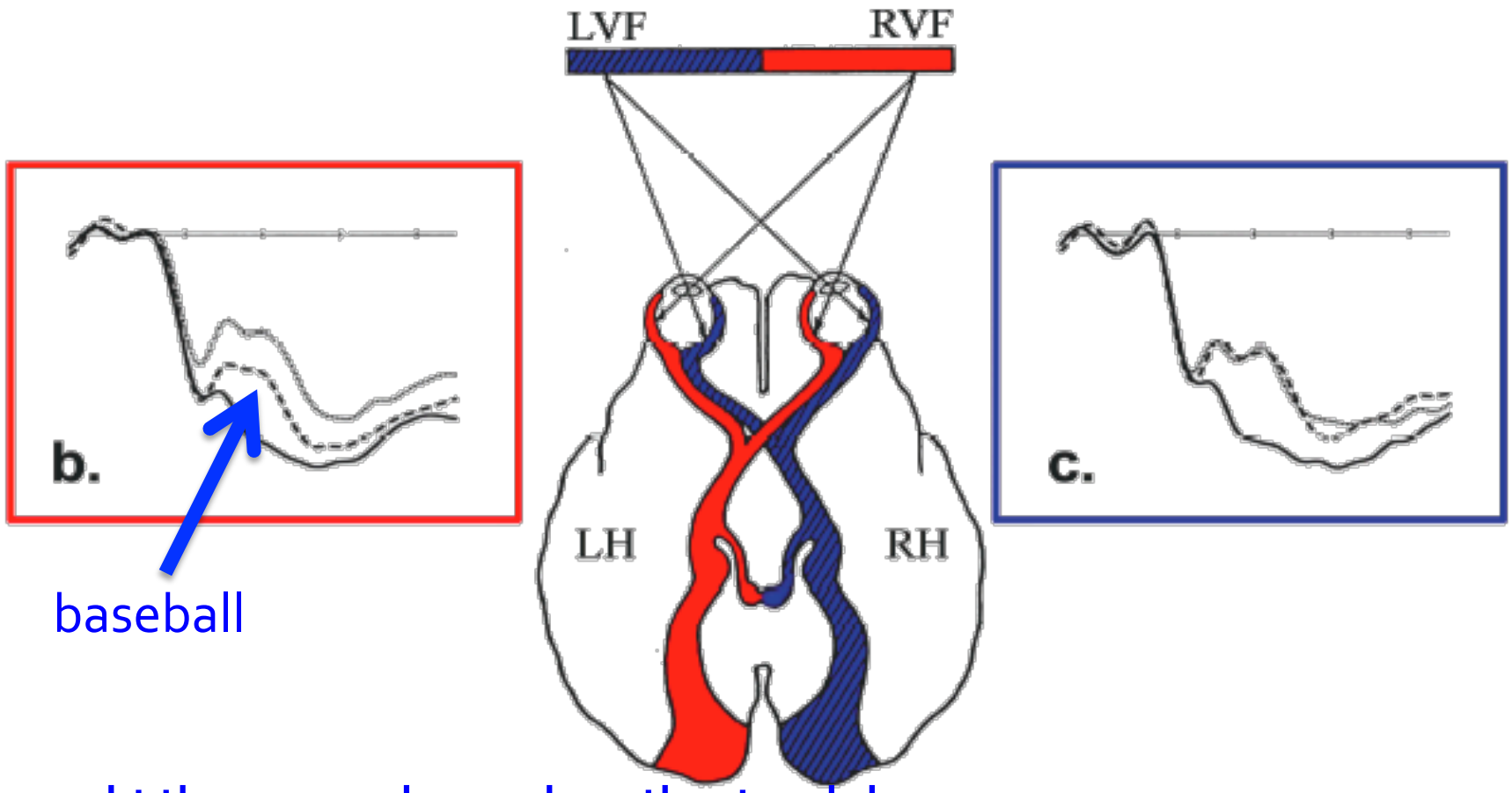
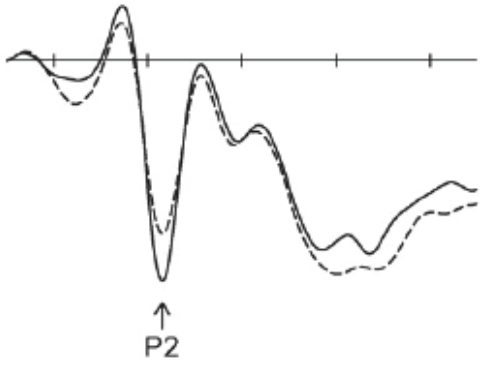
Hemispheric differences in prediction



He caught the pass and scored another touchdown.
There was nothing he enjoyed more than a good game of …

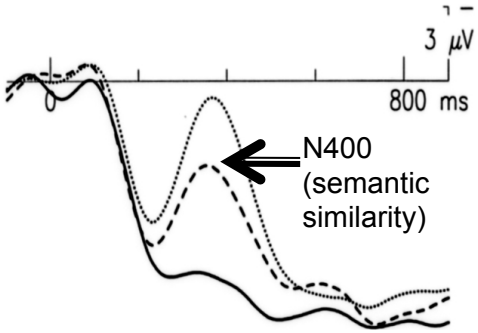
Federmeier & Kutas, 1999

ERP correlates of prediction



Strongly Constrained

Weakly Constrained



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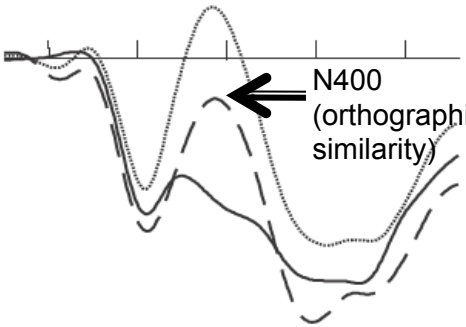

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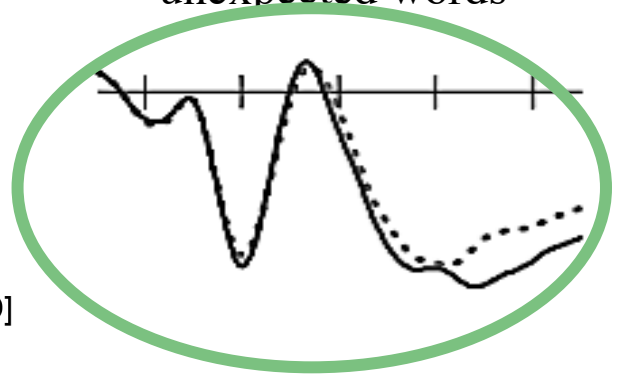
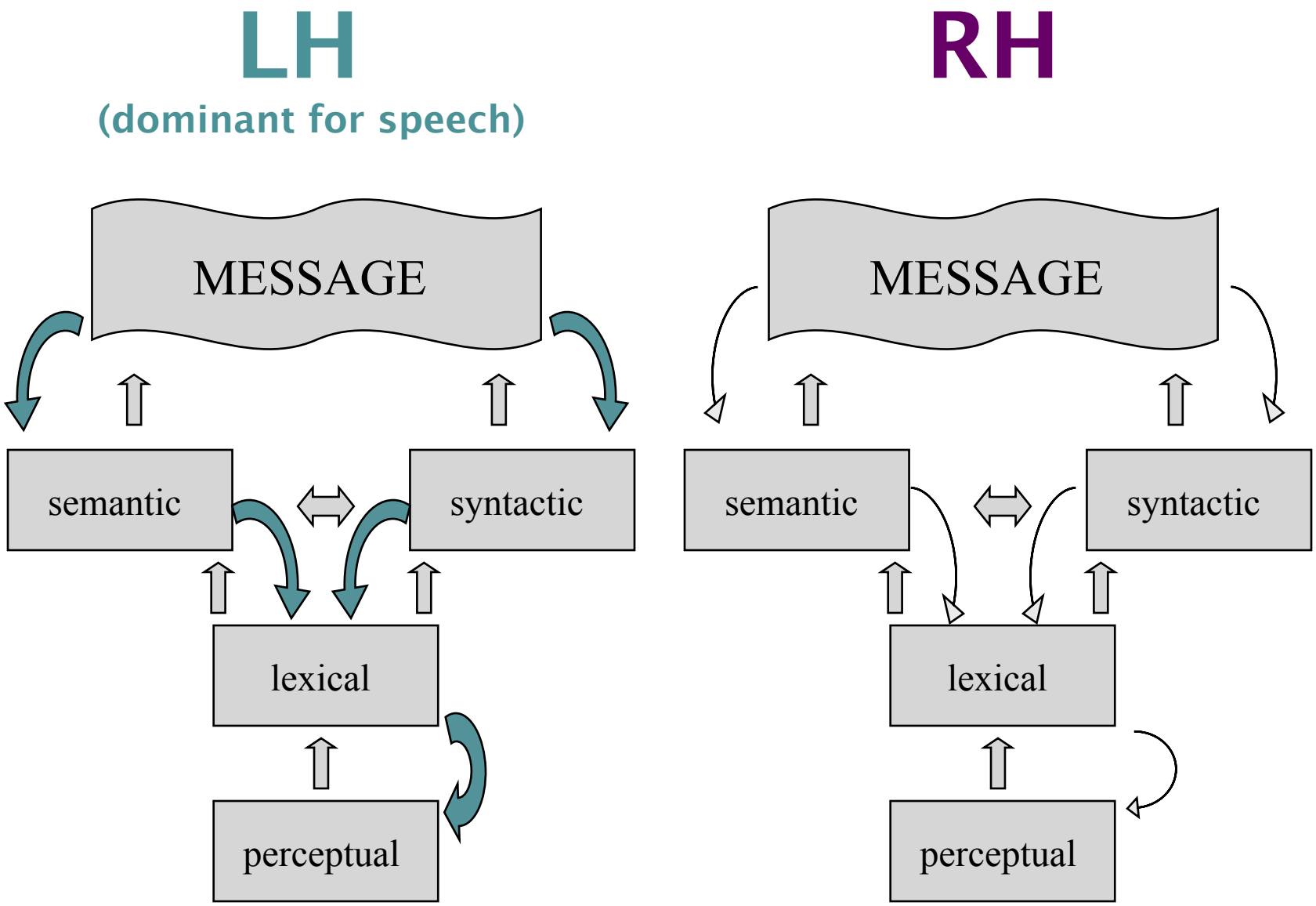


Strongly Constrained

Weakly Constrained

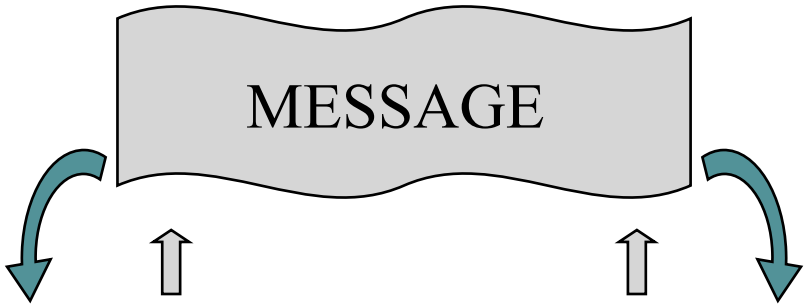
Wlotko & Federmeier, 2007; Federmeier & Kutas, 1999; Laszlo & Federmeier, 2009; Federmeier et al., 2007



PARLO (Federmeier 2007):
Production Affects Reception in Left Only

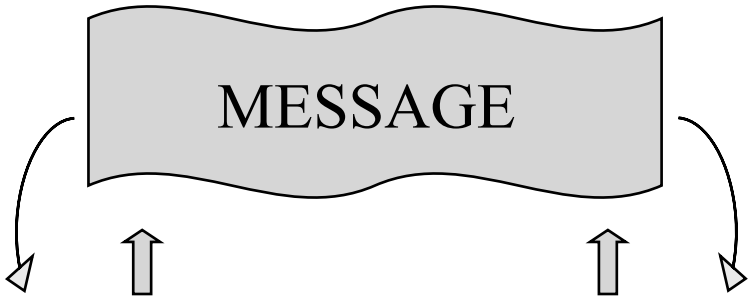
LH

(dominant for speech)



- engages predictive processing mechanisms
- benefits from even weak context
- readily recruits processes to select, revise, and reorder language information

RH



- maintains veridical representation of the stimulus stream
- engages imagery in response to concrete language
- flexibly deals with some kinds of unexpected information, such as when processing jokes (e.g., Coulson & Williams, 2005)

PARLO (Federmeier 2007):
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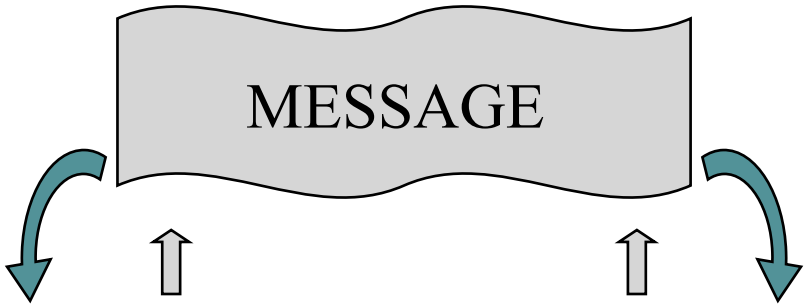

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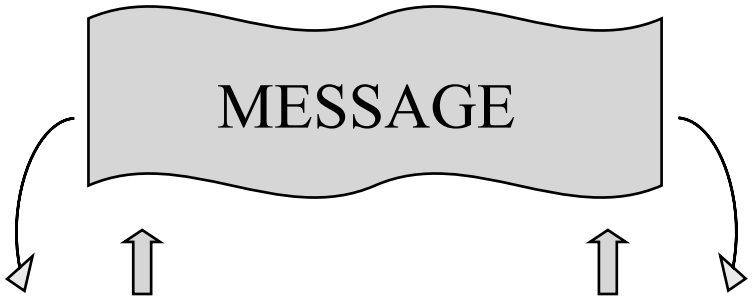

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PARLO (Federmeier 2007):
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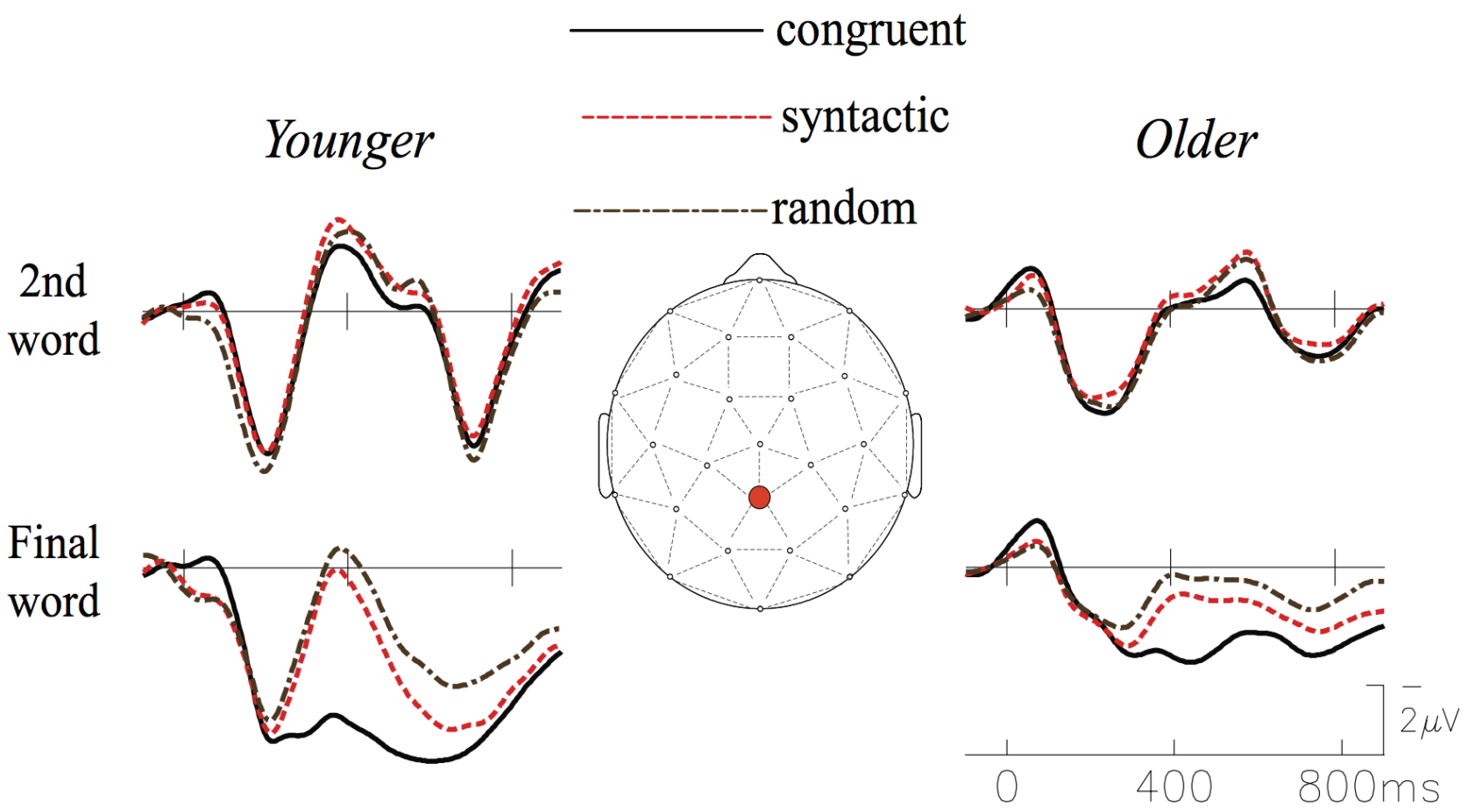
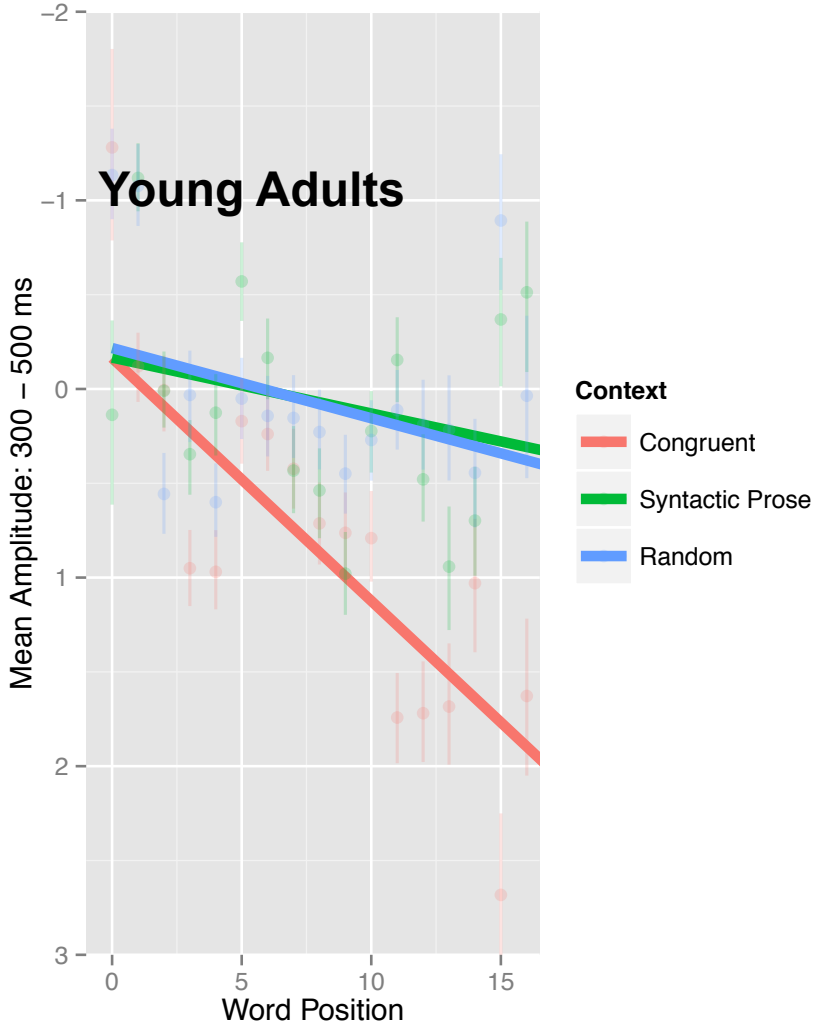
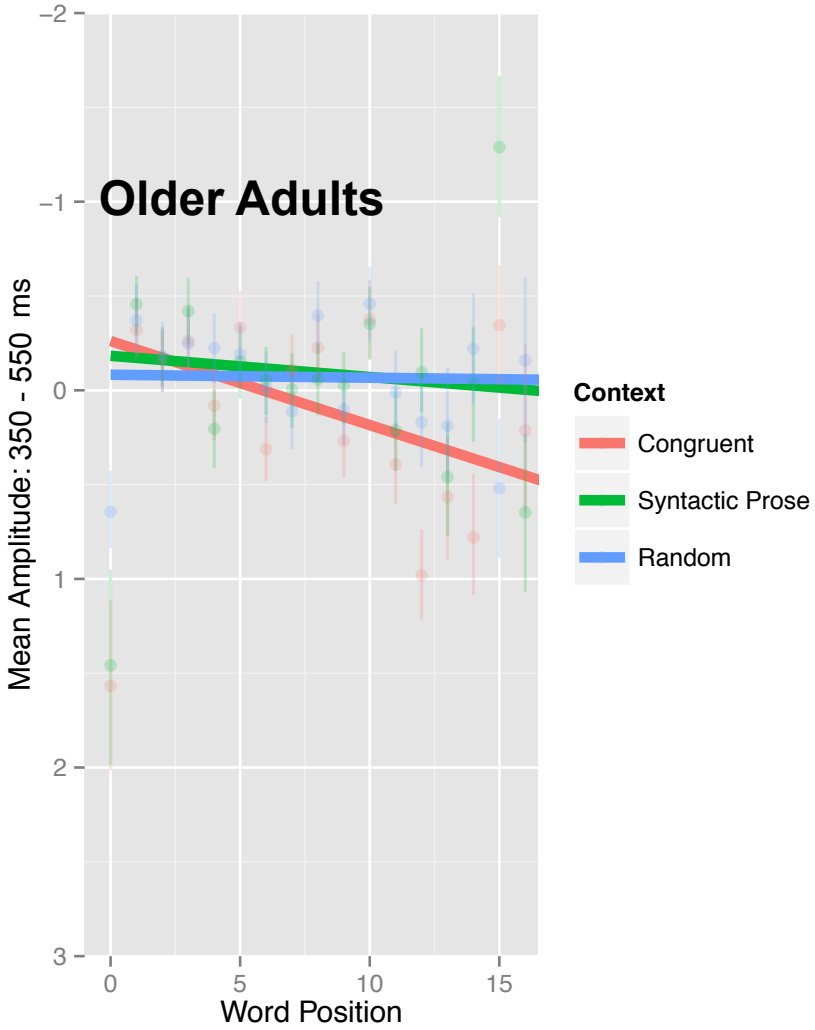
Aging and the word position effect



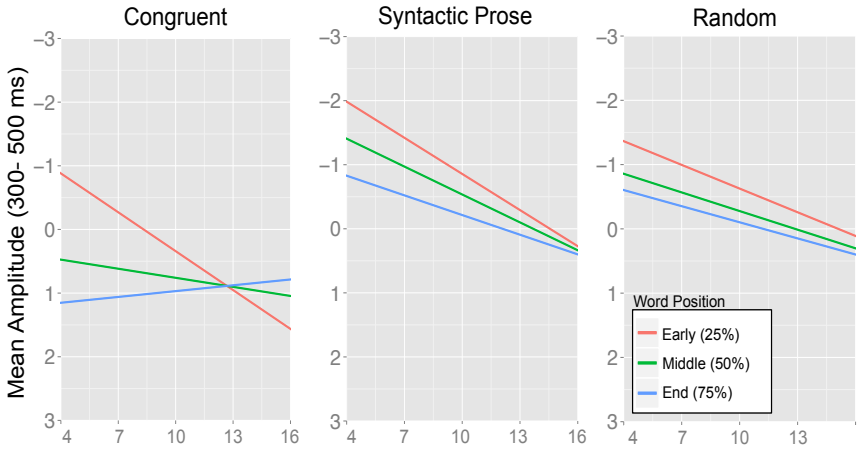
Payne & Federmeier in prep



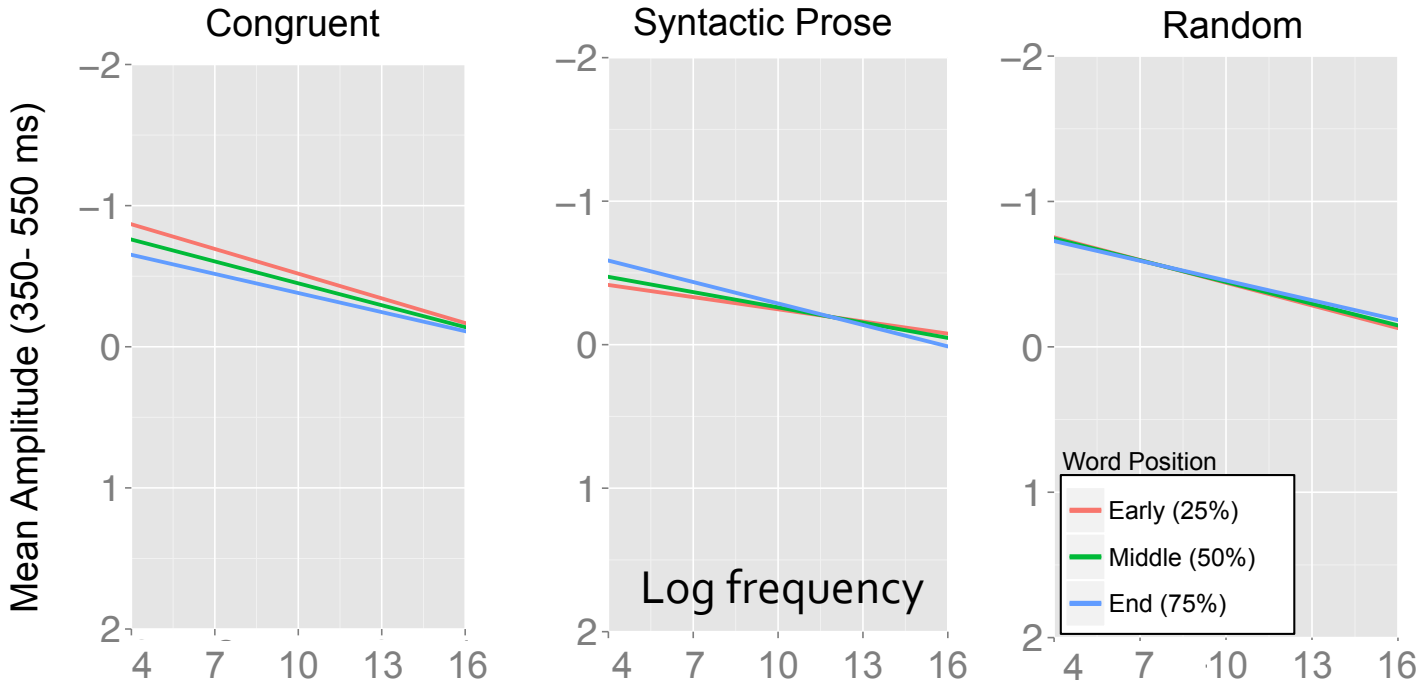


Payne & Federmeier in prep

YOUNG ADULTS: N400 frequency effect



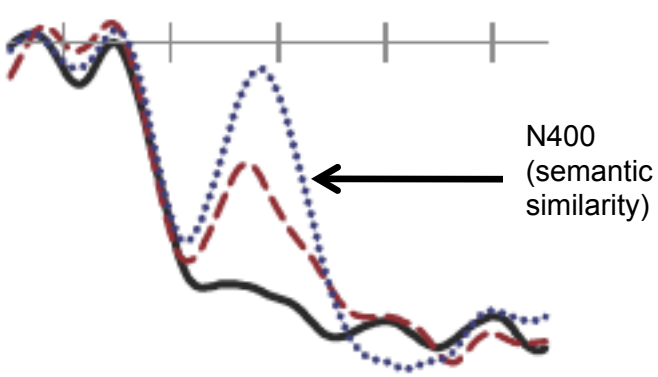
OLDER ADULTS



Payne & Federmeier in prep

Aging effects on prediction (word by word reading)

YOUNGER ADULTS



He caught the pass and scored another touchdown.
There was nothing he enjoyed more than a good game of …

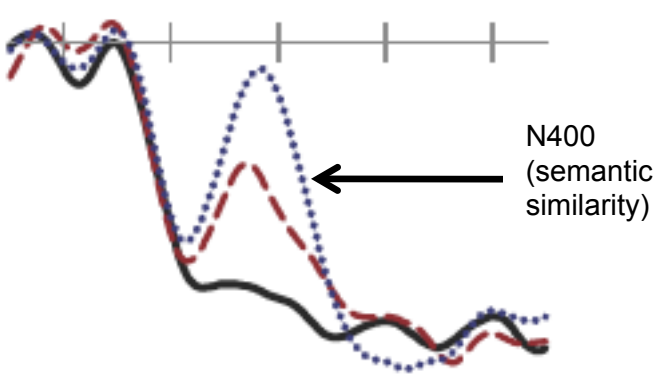
chess ····· *Between Category Violations*

baseball ----- *Within Category Violations*

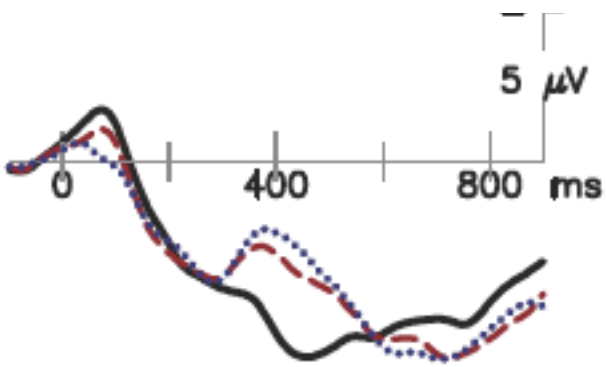
football —— *Expected Exemplars*

Aging effects on prediction (word by word reading)

YOUNGER ADULTS



OLDER ADULTS



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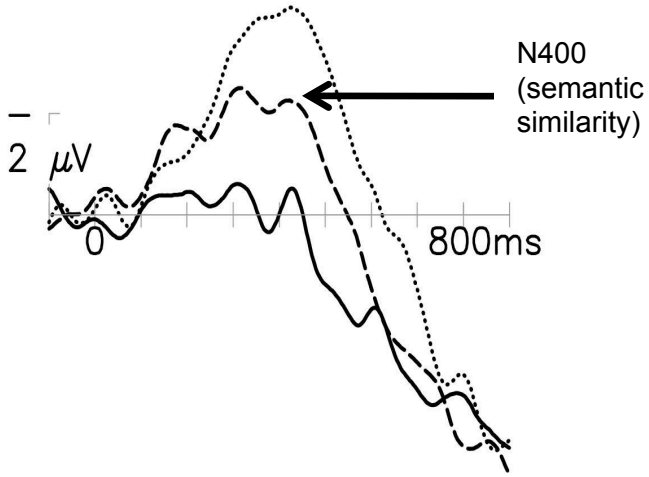
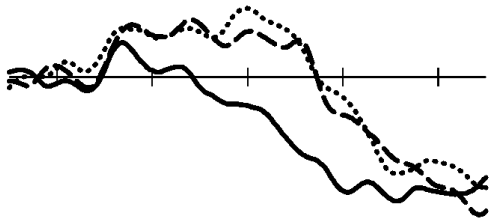
football —— *Expected Exemplars*

Aging effects on prediction (listening to natural speech)

YOUNGER ADULTS



OLDER ADULTS



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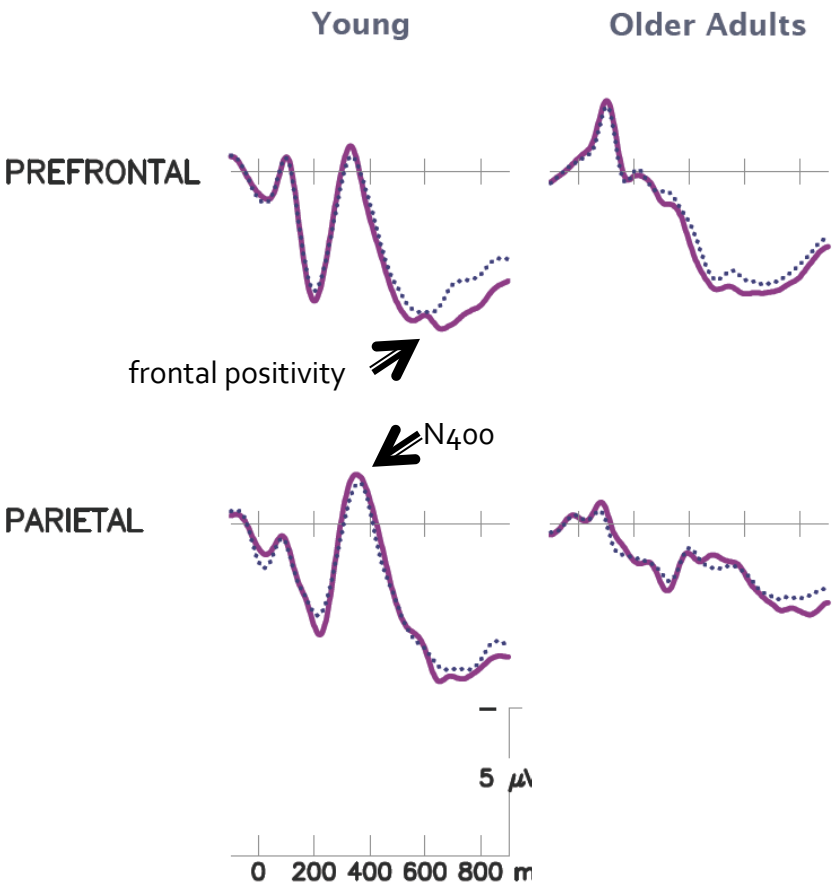
football —— *Expected Exemplars*

Federmeier et al., 2002



Strongly constrained unexpected:

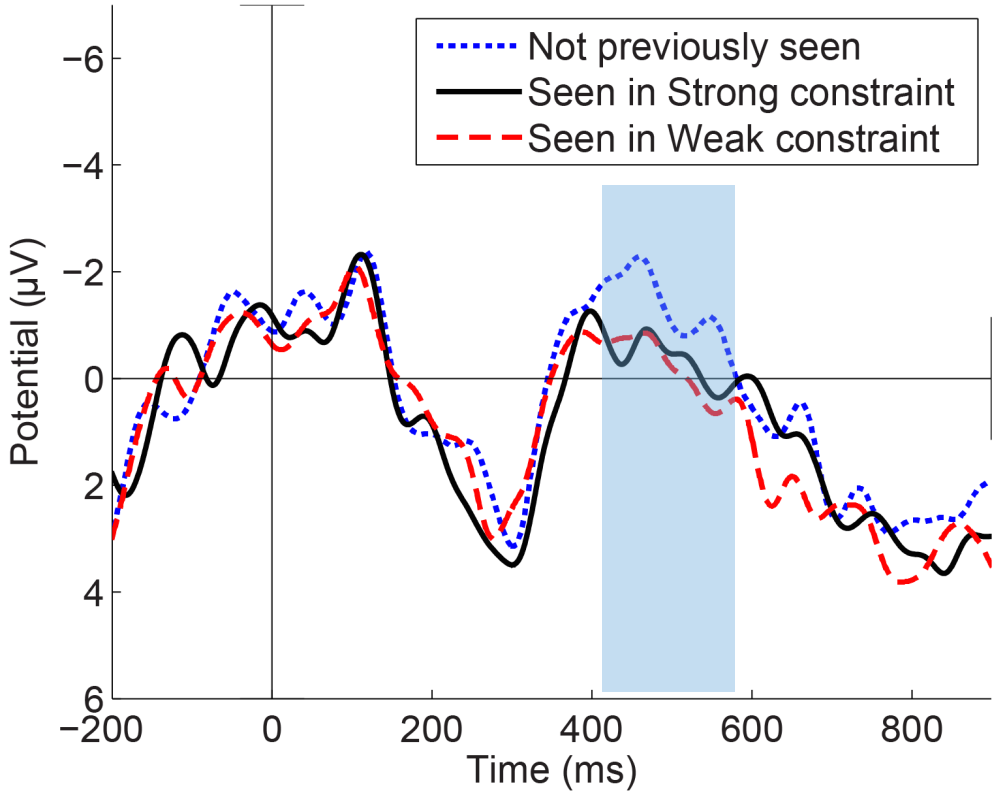
When the two met, one of them held out his BADGE (HAND).

Weakly constrained unexpected:

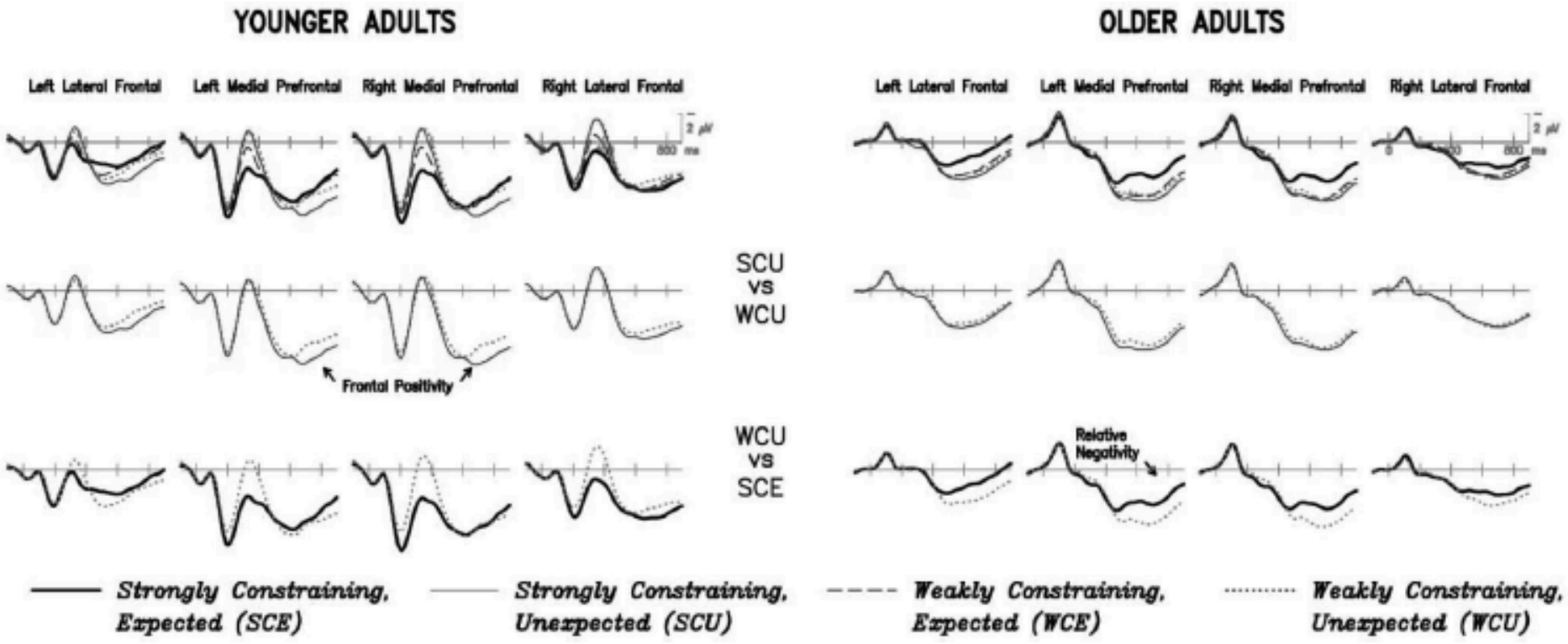
Sandy always wished that she'd had a BADGE (DOG).

Wlotko et al., 2012

Diminished stimulus encoding when predicting



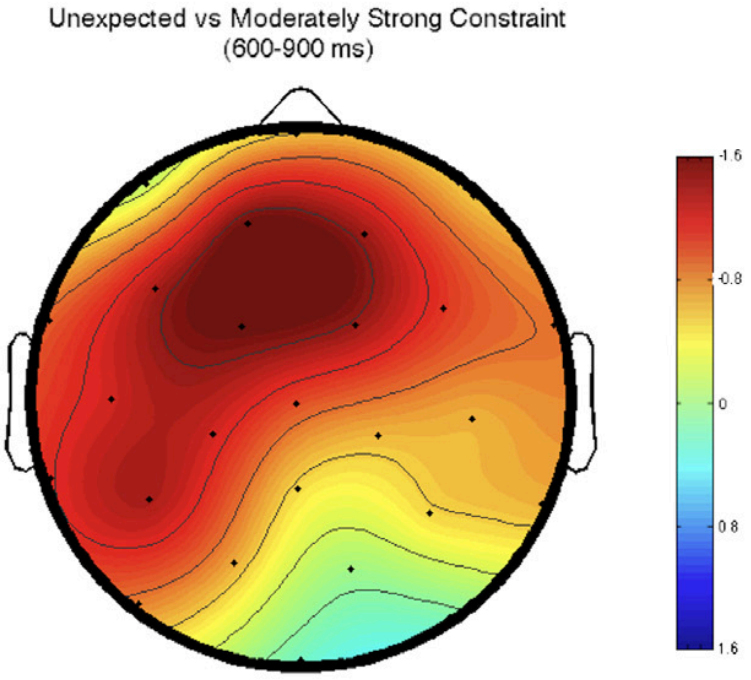
Frontal NEGATIVITY observed in both processing "modes"



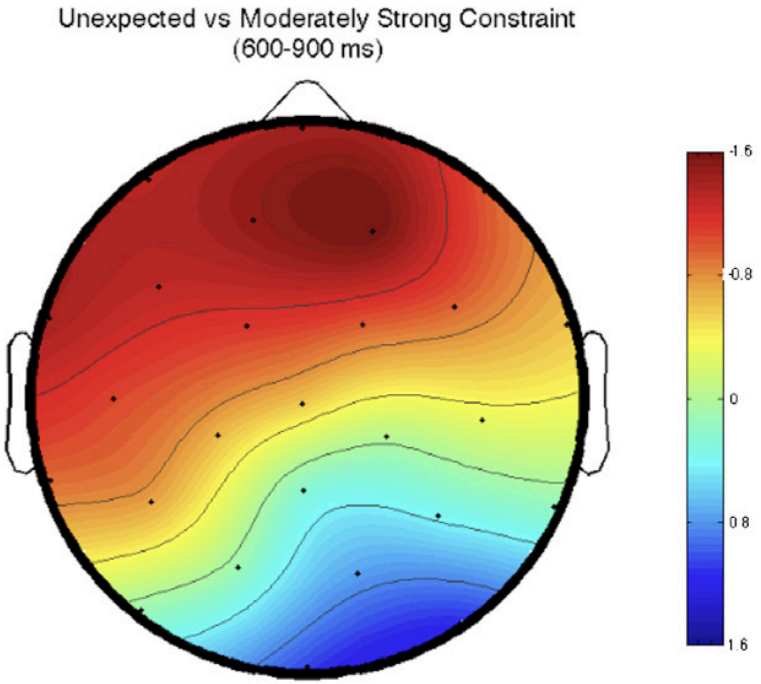
Wlotko et al., 2012

Frontal NEGATIVITY observed in both processing "modes"

Young Adults



Older Adults



Wlotko & Federmeier, 2012

Making prediction less useful …

When the two met, one of them held out his

HAND BADGE. Strongly Constrained

Sandy always wished she'd had a

DOG BADGE. Weakly Constrained

Making prediction less useful …

Related and Unrelated Unexpected Endings were carefully matched for cloze

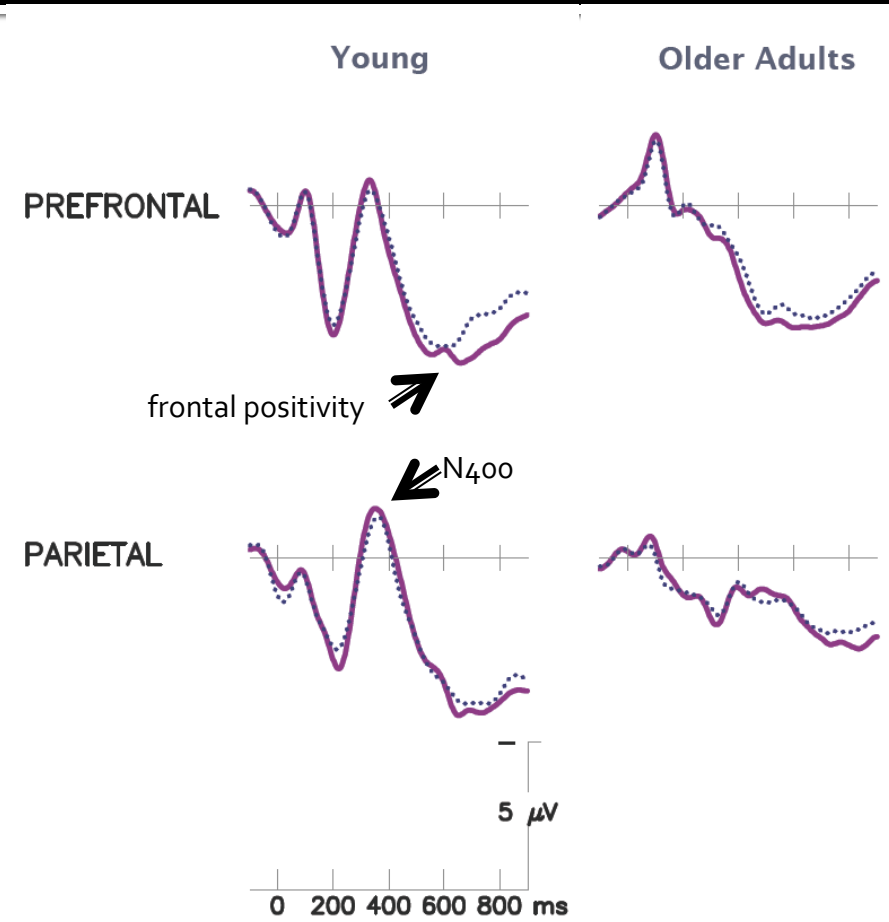
When the two met, one of them held out his

HAND / FINGERS / BADGE. **Strongly Constrained**

Sandy always wished she'd had a

DOG / PUPPY / BADGE. **Weakly Constrained**

Flexible strategies



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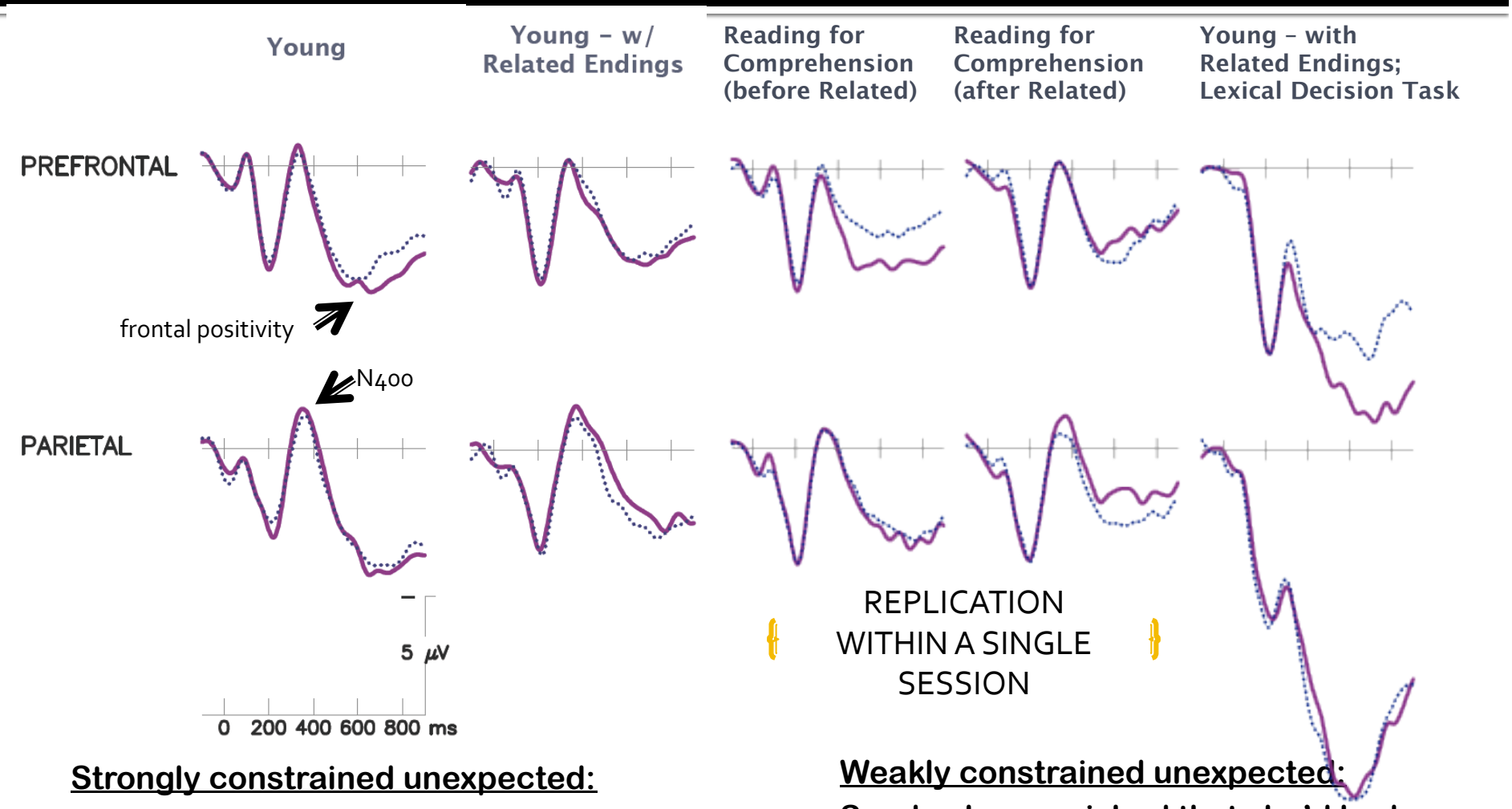
Flexible strategies



REPLICATION WITHIN A SINGLE SESSION

Strongly constrained unexpected:

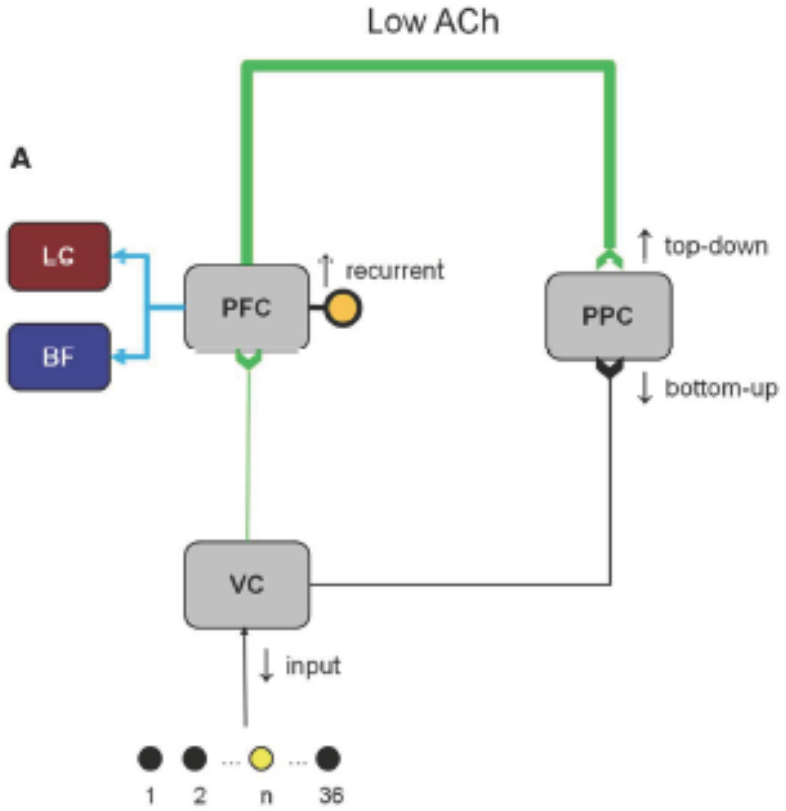
When the two met, one of them held out his BADGE (HAND).

Weakly constrained unexpected:

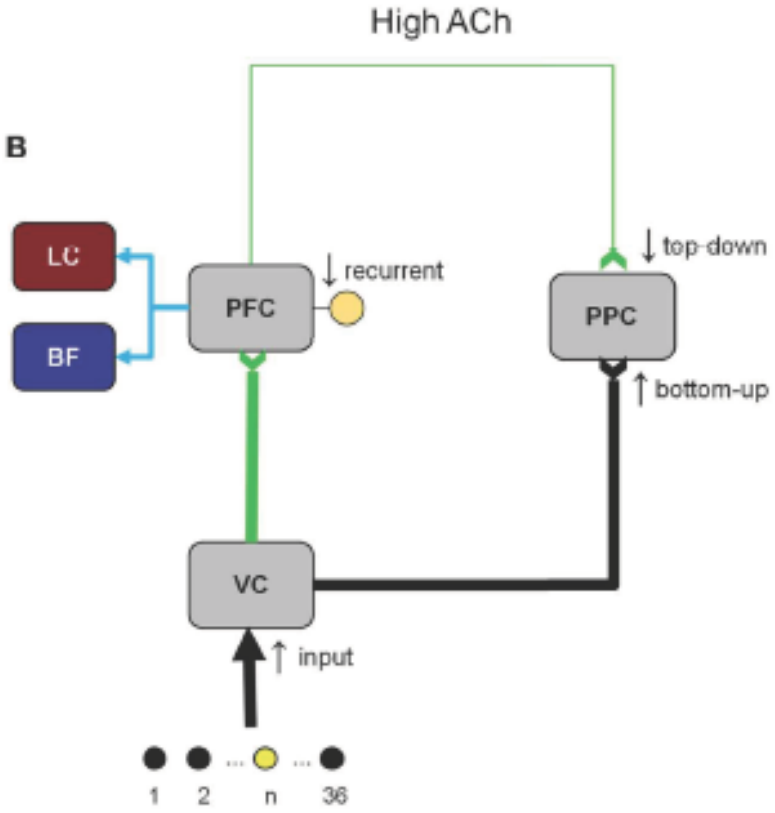
Sandy always wished that she'd had a BADGE (DOG).

Wlotko et al., 2012; Wlotko et al., in prep

Low expected uncertainty



High expected uncertainty



Conclusions

- Semantic access involves synchronous activity across a distributed, multimodal long term memory network.
- Access is triggered in a delimited time window with respect to sensory input, and not by a functional outcome.

Conclusions

- The brain processes meaning information incrementally, building higher-order meaning representations as context accrues.
- Incremental processing can include prediction – i.e., the preactivation of likely upcoming information via top-down connectivity.
- However, (this kind of) prediction is not ubiquitous, and becomes less likely with age.

Conclusions

- Older adults remain good comprehenders.
- However, they use substantively **different** processing mechanisms from young adults, with different strengths and weaknesses.
- Meaning comprehension can and does arise from multiple processing mechanisms/modes -- even in young adults.

Conclusions

Comprehension is flexible and multifaceted, which is what allows us to find meaning in time … over a lifetime.

The Cognition and Brain (CAB) Lab
(past and present)

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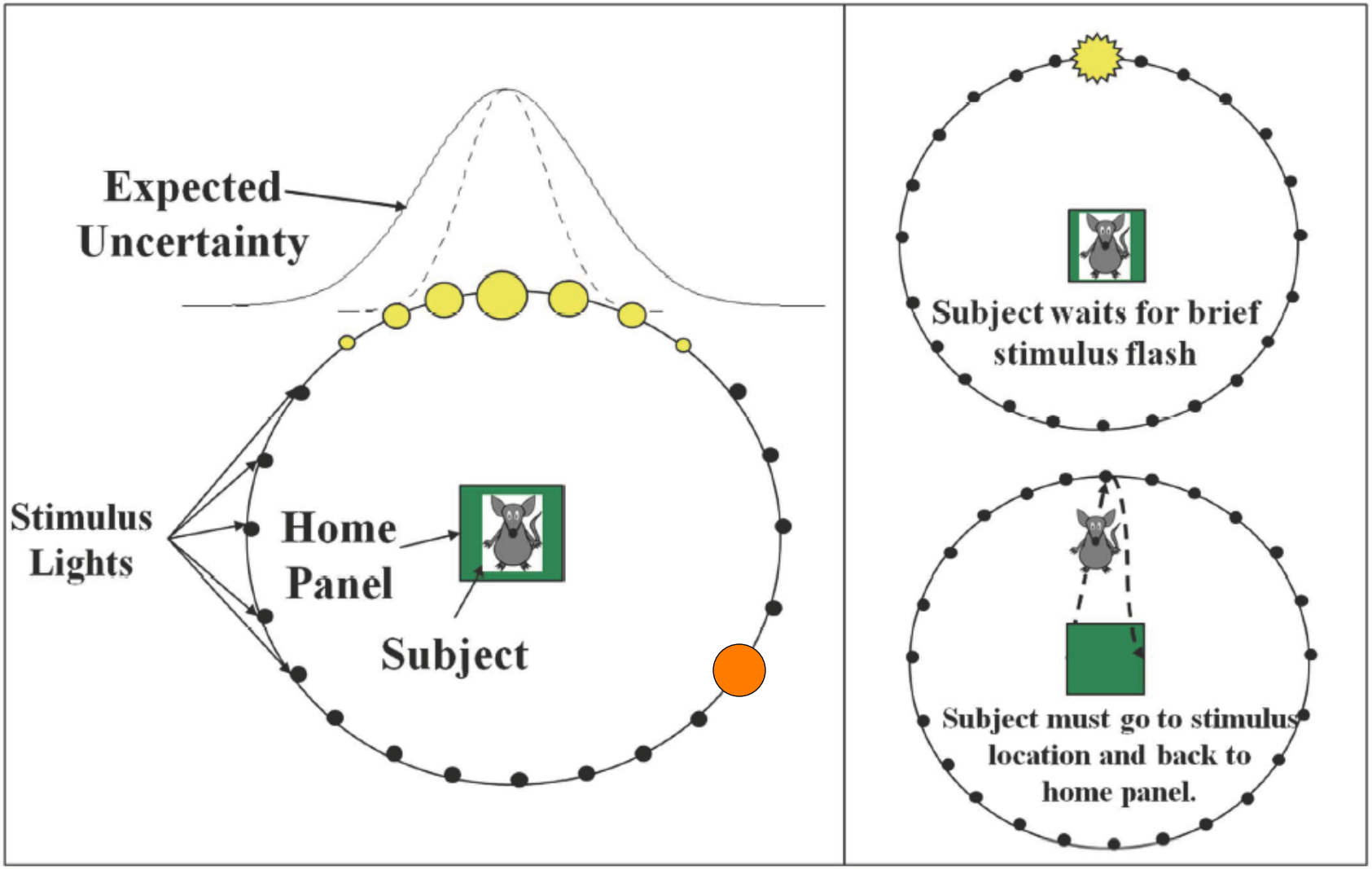
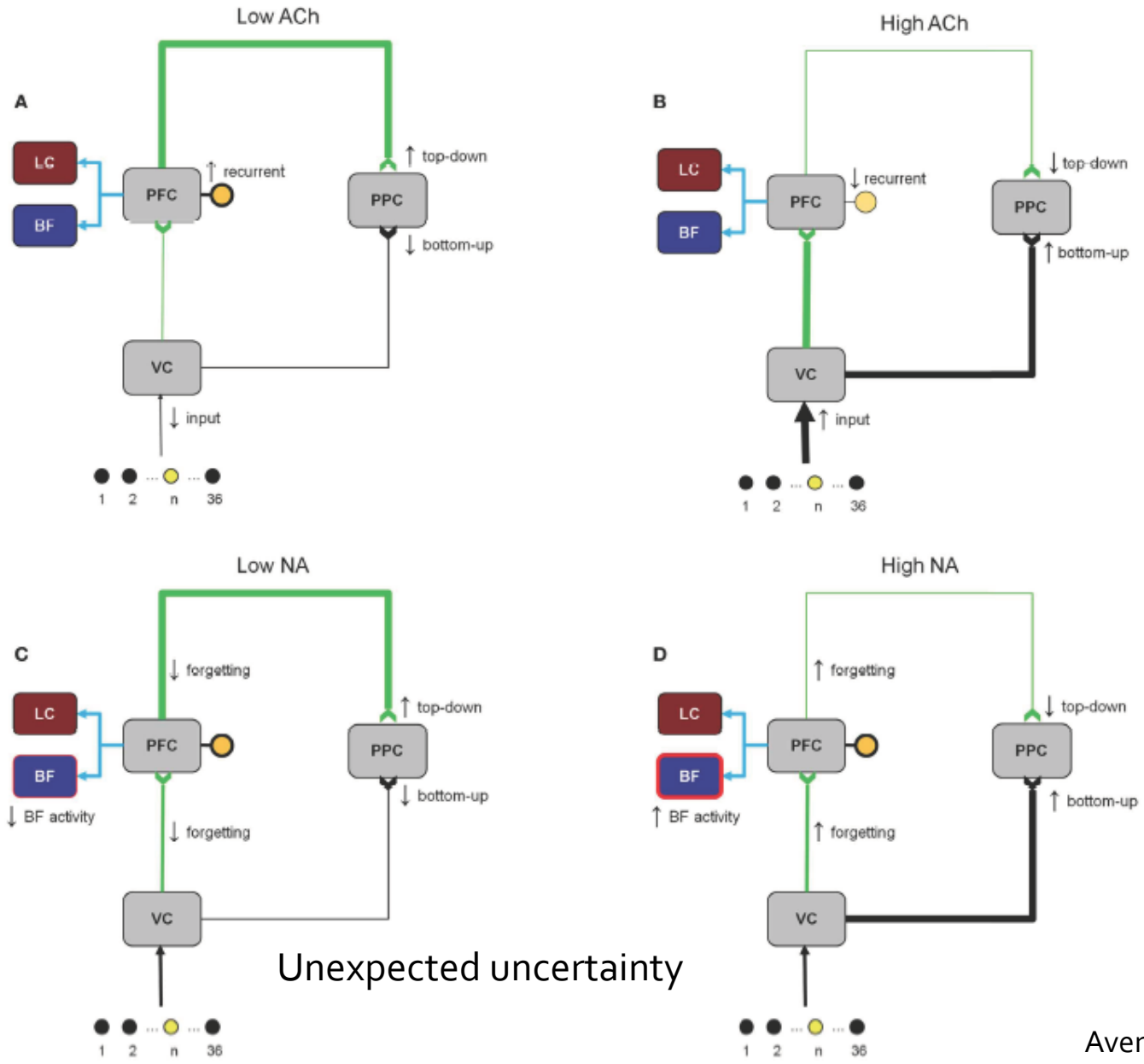


Avery et al., 2012



Unexpected uncertainty

Avery et al., 2012