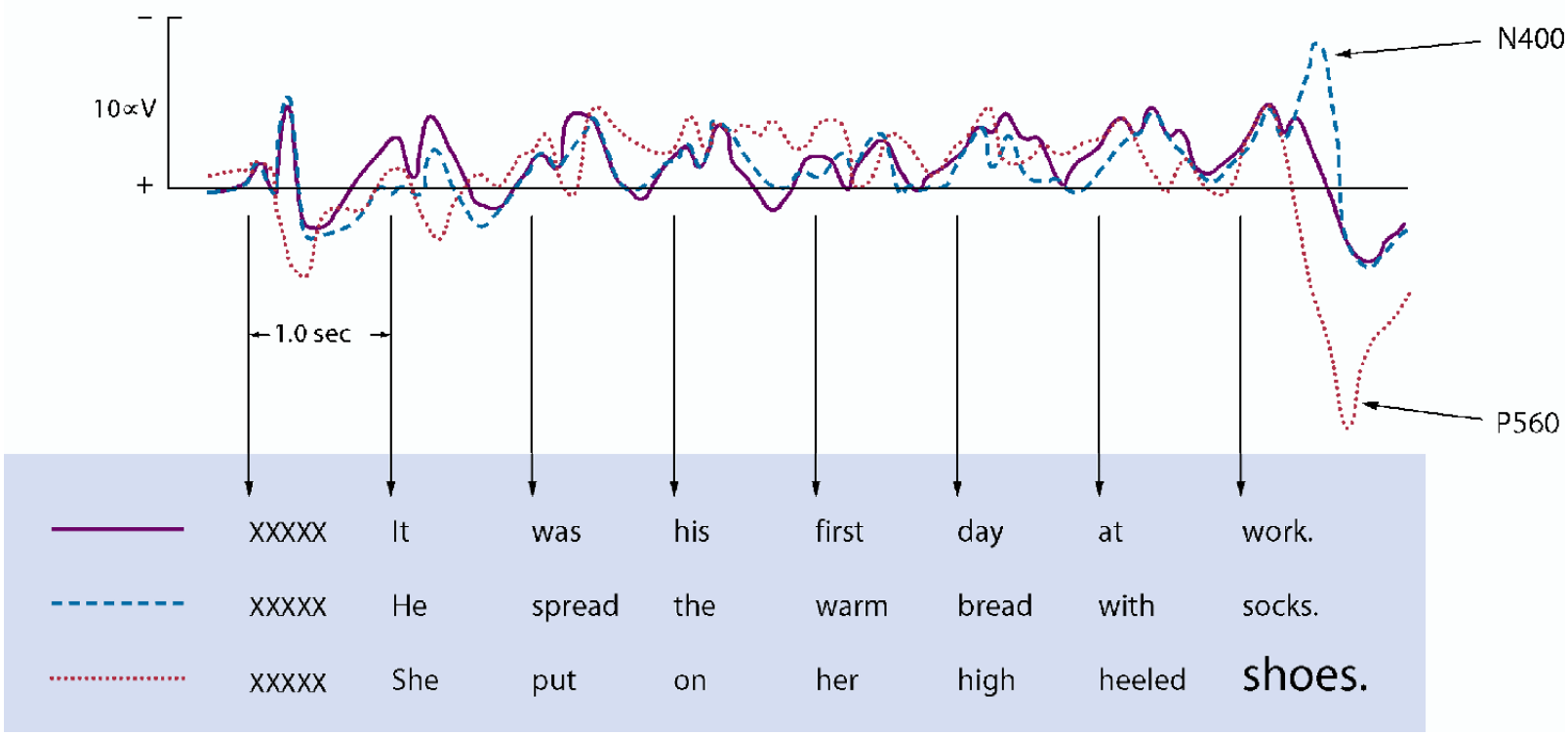
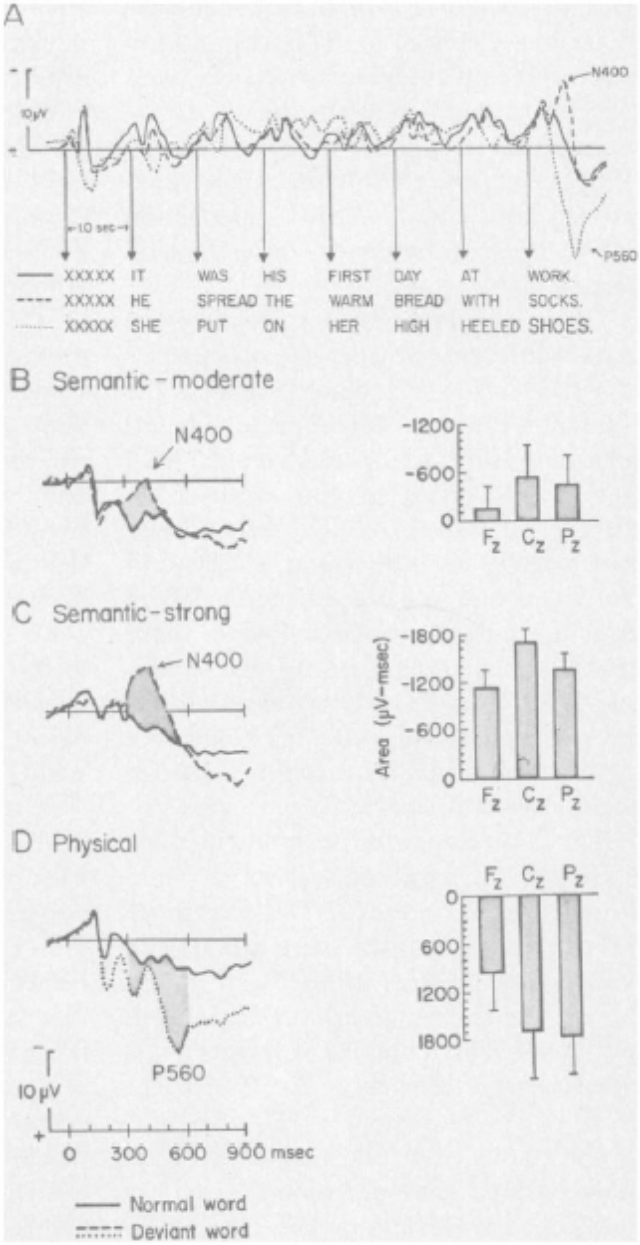
N400: Functional Significance


−
10∝V
+
N400
P560
1.0 sec
XXXXX It was his first day at work.
XXXXX He spread the warm bread with socks.
XXXXX She put on her high heeled shoes.



Difference Waves

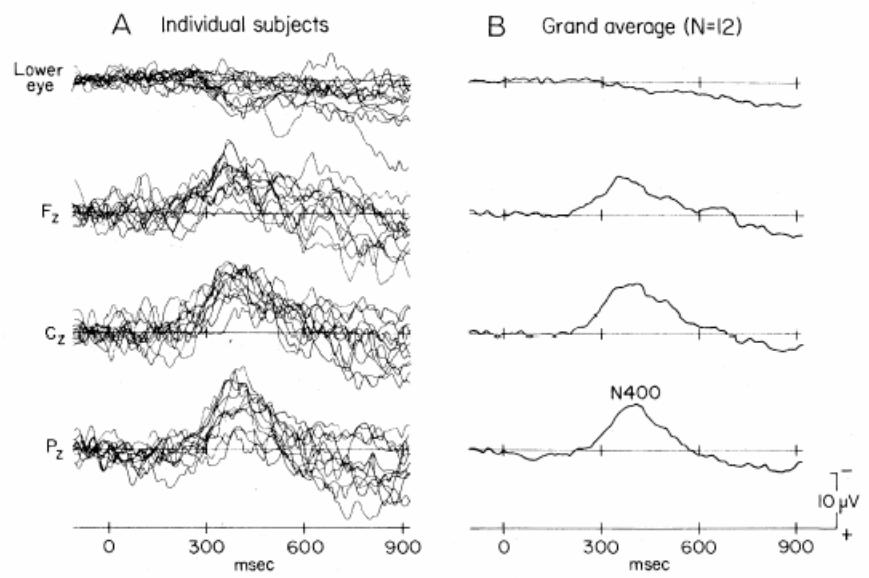
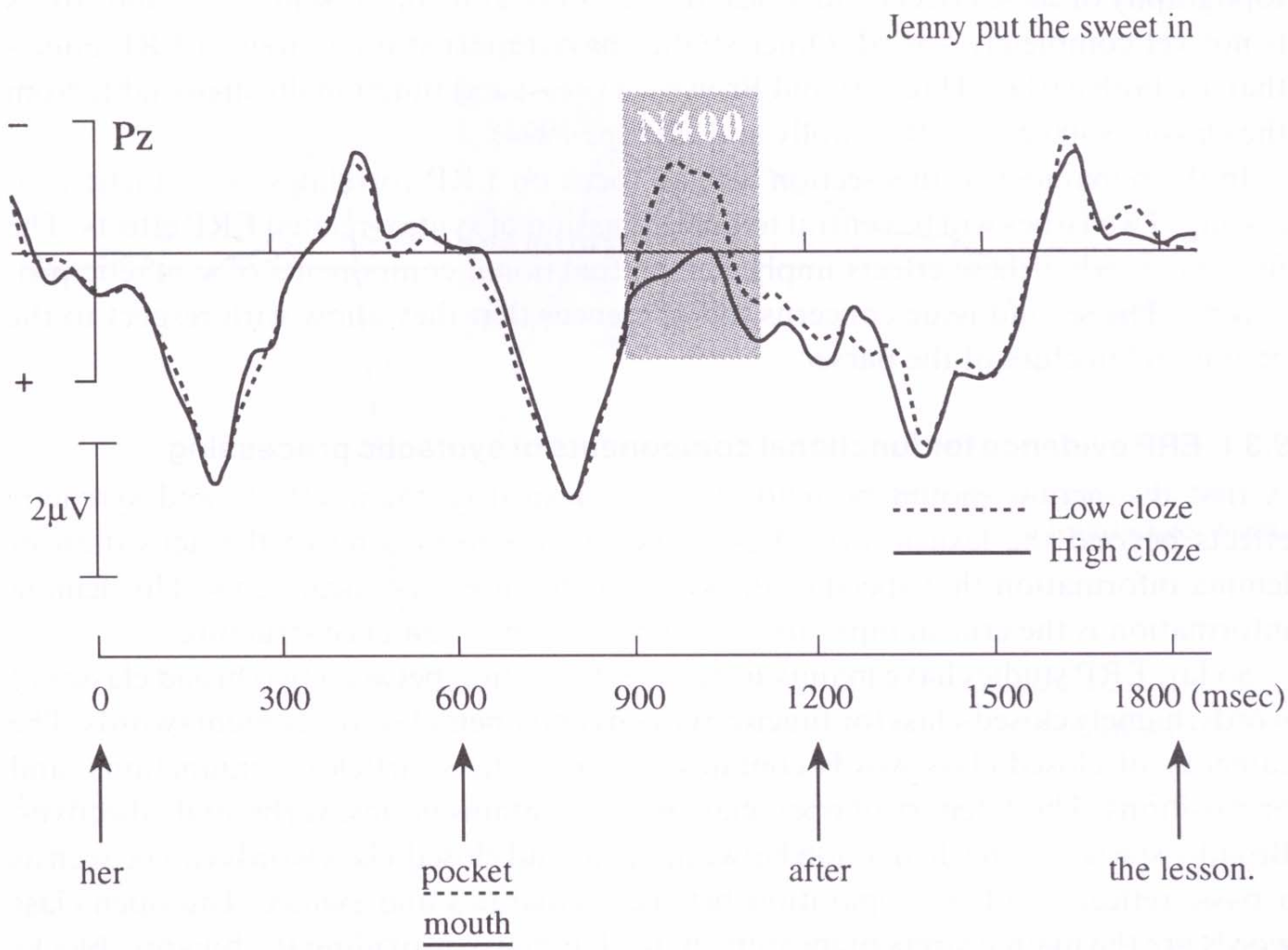


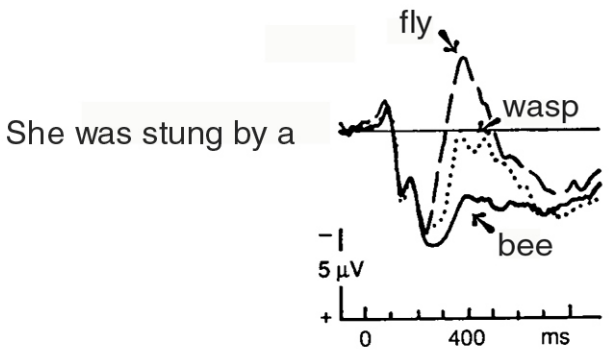
Fig. 2. Difference waves from experiment 2 (strong semantic incongruity). These difference waveforms were obtained by subtracting the averaged ERP's to the semantically congruous words from the ERP's to the semantically incongruous seventh words. Each superimposed tracing (A) represents the difference wave from one subject. The ERP's in (B) are the corresponding grand average waveforms over all 12 subjects.

Sentence Intermediate Words



Sensitivity to Cloze Probability

- Cloze Probability
- Graded Sensitivity
  - Unexpected:
    - Large Negativity
  - Less expected:
    - Medium Negativity
  - Expected:
    - Small Negativity or
    - Positive-going response
- Amplitude indexes lexical integration difficulty



Sensitivity to Buildup of Context

- Van Petten & Kutas (1991)
- N400 to words early, middle, and late in unrelated sentences and texts
- Ordinal position effects in sentences reflects buildup of context
  - Smaller N400 to words late in sentence reflects facilitation of lexical integration
  - Why isn't this observed in texts?

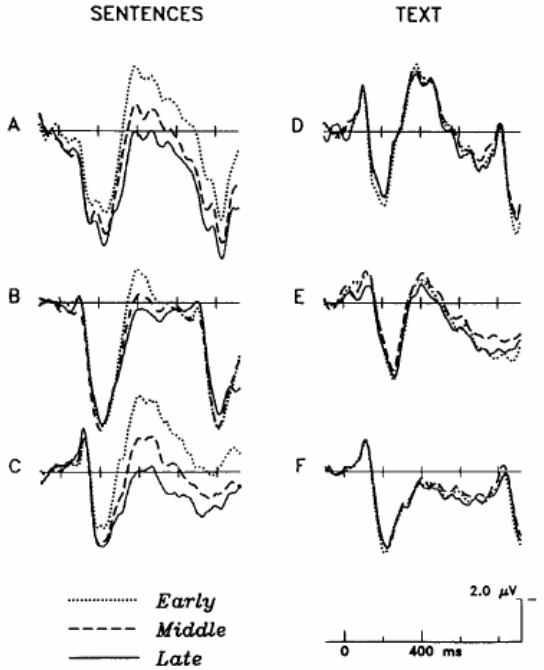
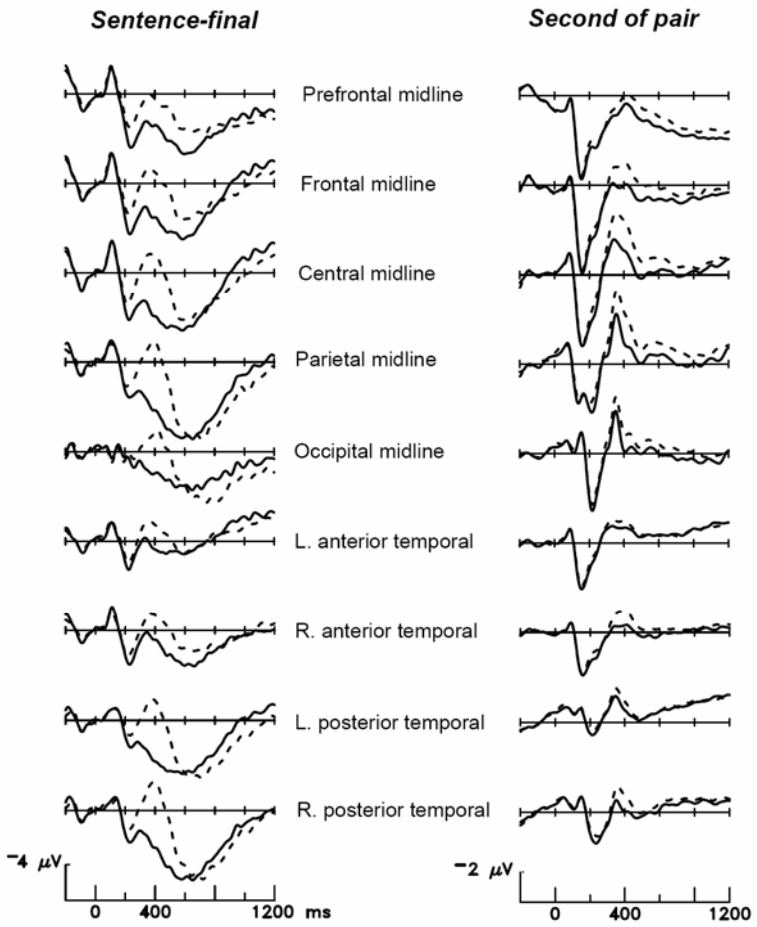


Figure 4. Grand average ERPs elicited by open class words according to position within congruous sentences, excluding initial and final words. Experiments A–C used isolated sentences; Experiments D–F used connected text. The numerical positions of *early*, *middle*, and *late* vary somewhat across experiments but correspond roughly to positions 2–3, 4–6, and 7+. Scalp site Cz. Data are from (A) Van Petten (1993), (B) Van Petten and Kutas (1991a), and (C) Van Petten and Kutas (1990). (D) Data are from unpublished observations from Kutas, Bates, Kluender, Van Petten, Clark, and Blesch (1988). The subjects were 15 adult monolingual English speakers reading children's stories in English. (E) Data are from unpublished observations from the experiment described in Van Petten, Kutas, Kluender, Mitchiner, and McIsaac (1991). The subjects were 16 adult monolingual English speakers reading nonfiction texts drawn from the *Reader's Digest*. (F) Data are from unpublished observations from Kutas et al. (1988). The subjects were 30 Spanish/English bilingual adults reading children's stories in Spanish.

Words vs. Sentences



- Similar N400 effects observed for lexical context (word) and for sentence context
- Curious because thought to be mediated by different processing mechanisms
  - Low level lexical effects
  - High level sentence effects

Interaction vs. Autonomy

Lexical Access & Sentence Parsing

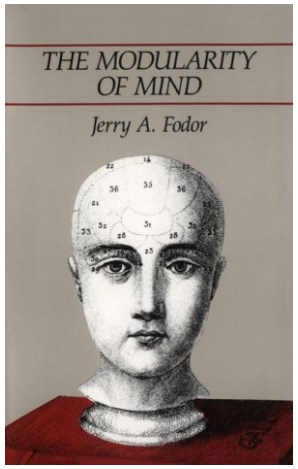
Boland & Cutler 1996

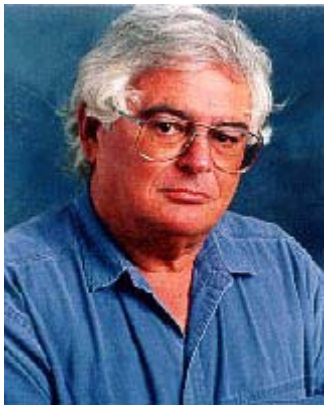
- The debate over interaction/autonomy in lexical access focuses on the *generation* (*activation*) stage

- There is broad agreement that context affects lexical choices once multiple candidates have been generated

Fodor's Modularity Thesis

- Properties of *Input Modules*
  - Domain Specificity: e.g. color or pitch-sensitive cells, duplex perception
  - Mandatory Processing of Input
  - Speed
  - Impenetrability to Conscious Inspection: phoneme-internal details rapidly lost
  - Encapsulation:
  - Shallow Outputs:





Cross-Modal Priming

The guests drank vodka, sherry and port at the reception

(Swinney 1979, Seidenberg et al. 1979)

Cross-Modal Priming

The guests drank vodka, sherry and port at the reception

(Swinney 1979, Seidenberg et al. 1979)

Cross-Modal Priming

- Conflicting results over effect of context on multiple access

- Tabossi (1998)

  - *The violent hurricane did not damage the ships which were in the **port**, one of the best equipped along the coast.*
  - Contexts are highly constraining, prime a specific feature of the target meaning.

Van Petten & Kutas

- Test time course of lexical access with ERPs
- Is there evidence for a modular stage of word recognition?

Materials

Table 1. *Examples of the Lexical Ambiguity Stimuli*[a]

	Contextually relevant	Contextually irrelevant	Unrelated
Homograph sentences, subordinant			
He was not used to hard labor and soon began to tire.	sleep	wheel	rifle
The protestors wanted to shut down the nuclear power plant.	factory	green	mouth
When the judge entered the courtroom the audience all rose.	stood	flower	fashion
Homograph sentences, dominant			
The old car had a flat tire.	wheel	sleep	rifle
While she was away her next door neighbor fed the cats and watered the house plants.	factories	green	mouth
The florist gave his wife a single red rose.	flower	stood	fashion
Nonhomograph sentences			
His uncle wanted to know why he hadn't settled down and gotten married.	single	—	trade
She let the phone ring six times but there was no answer.	question	—	room

[a]The first ambiguity experiment described in the text (Van Petten & Kutas, 1987a) used sentences biasing the subordinant meaning of homographs. The second experiment (unpublished) used sentences biasing the dominant meaning. Both used an equal number of sentences ending with unambiguous words.

Results

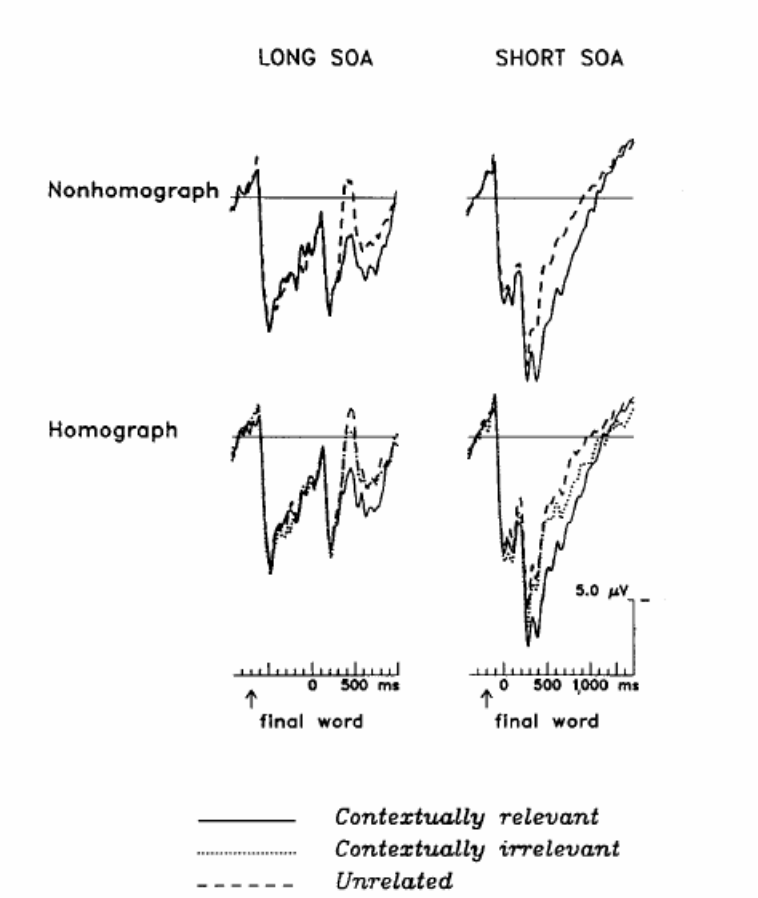


Figure 1. Grand average ERPs from site Cz. Fifteen subjects were in the long SOA group, and 18 were in the short SOA group. Time 0 marks the onset of probe words following sentences that end with homographic or nonhomographic words. Onset of the sentence-final words is marked by the arrow (data from Van Petten & Kutas, 1987a).

LONG SOA

- Nonhomograph
  - N4 unrelated > N4 contextually relevant
- Homograph
  - N4 contextually irrelevant = N4 unrelated
  - N4 unrelated > N4 contextually relevant
- *Does this support modular or interactive access? or both accounts?*

Results

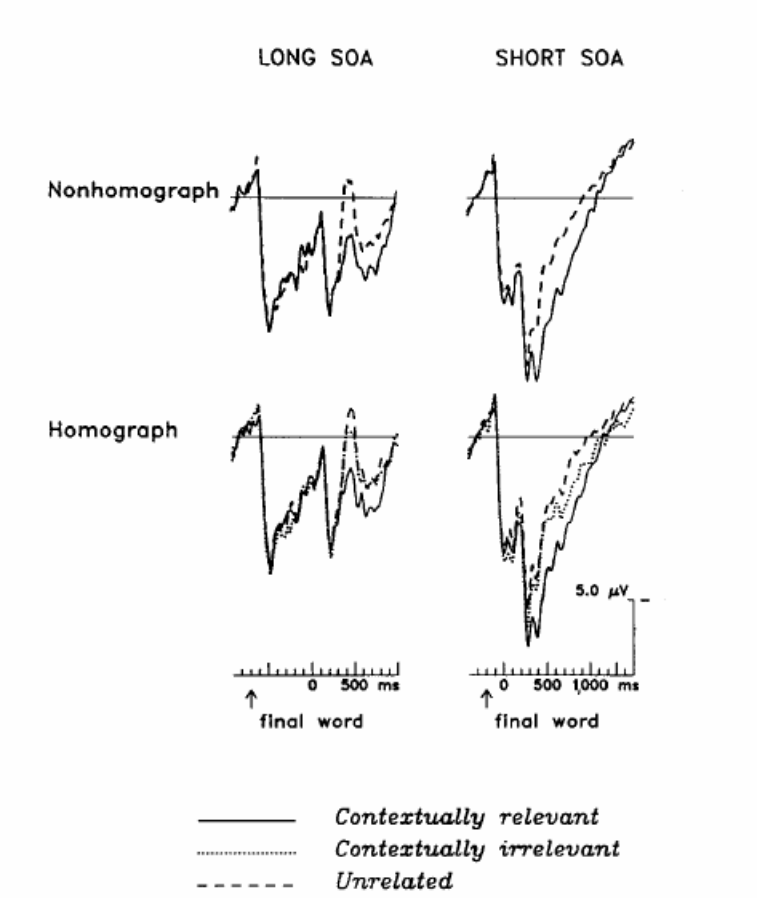
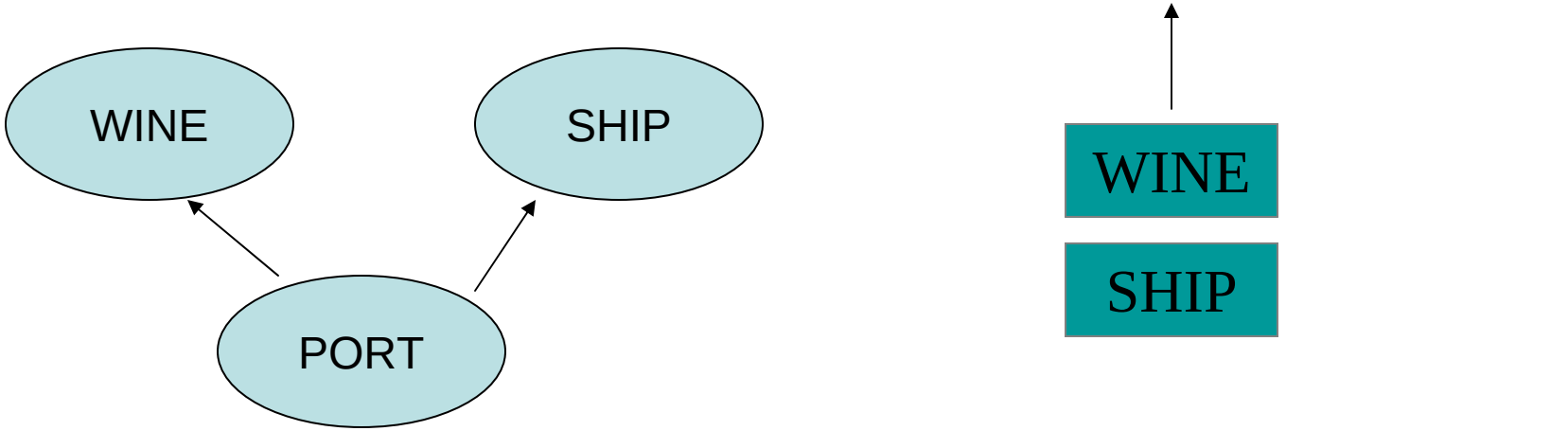


Figure 1. Grand average ERPs from site Cz. Fifteen subjects were in the long SOA group, and 18 were in the short SOA group. Time 0 marks the onset of probe words following sentences that end with homographic or nonhomographic words. Onset of the sentence-final words is marked by the arrow (data from Van Petten & Kutas, 1987a).

- SHORT SOA
- Nonhomograph
  - N4 unrelated > N4 contextually relevant
- Homograph
  - N4 unrelated/irrelevant > N4 contextually relevant
  - Initially ERPs to
    - contextually irrelevant = unrelated
  - Later ERPs to
    - unrelated > contextually irrelevant
- Note differences in waveshape in long vs. short SOA
  - *Why might this be happening?*
- *Do these data support the modularity of lexical access?*

Cross-Modal Priming

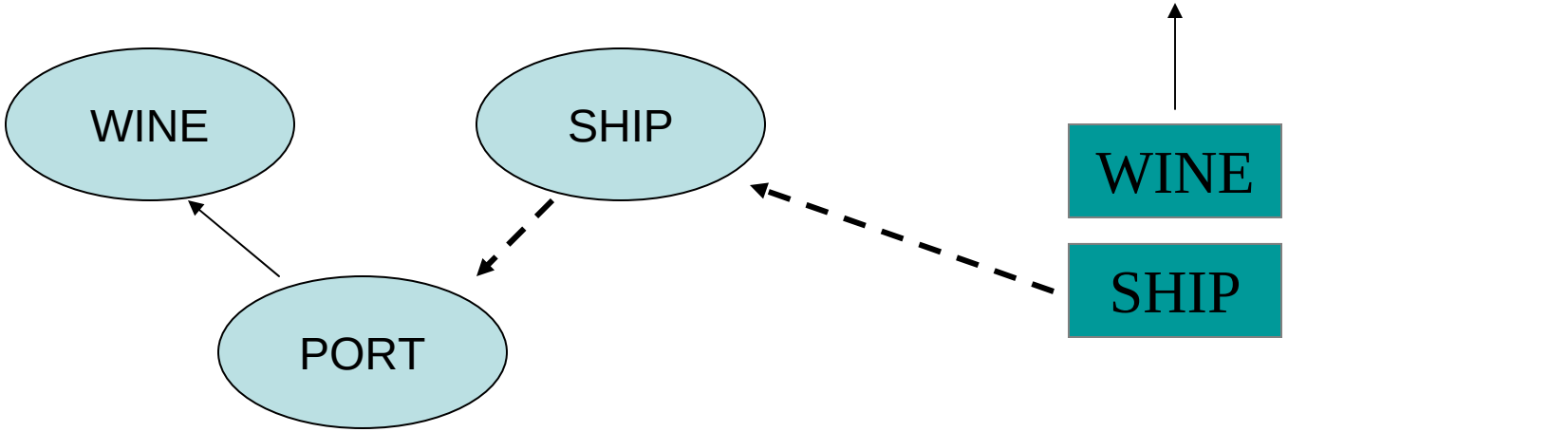
The guests drank vodka, sherry and port at the reception



(Swinney 1979, Seidenberg et al. 1979)

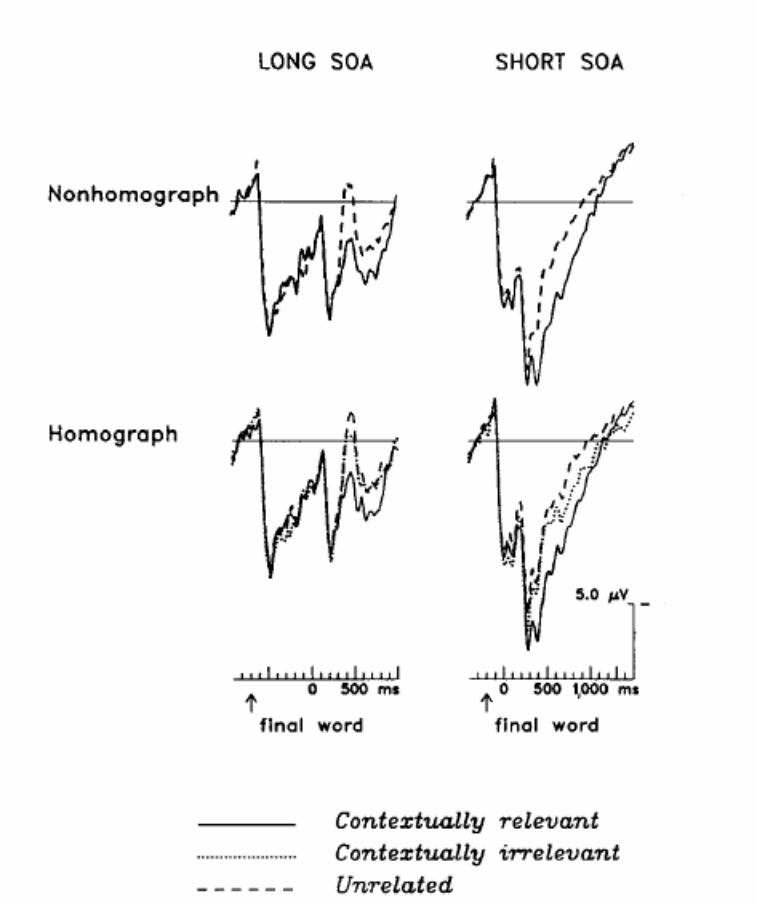
Backwards Priming

The guests drank vodka, sherry and port at the reception



(Swinney 1979, Seidenberg et al. 1979)

Backward Priming



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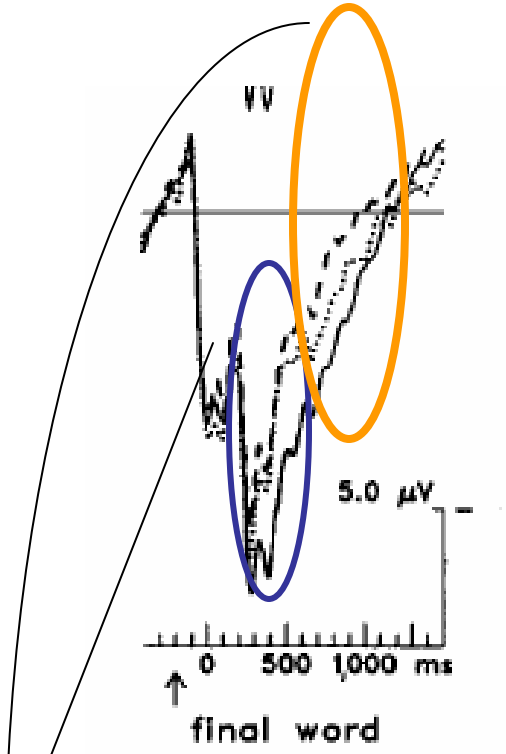

- Irrelevant meaning not initially active
- Probe activates irrelevant meaning

Words vs. Sentences

- Much of Van Petten's work (discussed in 1995 paper) motivated by hypothesized distinction between lexical and sentence context effects and doubt in the modularity of lexical processing
- THEME: find variable that influences lexical processing and see if it changes as a function of higher level contextual factors

Lexical vs. Sentential Factors

Lexical

- Word Frequency in language
- Word Associations
- Word Class
  - Open (nouns, verbs, adjectives)
  - Closed (determiners, prepositions)

Sentential

- Ordinal position in sentence
- Is sentence grammatically well-formed?
- Does sentence make sense?

Sentence Context & Word Frequency

- Frequency is a prototypical lexical variable
- Affects word recognition difficulty
  - Greater RTs on word/nonword decisions for rare words
  - Longer fixation times in reading for rare words
  - Larger N400 for rare words
- Do frequency effects ever go away?
  - E.g. if context motivates the use of a rare word
  - High-level mechanisms changing operation of low-level (encapsulated) lexicon

Materials

Table 2. *Examples of the Congruent, Syntactic, and Random Sentences*[a]

Congruent	The tenants were evicted when they did not pay the last two months rent.
	Most new drugs are tested on white lab rats.
	She played the drums in a rock and roll band.
Syntactic	He ran the half white car even though he couldn't name the raise.
	In the wet levels fathers were smoking by congress.
	He prepared at the back hand to pair up his robbers.
Random	To prided the bury she room she of peanut the had china.
	She which had jazz anchor a she to straight couldn't gun.
	Be place prefer the was city it and sure be perfume.

[a]One hundred sentences of each type were used in Van Petten and Kutas (1991a).

Results

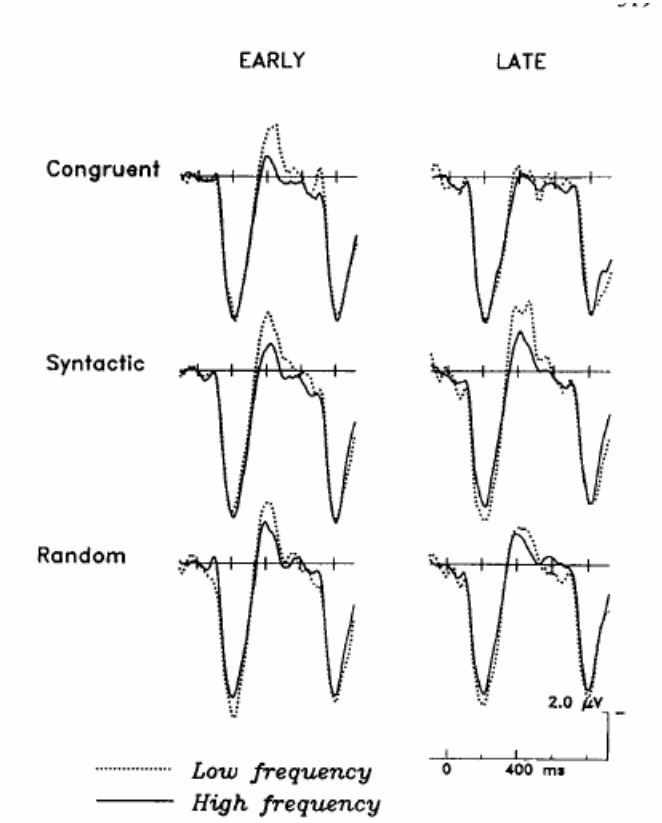

Figure 7. Grand average ERPs elicited by open class words at Cz in three sentence types. *Early* and *late* refer to approximately the first and second halves of the sentences, excluding the initial and final words. *High frequency* is defined as 30/million or higher when summed across all regularly inflected forms in the Francis and Kucera (1982) corpus; *low frequency* is 29/million or lower (Van Petten & Kutas, 1991a).

- Random
  - Small frequency effect for words that appear early and late
- Syntactic
  - Large frequency effect for words that appear early and late
- Congruent
  - Large frequency effect for words that appear early in the sentence
  - No frequency effect for words that appear late in the sentence
- *What does this mean?*

Sentence Context & Word Associations

- Word Associations facilitate word recognition
  - Spreading activation between related words
- Independent of high level sentence comprehension mechanisms
- Doctor-Nurse vs. Doctor-Sock
  - Longer RTs on word/nonword task
  - Larger N400

Materials

Table 3. *Examples of the Stimuli Used to Compare Lexical and Sentence-Level Context*[a]

Congruent associated	When the *moon* is full it is hard to see many *stars* or the Milky Way.
	There were advantages to living in a *city* but Martha moved to a small *town* for the peace and quiet.
Congruent unassociated	When the *insurance* investigators found out that he'd been drinking they *refused* to pay the claim.
	The biologist went to the desert every *week* to collect a particular *species* of lizard that he hoped to study.
Anomalous associated	When the *moon* is rusted it is available to buy many *stars* or the Santa Ana.
	There was jewelry to drumming in a *city* but Martha turned to a gray *town* for the lizard and scones.
Anomalous unassociated	When the *insurance* supplies explained that he'd been complaining they *refused* to speak the keys.
	The shirt went to the gun every *week* to keep a good *species* of fumes that it hired to see.

[a]One hundred twenty sentences of each type were used in Van Petten (1993). Across conditions, the critical words (italicized) were matched for length, frequency, and position in the sentences. The experiment was conducted in two sessions so that subjects saw each critical word pair only once in each session.

- Stimuli should elicit lexical and sentential context effects
- Does lexical context effect begin earlier than sentence context effect?

Replication of Frequency x Sentence Position Effects

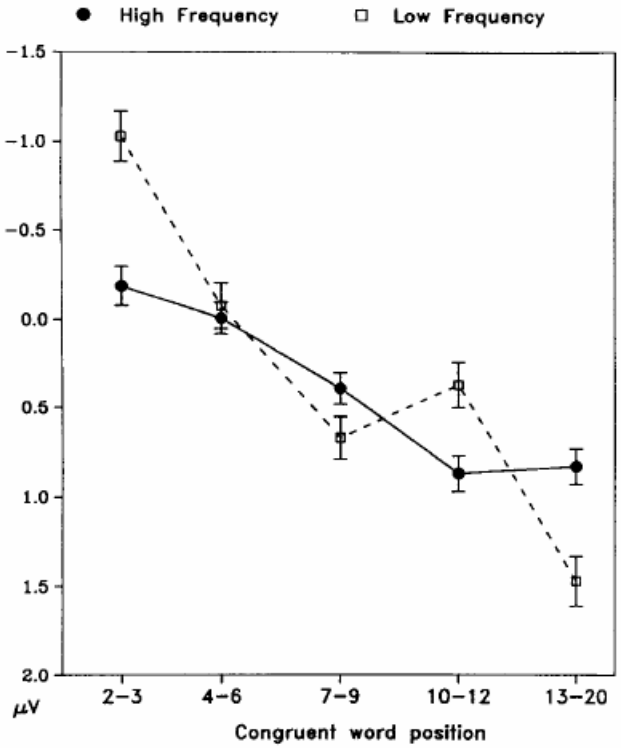

Figure 8. Mean voltage within the peak latency range of the N400 (300–500 ms poststimulus onset) for open class words in congruent sentences relative to a 100-ms prestimulus baseline. Examples of the sentences are shown in Table 3; the critical word pairs shown there were also excluded. The amplitude measure is averaged across all electrode sites (Van Petten, 1993).

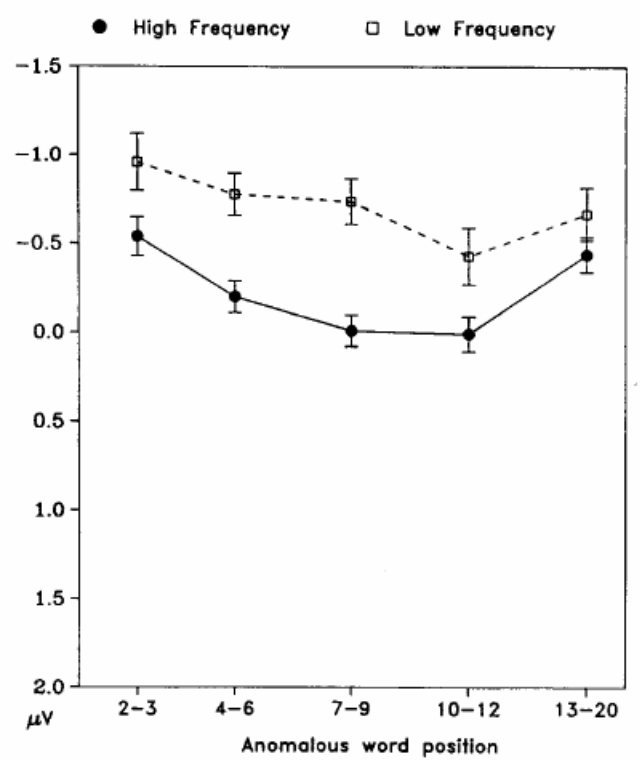

Figure 9. Mean voltage within the peak latency range of the N400 (300–500 ms poststimulus onset) for open class words in semantically anomalous sentences relative to a 100-ms prestimulus baseline. Examples of the sentences are shown in Table 3; the critical word pairs shown there were also excluded. The amplitude measure is averaged across all electrode sites (Van Petten, 1993).

Replication

- Isn’t replication a waste of time? What’s the point of retesting something you’ve done before?
- What are some differences between this experiment and Van Petten’s first frequency experiment?
- Why is replication a good thing?
  - Am I repeating myself? ☺

Materials

Table 3. *Examples of the Stimuli Used to Compare Lexical and Sentence-Level Context*[a]

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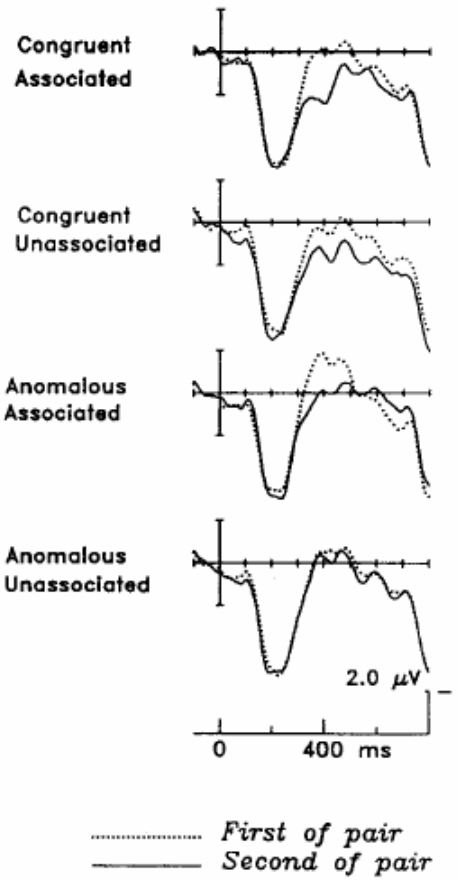


Figure 10. Grand average ERPs from 28 subjects at scalp site Cz (Van Petten, 1993).

- Onset sentence context N400 effect same time as word association N400 effect
- Amplitude of N400 in congruous associated additive combination of lexical and sentence context effects
- Word and sentence level context both influence N400 amplitude
- No evidence for discrete lexical stage of processing

Individual Differences

- Subjects differ in their ability and willingness to do experimental tasks
- How does this impact ERP findings?
- Van Petten found that task performance affected sentence context effects more than word context effects
  - Task was probe word recognition administered after each sentence. WAS?
  - Do you remember why they used this task?

Individual Differences

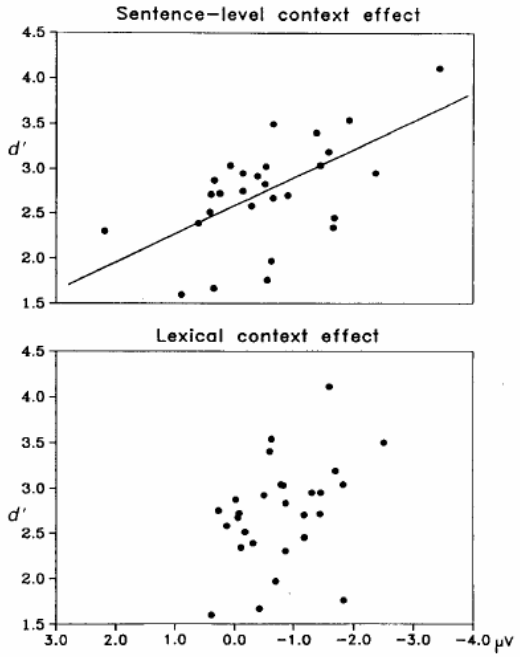


Figure 11. The top panel illustrates the relationship between behavioral performance in the working memory task embedded within the experiment. The y-axis represents performance summarized by *d'*. This measure combines accuracy for targets that occurred in the preceding sentence (correct response of "yes/present") and targets that did not occur in the preceding sentence (correct response of "no/absent"). The *d'* was calculated by considering correct responses to "present" probes as hits and incorrect responses to "absent" probes as false alarms. The x-axis represents the difference in the amplitude of the N400s elicited by the first and second members of the critical pairs in the congruent-unassociated condition (mean voltage 300–500 ms poststimulus onset, collapsed across all electrode sites). Negative amplitudes thus reflect larger context effects. Each data point represents one subject, and the regression line reflects the statistical relationship between performance and the ERP context effect. The bottom panel illustrates the lack of relationship between behavioral performance and our measure of the lexical context effect, the amplitude difference of the N400s elicited by the first and second members of anomalous-associated pairs. The regression analysis of the date in the bottom panel did not yield a significant correlation (data from Van Petten, 1993).

- Sensitivity in task performance correlates with size (in microvolts) of sentence-level N400 context effect
  - Good at task, big sentence context N400
- Does not correlate with word level context effect
  - Word context N400 similar size in most people
- Working memory capacity affects ability to utilize sentence context for language comprehension
- Maybe word level context doesn't require much WM

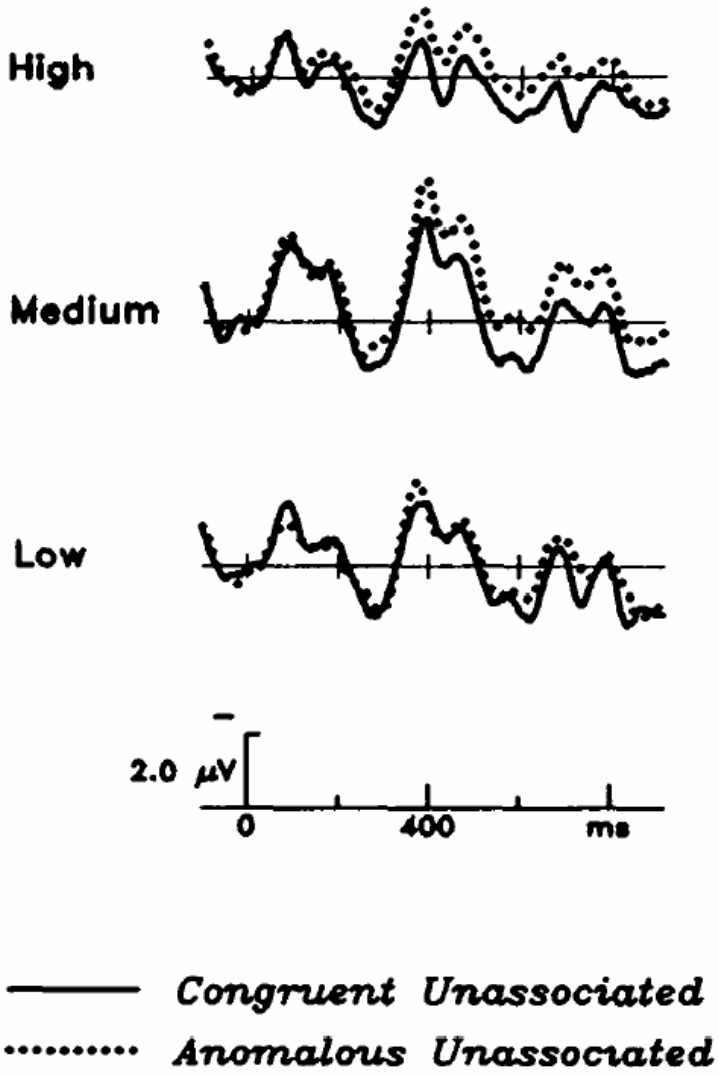
Van Petten, et al.,

Table 1 *Examples of the four sentence types*

Type	Example
Congruent-associated	When the **moon** is full it is hard to see many **stars** or the Milky Way
Congruent-unassociated	When the **insurance** investigators found that he'd been drinking they **refused** to pay the claim
Anomalous-associated	When the **moon** is rusted it is available to buy many **stars** or the Santa Ana
Anomalous-unassociated	When the **insurance** supplies explained that he'd been complaining they **refused** to speak the keys

Note The critical pairs of words are shown in bold

WM Span & N400 Context Effects



- Sentence context effects present in High and Medium span subjects' ERPs
- Sentence context effects absent from Low span subjects' ERPs

WM Span and Word Context Effects

- Note impact of word level context on close but not distant pairs
  - Word level context effects short-lived
- All subjects showed similar word level context effects on the N400