Predicted Outcomes for any ERP effect

If old and similar new ERP pattern together then ERP effect must reflect familiarity, not recollection

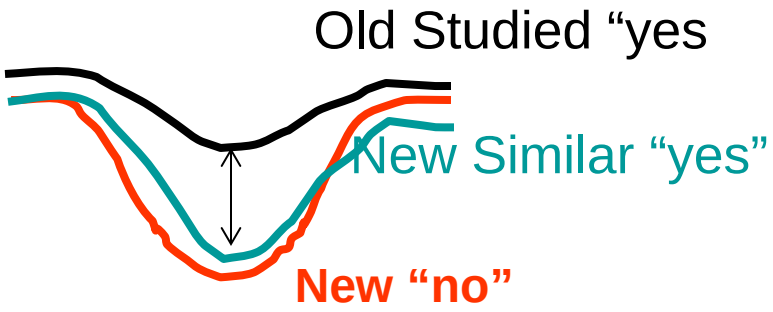
New [no] <Similar [yes] = Studied [yes]

(low fam < hi fam = hi fam)

If new and similar new ERP pattern together then ERP effect must reflect recollection, not familiarity

IF New [no] = Similar [yes] < Studied [yes]

(low rec = low rec < hi rec)



The two hypotheses differ in their prediction for the <u>new similar items that participants mistakenly consider old.</u>

RETRIEVAL FROM LONG TERM MEMORY (LTM)

Monitor slow waves – much like CNV – to examine retrieval from long term memory. For example, Roesler, Heil and colleagues capitalize on fan effect to manipulate memory retrieval processes systematically.

FAN EFFECT: Time to decide whether two memory representations have an episodic link or not depends on the total number of links that branch from that representation (an item's fan is number of facts/links associated to a concept).

7 items per study list = 1 label, 3 tokens, 3 types

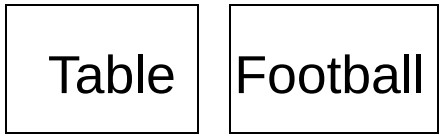
Label	Token	Type
STATION	Furniture	table
	Island	Malta
	Fruit	*banana*
LAWYER	Sports	football
	Car	Porsche
	Dog	*beagle*
SCHOOL	Furniture	table
	Car	Porsche
	Vegetables	*carrot*
RESTAURANT	Furniture	table
	City	Berlin
	Dog	*dachshund*
LECTURE	Sports	football
	City	Berlin
	Fruit	*orange*
APARTMENT	Sports	football
	Island	Malta
	Vegetables	*beans*

Each type has 1, 2 or 3 fans

Fan 1 – e.g., banana
Fan 2 – e.g, Malta
Fan 3 – e.g., table

Task: learn associations between label, category names, and exemplars

RETRIEVAL TASK



Are they in the same list or not?

Table	Football

Are they in the same list or not?

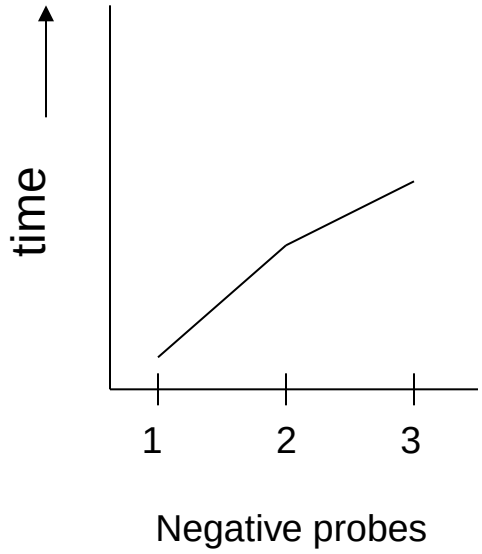
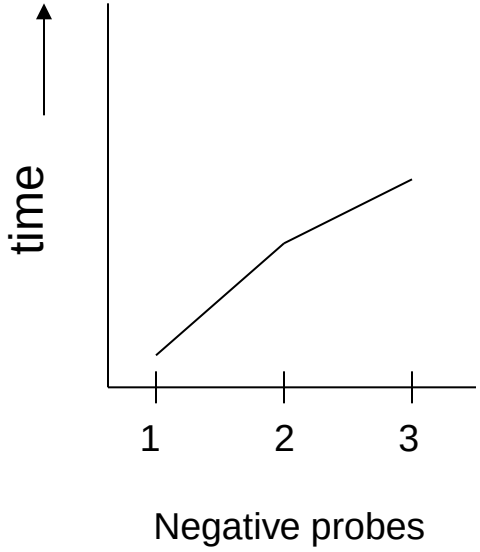
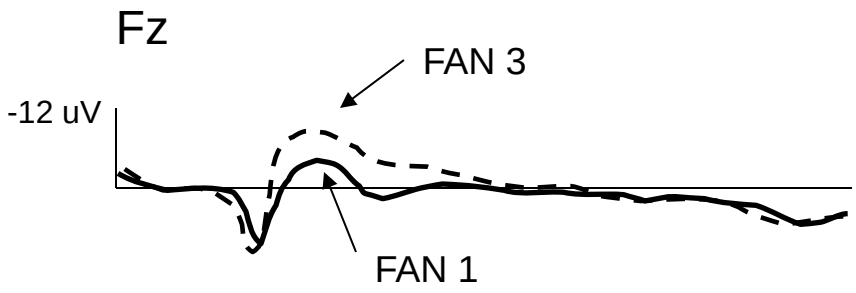


Table | Football

Are they in the same list or not?





Slow waves are systematically related to memory retrieval processes. Left frontal for semantic processes, with amplitude that varies with retrieval difficulty (fan size).

Do distinct long term memory storage sites exist for different kinds of information?

One major hypothesis is that engrams are consolidated and reactivated in the very same neocortical cell assemblies in which information is also processed on-line during perception.

ELSEVIER

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Material-specific long-term memory representations of faces and spatial positions: Evidence from slow event-related brain potentials

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Abstract

Motivated by models that propose material-specific cortical long-term memory representations we expected different topographies of event-related slow waves of the EEG during cued retrieval of two distinct types of information (faces and spatial positions), which are assumed to be processed and stored in topographically distinct cortical areas, i.e., in either the ventral or the dorsal visual pathway. Seventeen participants learned associations either between words and spatial positions or between words and faces. Each word was associated with either one or two positions or faces. In a cued recall test, one day later, participants saw two words and had to decide whether these were linked to each other via an associated spatial position or a face. Slow event-related potentials (ERPs) of the EEG were recorded from 61 scalp electrodes during both acquisition and recall. Response times increased monotonically with the number of faces and positions to be reactivated. Negative slow ERPs showed a comparable topography during anticipation learning and cued recall, but dissociated topographically for positions and faces. The maximum of the negativity increased when items were presented repetitively (compared to the first presentation) during learning, and also with the number of the to-be-reactivated associations during retrieval. These results are consistent with an information-processing model that assumes material-specific cortical representations of episodic memory contents, which are established as localized cortical cell assemblies during encoding, and which are being reactivated during recall.

Keywords: EEG; Slow waves; Episodic memory; Long-term representations; Object memory; Spatial memory

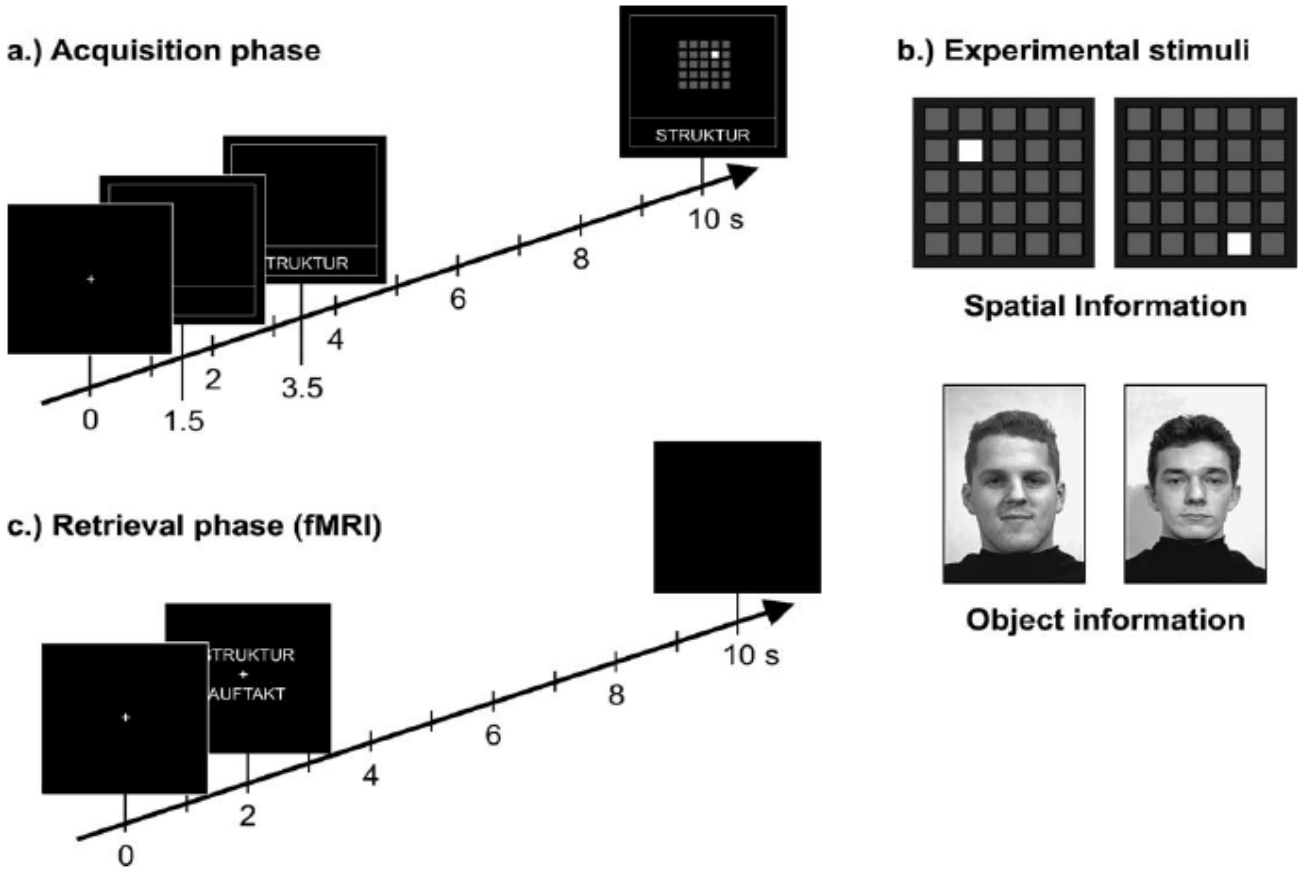


Fig. 1. Stimulus sequence of acquisition (a) and recall (c) trials. (b) Examples of faces and positions that had to be encoded during acquisition.

P. Khader et al. / NeuroImage 27 (2005) 805–816

Study: 54 nouns – half associated with 1 or 2 spatial locations; half with 1 or 2 faces
Test: two words – associated with same face? with same location?

The increasing number of associations that had to be activated during retrieval were evident in a monotonic increase of the amplitude of the negative slow wave.

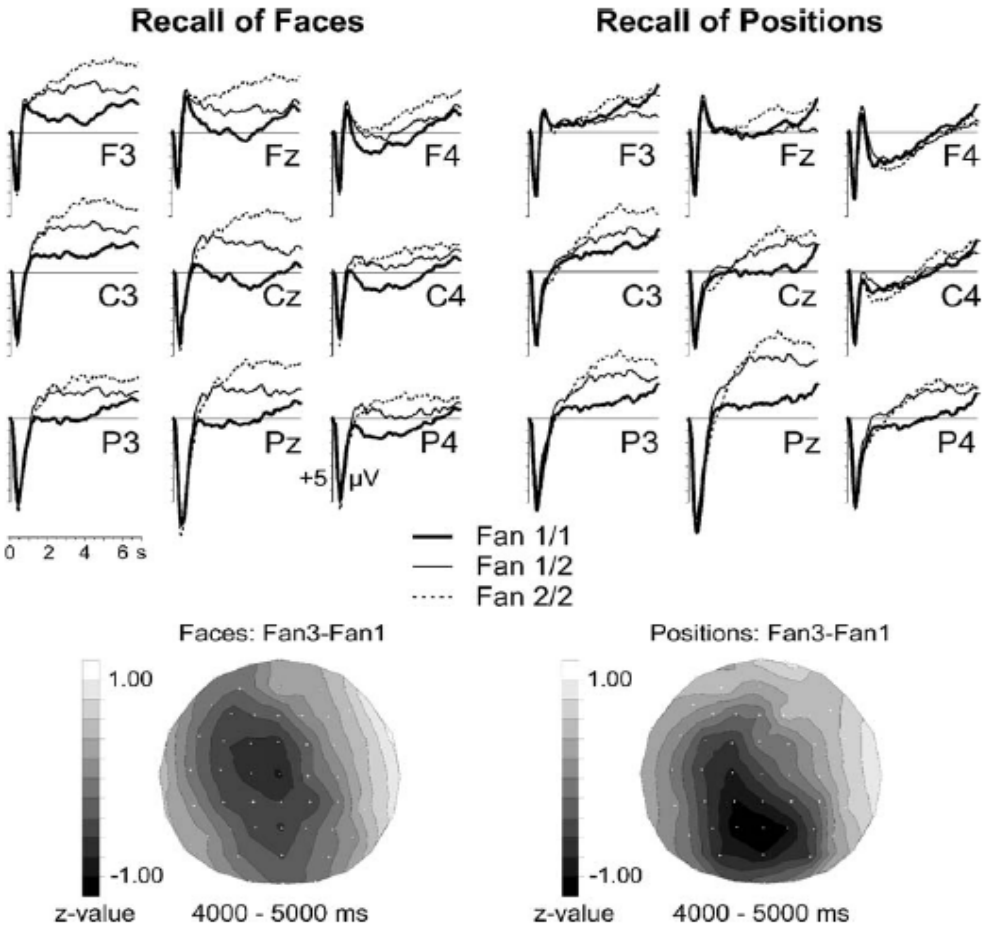


Fig. 6. ERPs during recall of faces and positions for different levels of fan. Below are the corresponding topographic difference maps "fan(2/2)–(1/1)" for faces and positions from 3000 to 4000 ms after onset of the retrieval cue. The maps were computed from all 61 scalp electrodes.

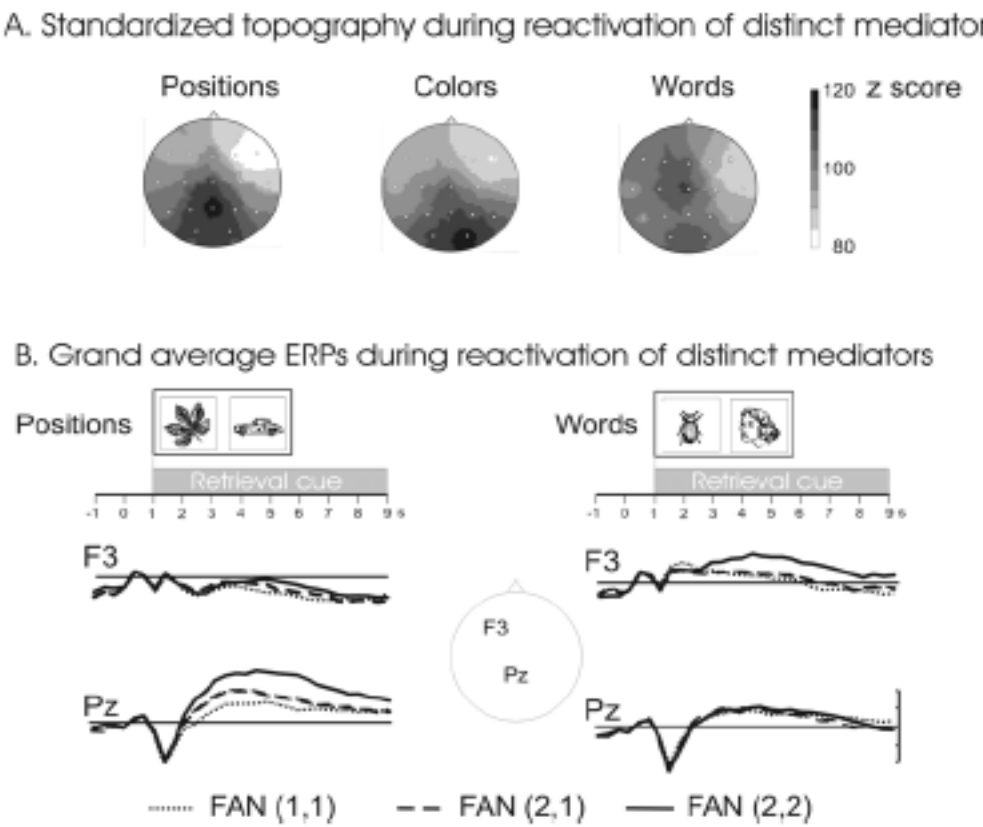


Figure 4. Slow ERPs during retrieval of different associations in long-term memory. **A.** Shows the topography of the average slow wave pattern between 3 and 4 s after a retrieval cue which triggered either spatial, color, or verbal associations (darker shading indicates relative larger negative amplitude, i.e. more activation of the underlying cortical areas) (Data from Rösler, Heil, Bajric, Pauls, & Hennighausen, 1995). **B.** Shows the time course of the retrieval situation and the slow waves for different levels of fan, i.e. a different number of associations which had to be scanned during retrieval. A more difficult task (larger fan) evokes a larger amplitude increase with a code-specific topography (Data from Heil, Rösler, & Hennighausen, 1997).

Negative slow waves are temporally linked to the process of retrieval.

The topography of the slow waves reflect what memory codes are accessed; it is larger over area known to be functionally involved in processing that type of information, e.g.,

- frontal – semantic
- parietal – spatial
- occipital – color

Amplitude of negativity is related to the difficulty of the retrieval (e.g., fan effect)

Language Comprehension and Language Learning

- early sensory components (N1 and speech segmentation)
- in speech, PMMN (phonological mismatch negativity)
- N200, P3b
- N400
- P600 (aka syntactic positive shift, SPS)
- frontal P600, parietal P600, PNP
- N400-700
- FSN (frequency sensitive negativity)/aka LPN, N280
- CPS (closure positive shift)
- left anterior negativity or LAN (ELAN, LAN)
- Nref effect
- slow potentials spanning clauses or sentences

Language Production

- LRP, nogo N200

Why are ERPs useful for studying language?

1. Language unfolds at multiple timescales and ERPs can track them all e.g., phonemes, syllables, words, phrases, clauses, sentences, discourse

2. No need for a secondary task beyond comprehension e.g., reading, listening, with or without comprehension questions

3. Many of debates in language center on whether certain language events are qualitatively or quantitatively different from others. Multidimensional nature of ERPs helps answer such questions

4. Other debates in language revolve around the order in which different language processes transpire (i.e., timing issues), and exquisite temporal sensitivity of ERPs helps resolve such issues.

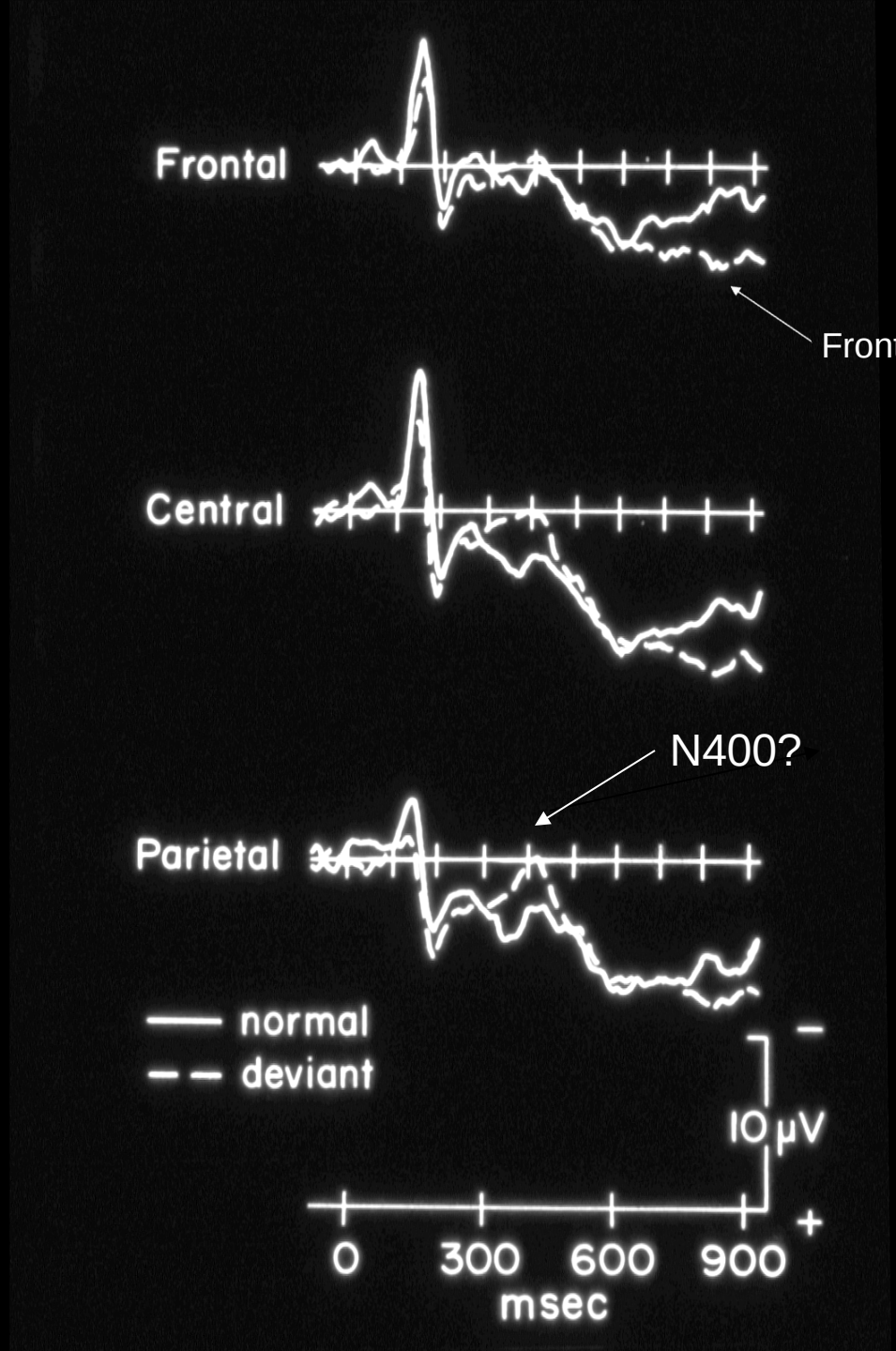
In this late seventies, we knew that P3b is elicited by binary decision, especially to surprising, low probability, unexpected events, with latency that varies with difficulty of categorization.

Perhaps, we can elicit P3 to semantically unexpected items in language and use P3 latency to examine how sentence context affects word processing.

Cliché: Roses are red and violets are *blue*.
Fact: A female chicken is called a *hen*.
Open-ended: He returned the book to the *library*.

Semantically Incongruent: I take coffee with cream and *milk*.

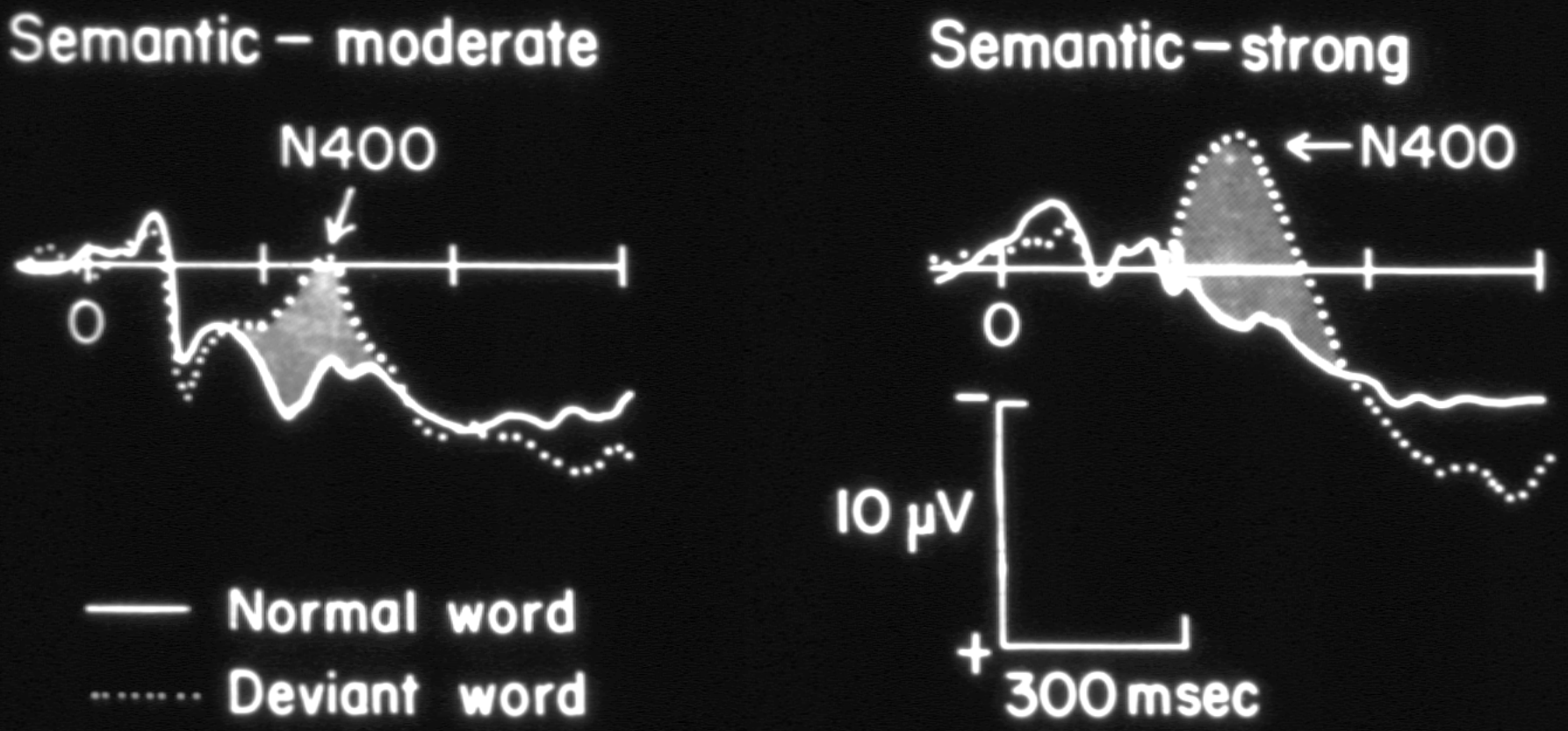
Incongruent: He shaved off his mustache and *eyebrows*.

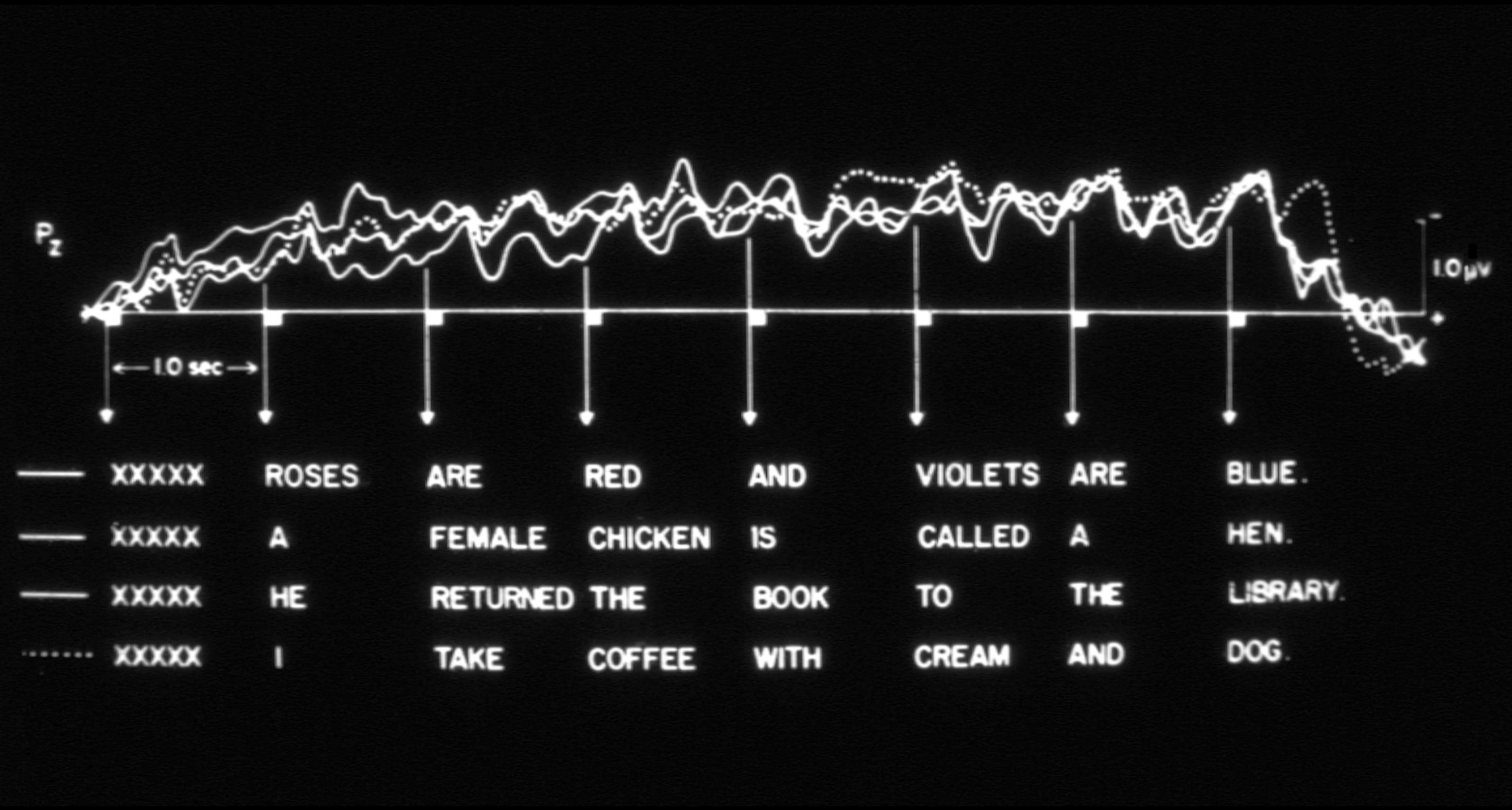

Frontal
Frontal P600 or PNP
Central
N400?
Parietal
normal
deviant
10 μV
−
+
0
300
600
900
msec

Semantic Anomalies

He shaved off his mustache and ***city***.

I take coffee with cream and ***dog***.


Semantic – moderate
N400
0
Normal word
Deviant word
Semantic – strong
N400
0
10 μV
300 msec


Pz
1.0 sec
1.0 μv
XXXXX ROSES ARE RED AND VIOLETS ARE BLUE.
XXXXX A FEMALE CHICKEN IS CALLED A HEN.
XXXXX HE RETURNED THE BOOK TO THE LIBRARY.
XXXXX I TAKE COFFEE WITH CREAM AND DOG.

Difference ERPs (incongruent-congruent)

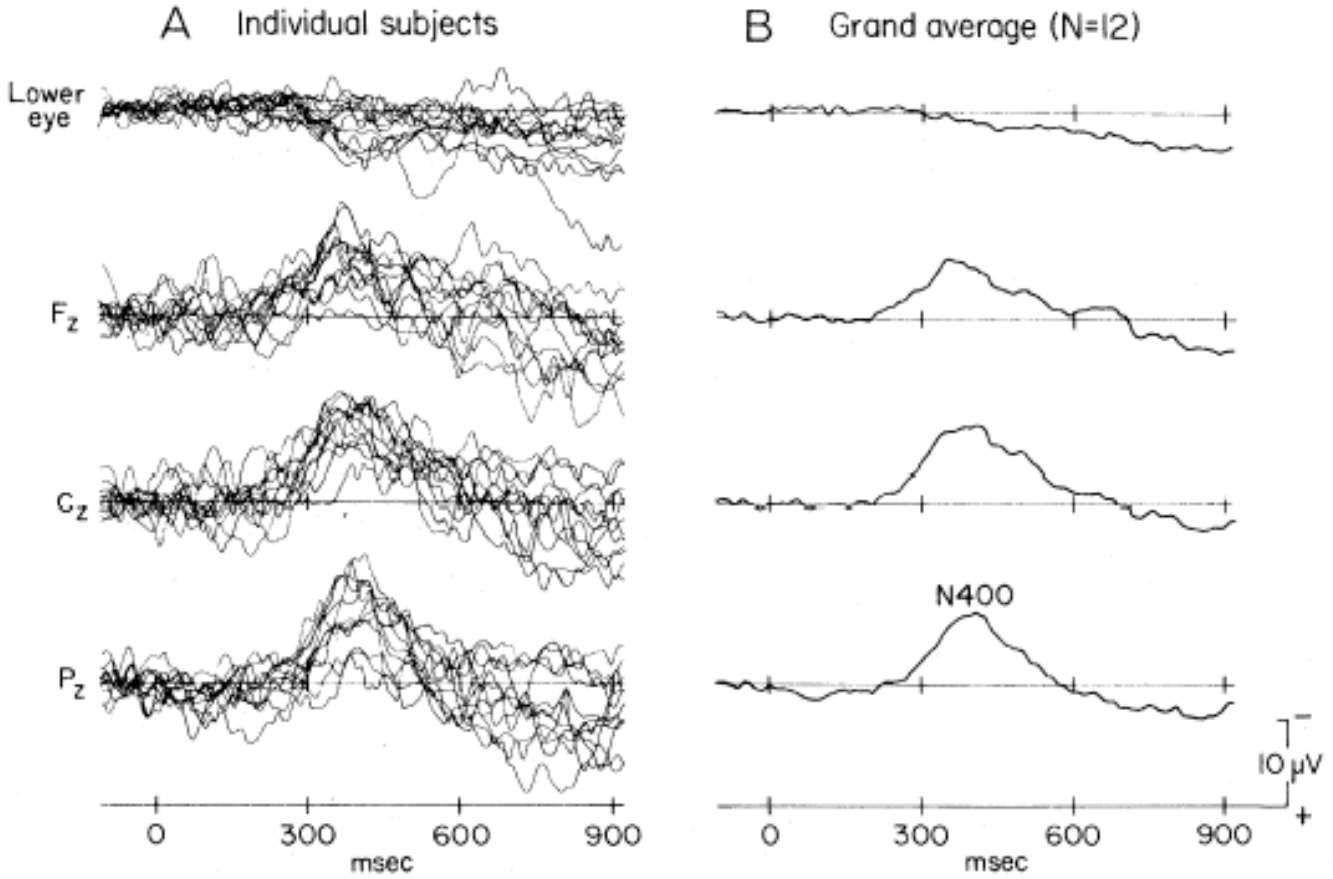
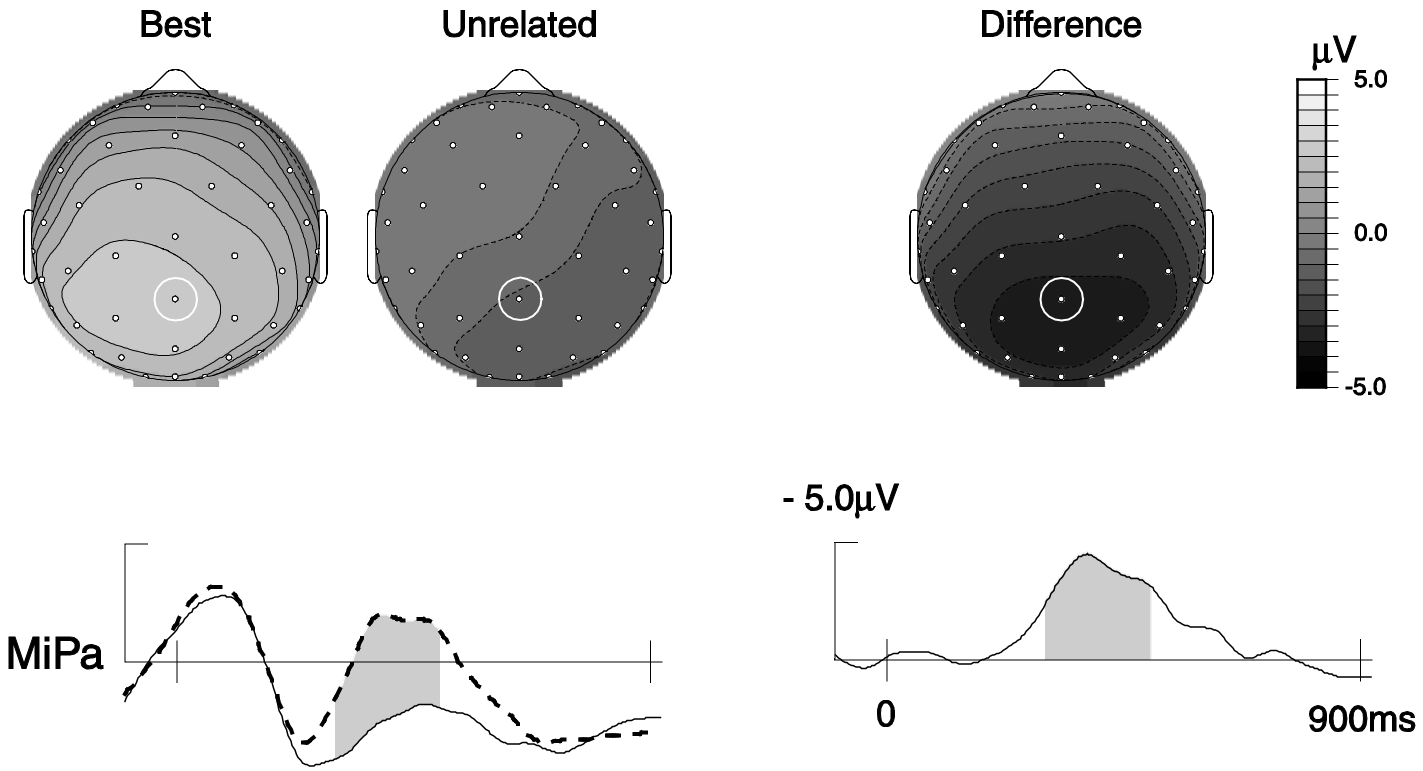


Fig. 2. Difference waves from experiment 2 (strong semantic incongruity). These difference waveforms were obtained by subtracting the averaged ERP's to the semantically congruous words from the ERP's to the semantically incongruous seventh words. Each superimposed tracing (A) represents the difference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

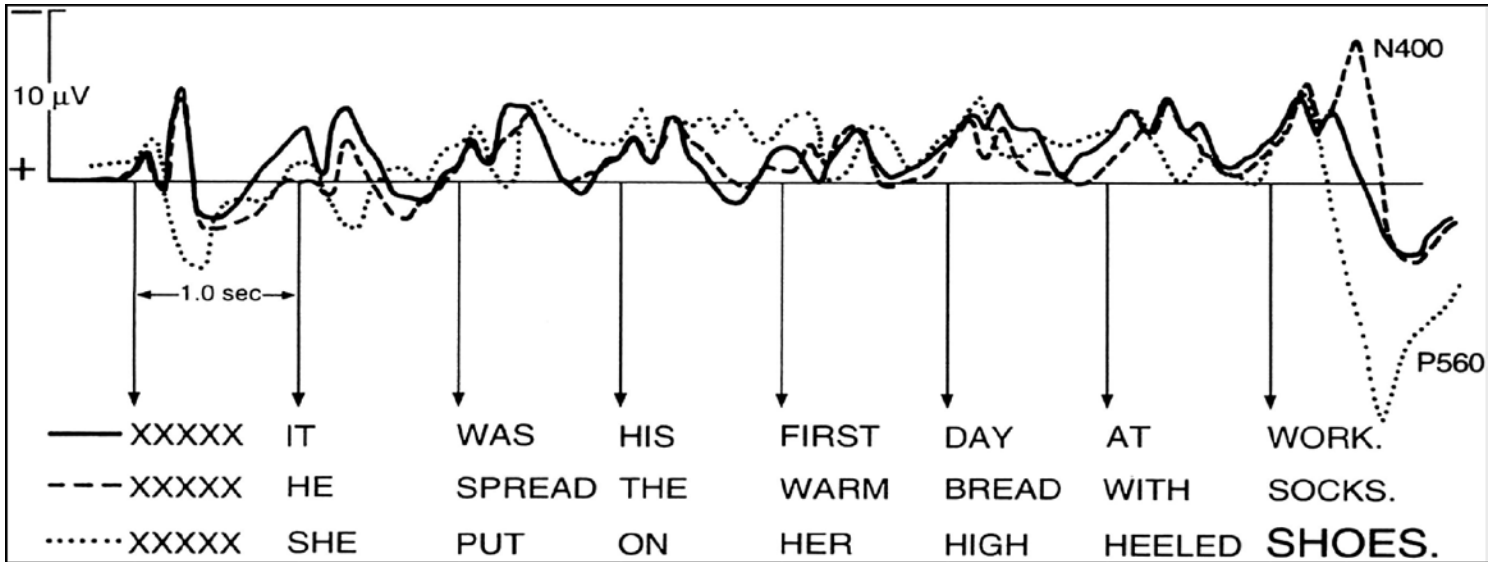
Sentence final word N400 ERP

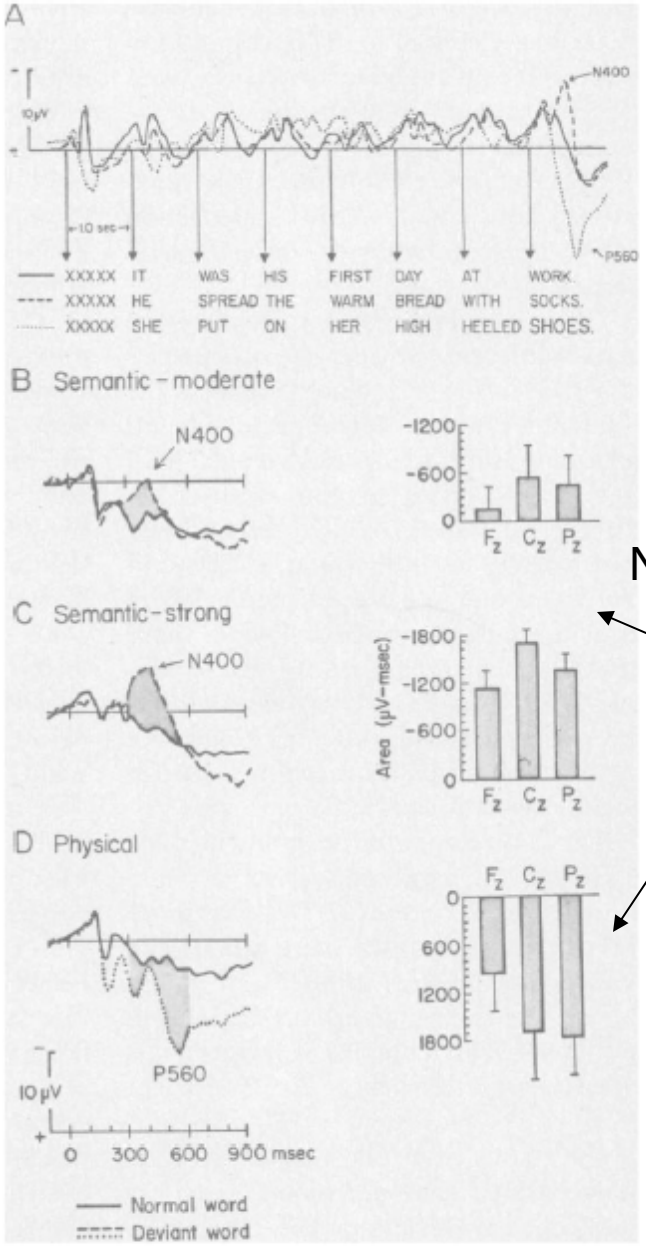
Mean potential 300-500 ms



Is this negativity (N400) the response to any kind of improbable event in a language/sentence context?

Cliché:	Roses are red and violets are *blue*.
Fact:	A female chicken is called a *hen*.
Open-ended:	He returned the book to the *library*.
Physically Incongruent:	I take coffee with cream and *SUGAR*.
Incongruent:	He shaved off his mustache and *BEARD*.


10 µV
+
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.



N400

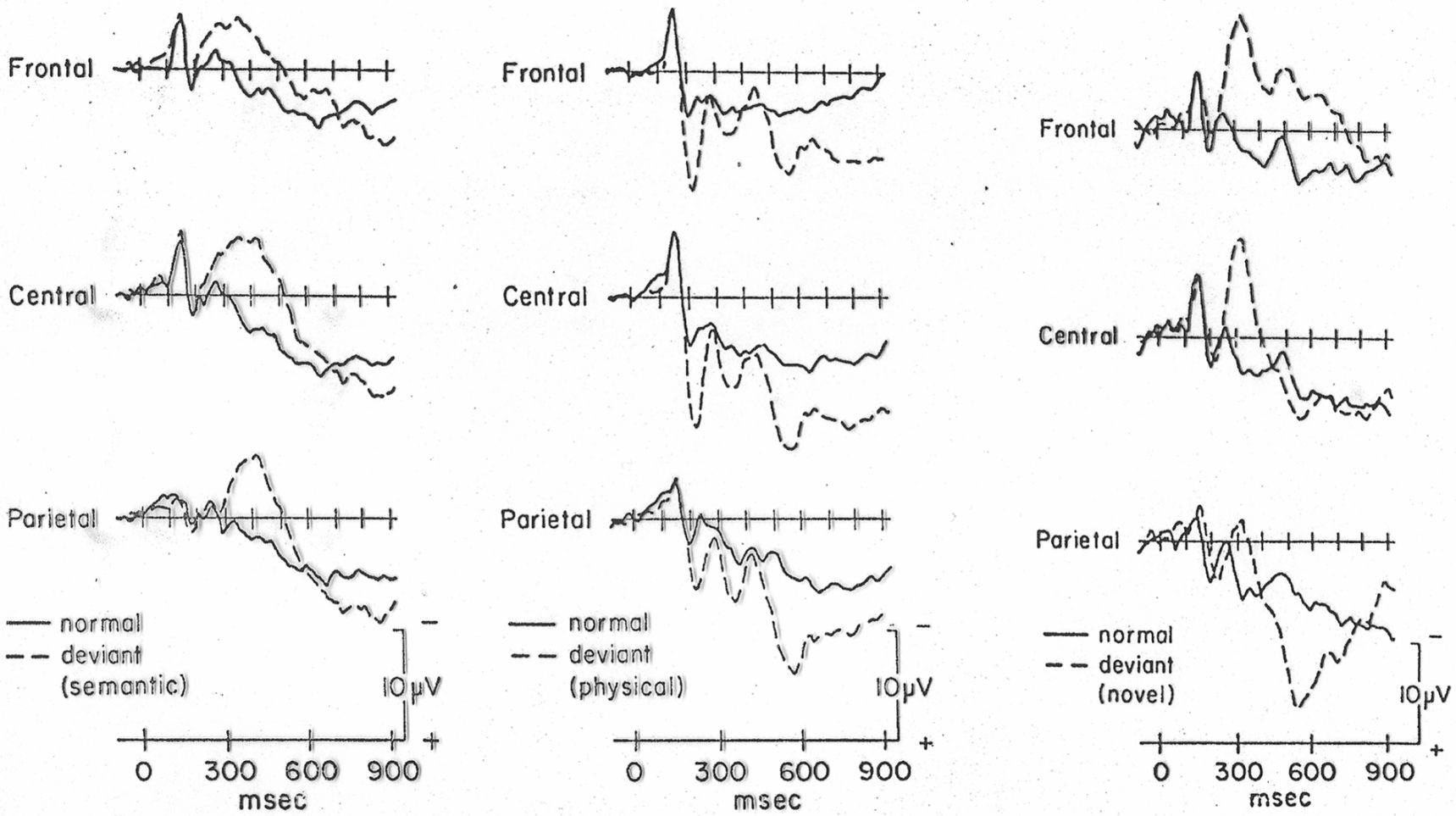
Like P3b, N400 has centro-parietal maximum over scalp

P3, LPC

Lexical-Semantic Violations

Physical Violations

"Novel" Pictures



Not any improbable event in a language context elicits an N400!

Why no P300 to this type of improbability?

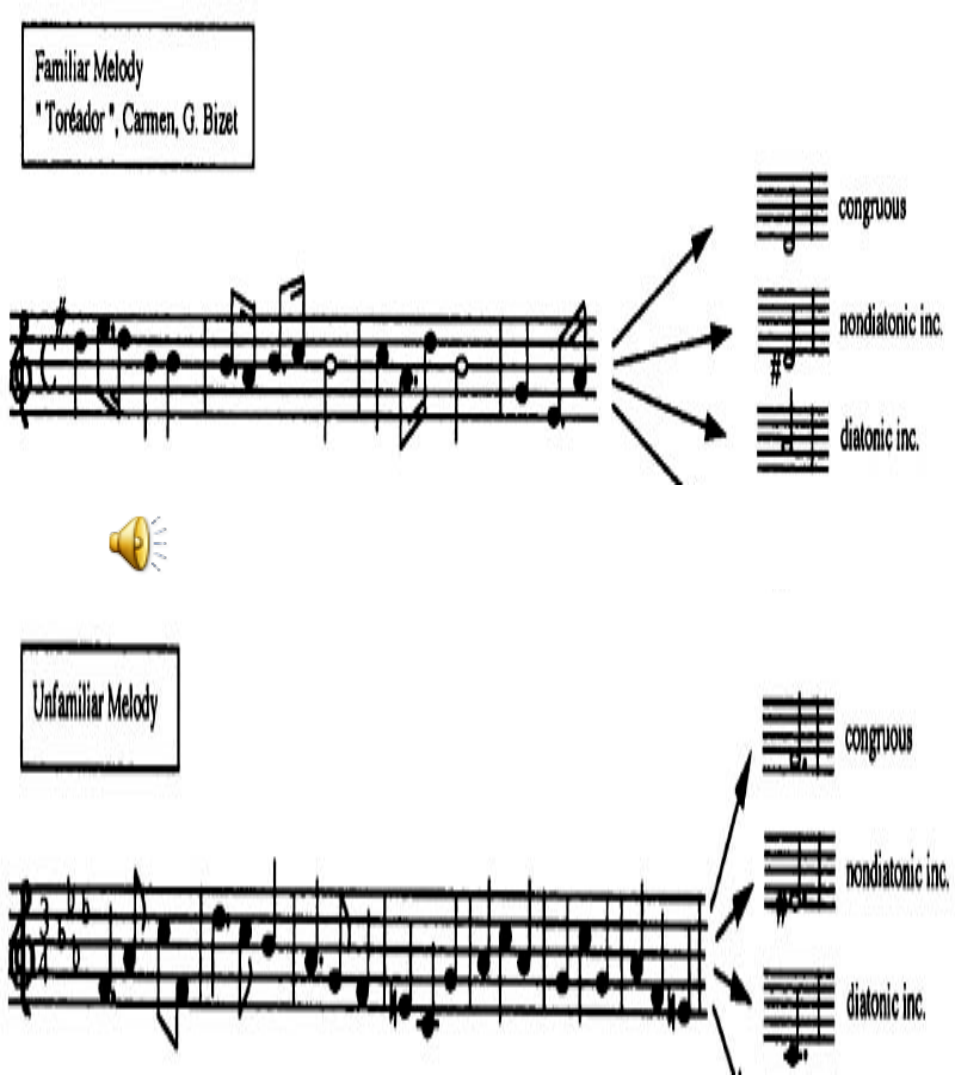
Perhaps P300/P3b reflects improbability relative to information maintained in working memory and N400 reflects improbability relative to information in long term memory (LTM).

What about violations within another domain that taps into LTM? e.g., music?

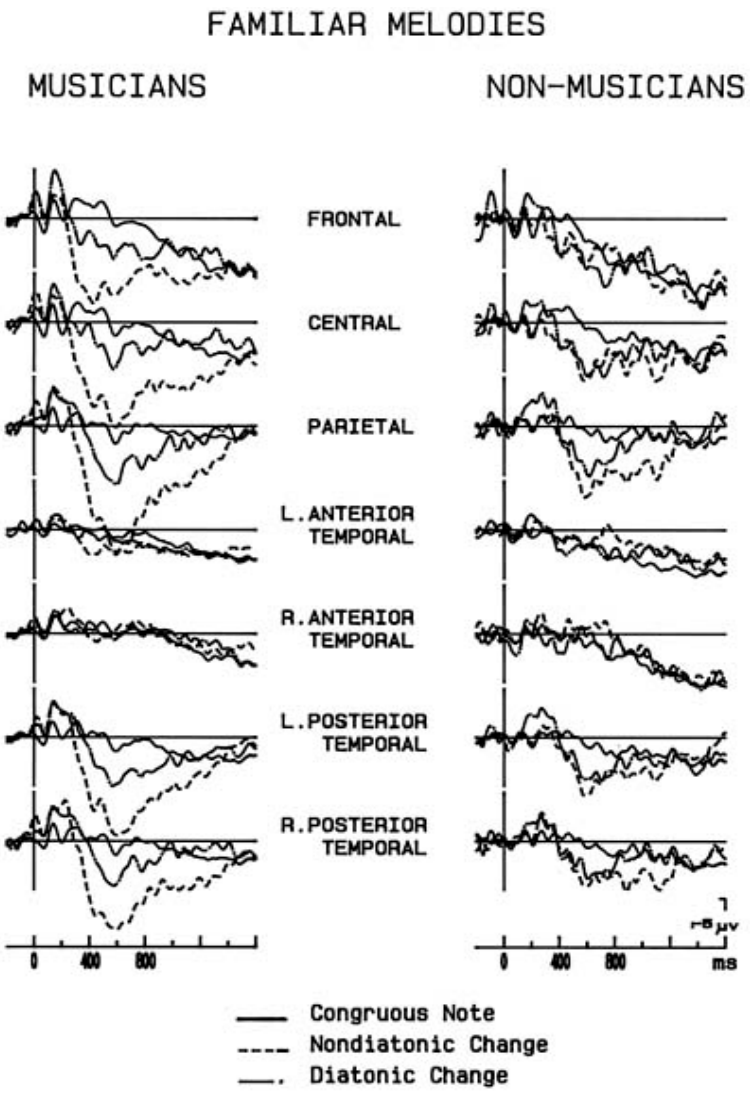
Musical violation experiment analogous to N400 language experiments

A musical “sentence”
(melody without accompaniment)

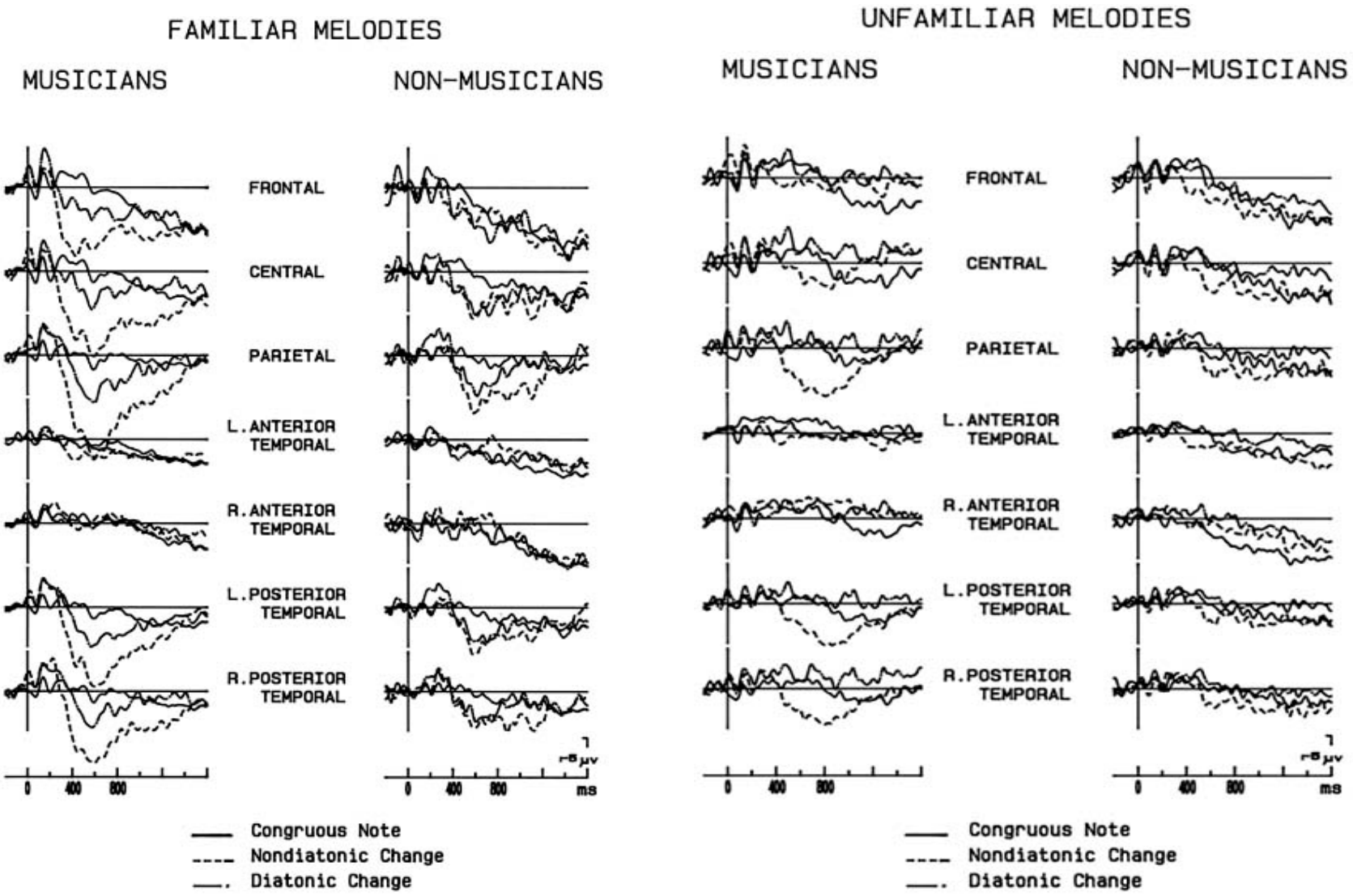
Two different types of incongruity:
- a *nondiatonic* change
  (i.e., the last note - out of key -
  violate rules of tonal structure),
- a *diatonic* change
  (respects tonal structure, but does
  not provide a sense of closure)



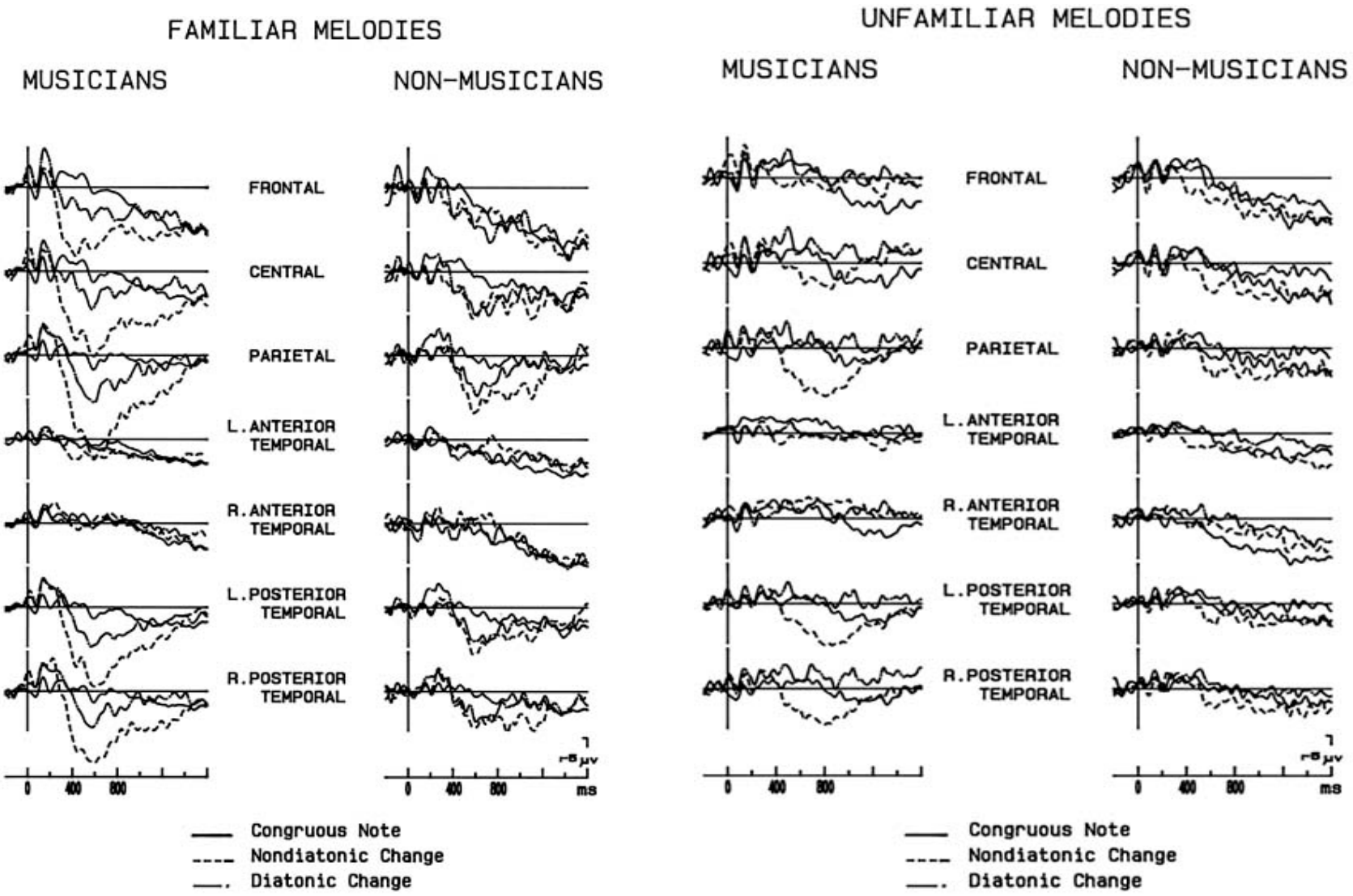
Besson & Faita


FAMILIAR MELODIES
MUSICIANS
NON-MUSICIANS
FRONTAL
CENTRAL
PARIETAL
L. ANTERIOR TEMPORAL
R. ANTERIOR TEMPORAL
L. POSTERIOR TEMPORAL
R. POSTERIOR TEMPORAL
0
400
800
ms
Congruous Note
Nondiatonic Change
Diatonic Change

What is the effect of a musical violation? Does it differ as a function of melody familiarity? Does it differ as a function of group? Do these factors interact? Is there an N400?



NO N400 to musical violations: Incongruous (nondiatonic) terminal notes in familiar melodies elicited large LPCs not N400s both in musicians and non-musicians!



Do any linguistic violations at the end of a sentence elicit an N400? And, is the N400 only seen to sentence final words? …as answers will constrain possible interpretations of N400.

The tiger is the largest and most powerful cat. Tigers live India in and other parts of Asia. There are no tigers in Africa. The tiger has beautiful dark stripes. It is very hard to see a tiger in long grass because its ***dreams*** look like shadows. The bobcat is a fierce cat which lives in parts of America. It is really a small Lynx. It has tufts on its ears and a short stubby tail. Bobcats hunt mice squirrels rabbits ***laughs*** and many other small animals. But sometimes they ***hunts*** much larger animals than themselves. Bobcats are often hunted for their soft ***radios***. The ocelot lives in America. It has a beautiful fur coat with a mixture of ***mice*** and stripes. It lives in dense forests where its stripes in blend ……

Kutas& Hillyard, 1983

Grammatical (morphosyntactic) Violations in written text

NOUN NUMBER

All turtles have four LEG and a tail but some have very different feet

In Africa there is a small soft shelled TORTOISES that lives among rocks.

Some storms have THUNDERS and lightning.

VERB NUMBER

Then she DIG a hole with her rear feet.

Its shell may VARIES from light brown to black.

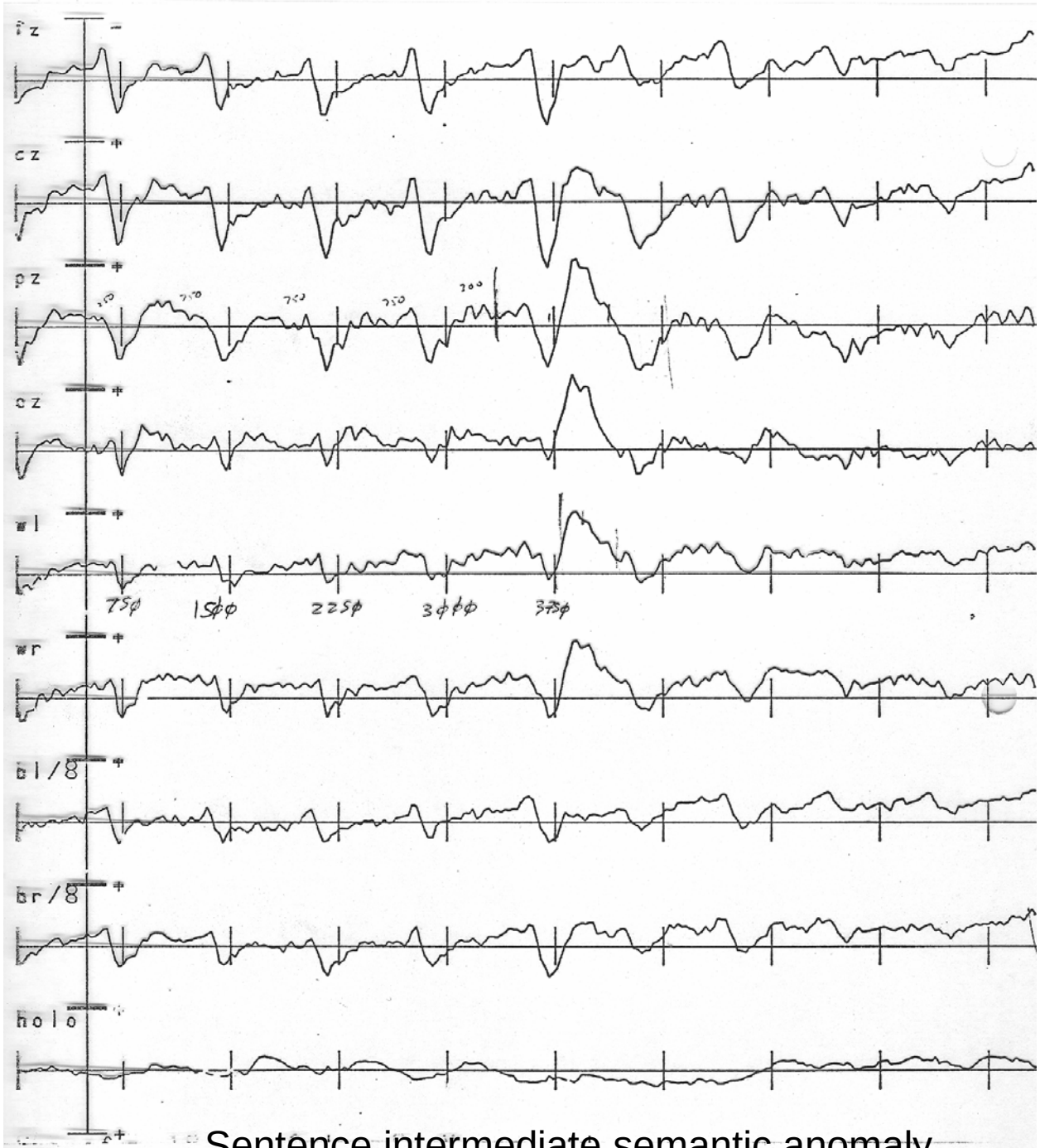
When cats IS climbing or fighting they put out out their claws.

VERB TENSE

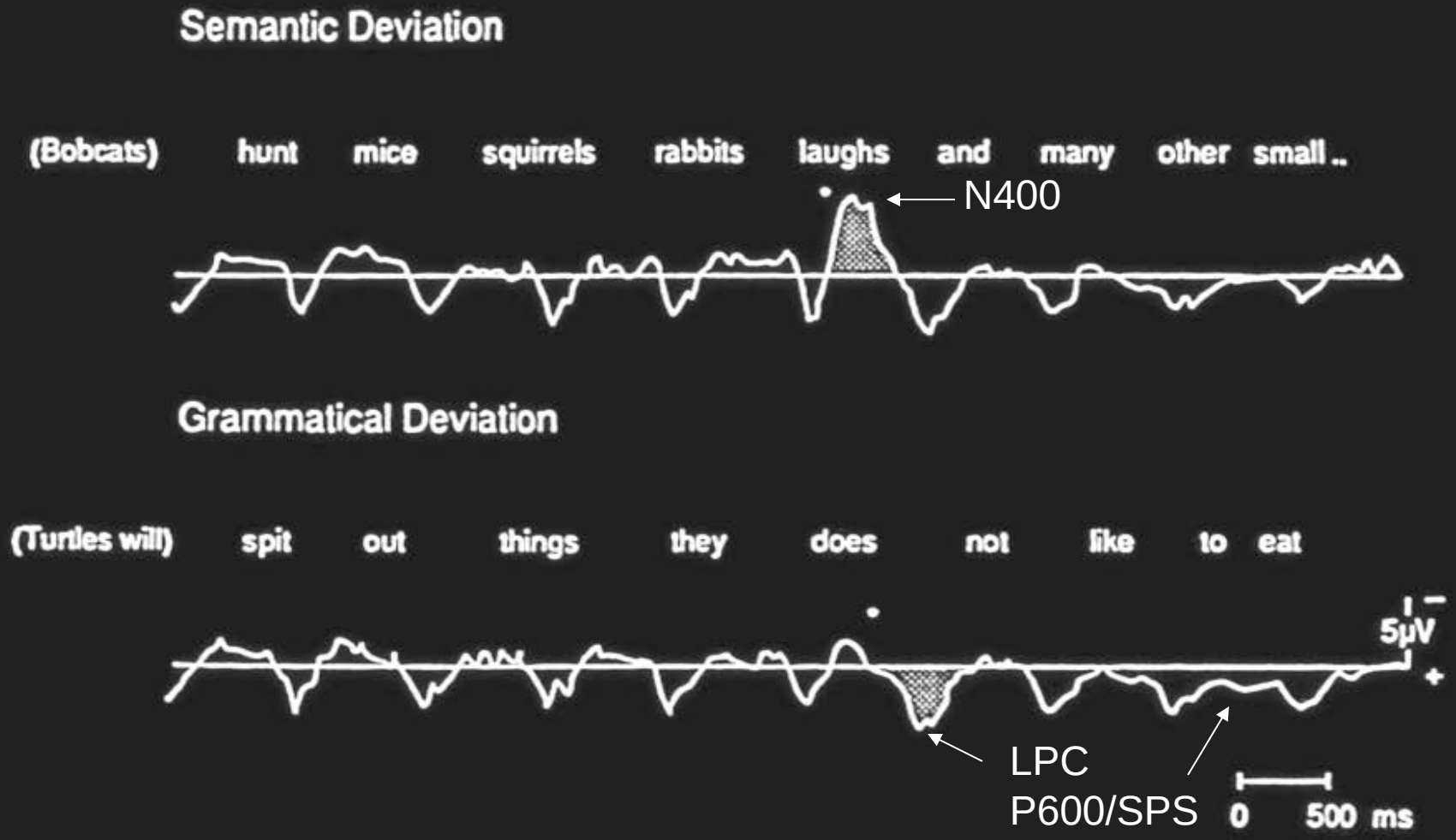
The eggs and meat of this turtle are CONSIDER choice food by many people.

This allows them to STAYED under water for a longer period.

If the air is so full of water vapor that it cannot HELD any more then the weather report says that the relative humidity is one hundred percent.



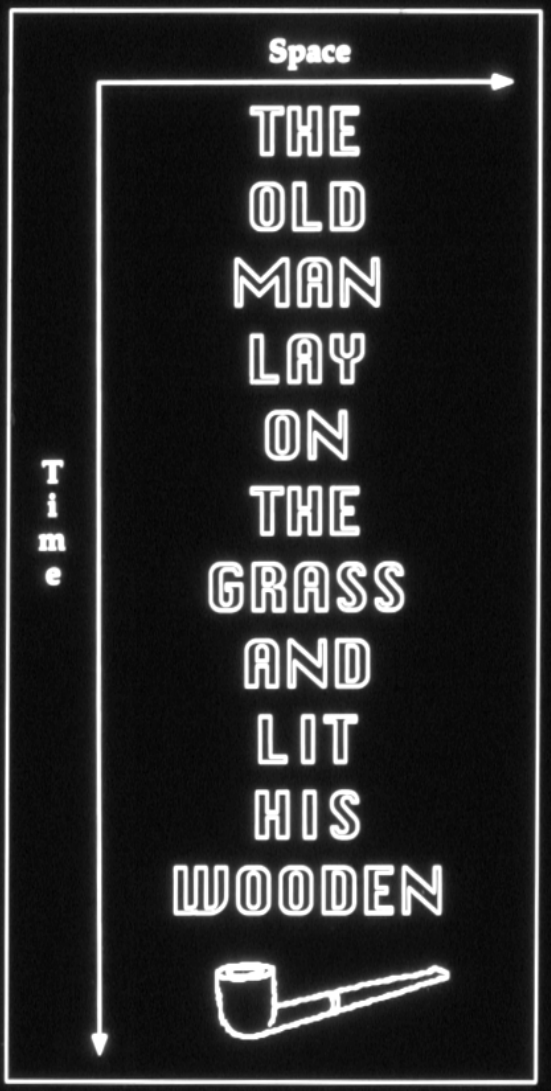
Sentence intermediate semantic anomaly


Semantic Deviation
(Bobcats) hunt mice squirrels rabbits laughs and many other small ..
N400
Grammatical Deviation
(Turtles will) spit out things they does not like to eat
5μV
LPC
P600/SPS
0 500 ms

N400 seems to be related to making sense or activating information in semantic memory related to making sense. It is seen in language context where the improbable event is linguistically relevant at the level of meaning, however, ***the N400 is not specific to language!***

N400 provides strong evidence for the immediacy of language processing. NO buffering to phrase, clause, or sentence boundaries.

Figure 1. One of the sentences used in the experiment. This is the actual font employed (Chicago). The relative size of the words and the picture is very close to reality.



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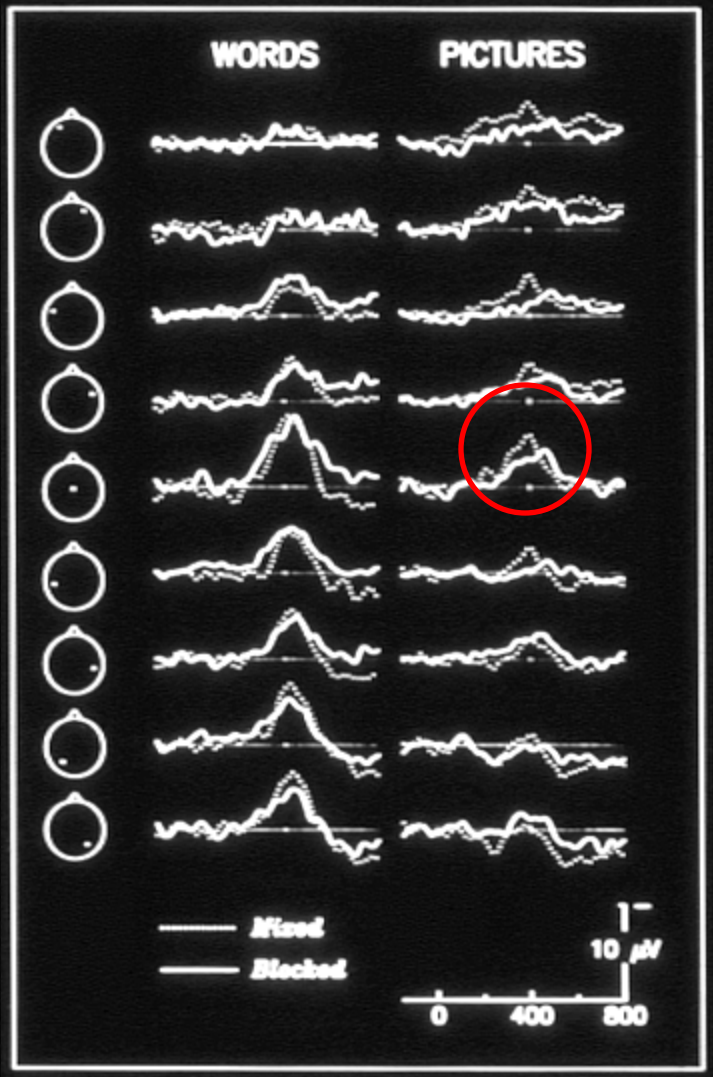


Figure 5. Difference ERP waveforms (incongruous minus congruous) obtained for words (left) and pictures (right) in the blocked (solid line) and mixed (dotted line) conditions.

Ganis, Kutas & Sereno 199x

N400 effect is also seen for incongruent vs congruent line drawings, but with a more frontal distribution, though still in language context.

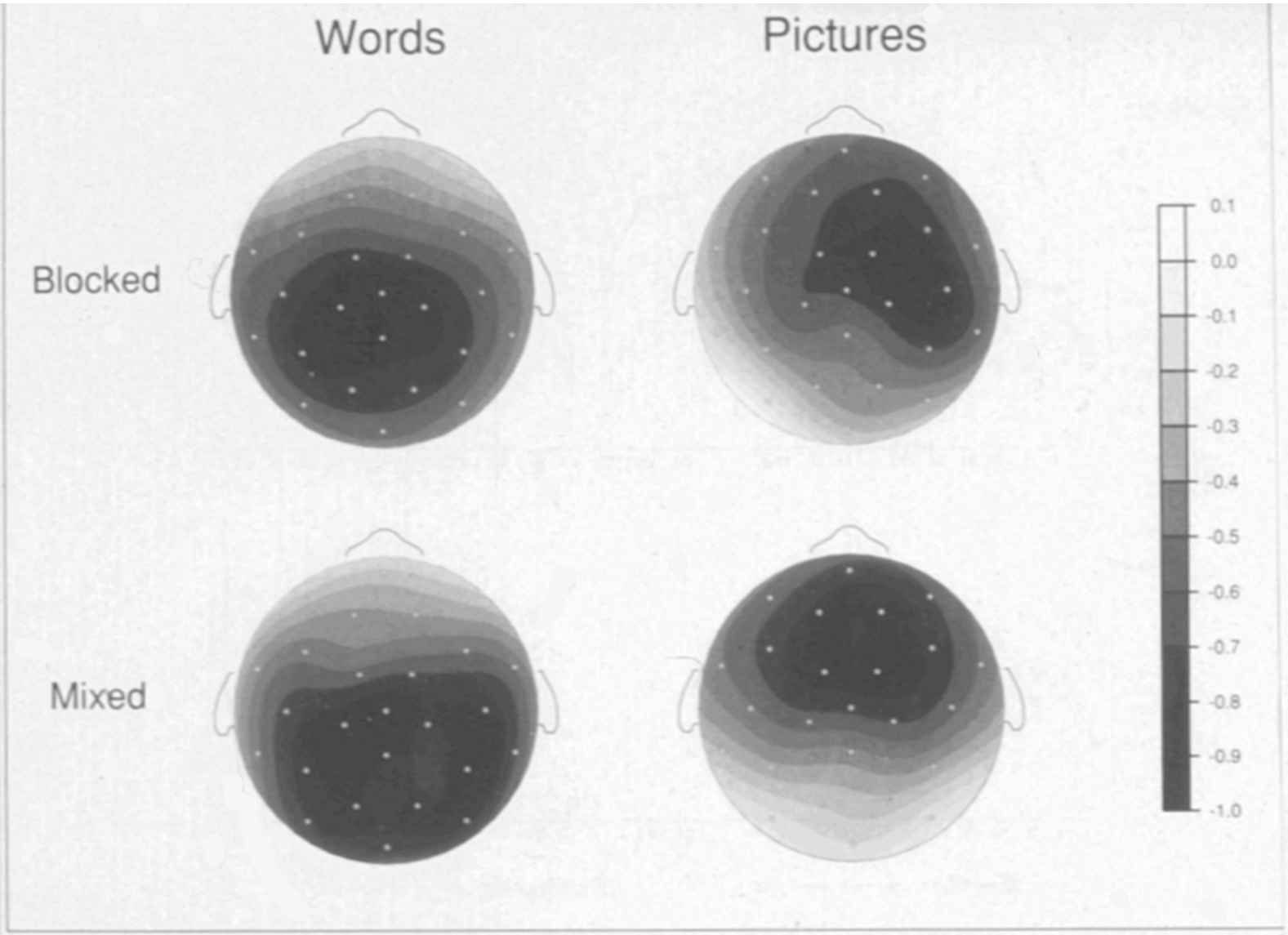
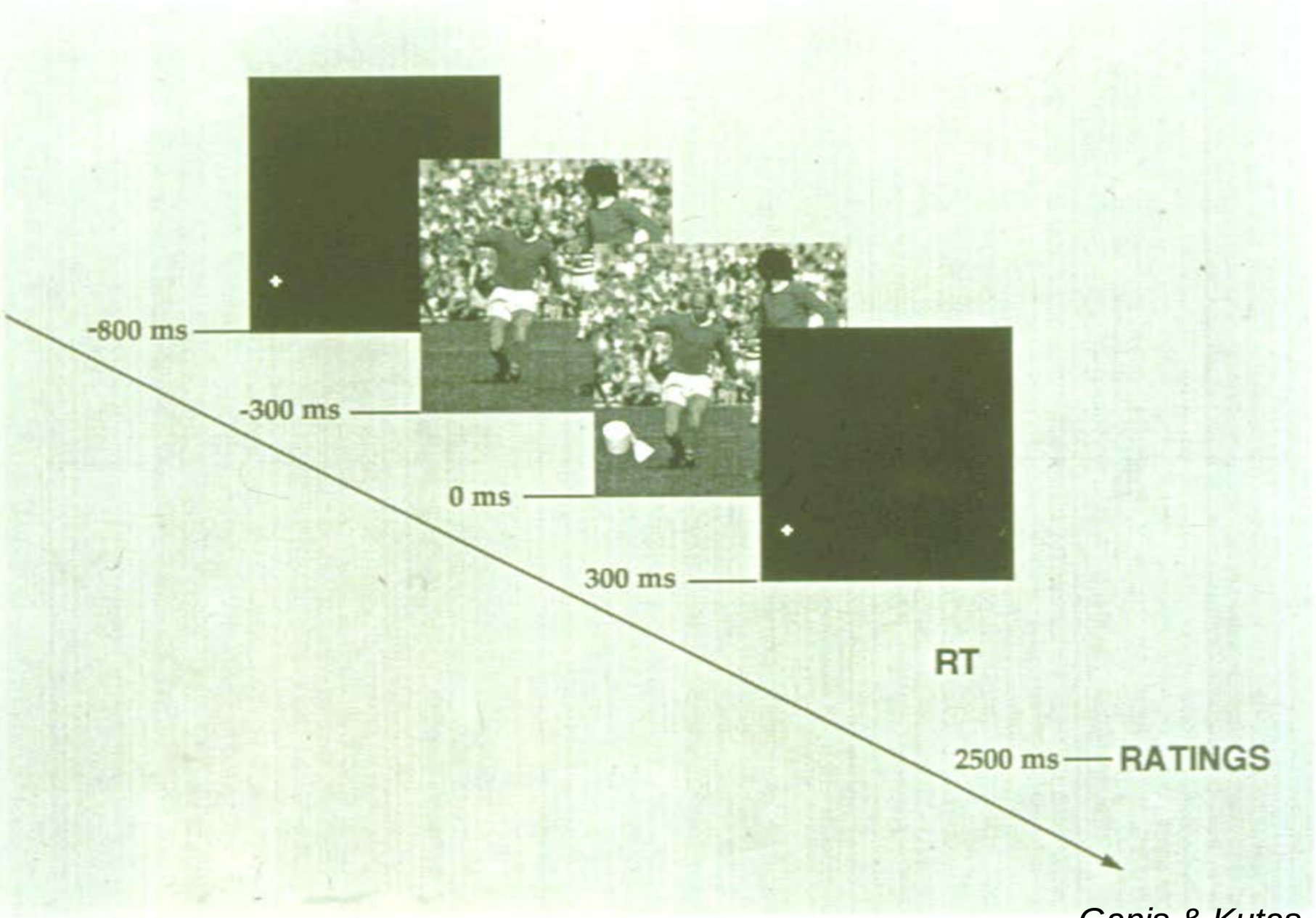


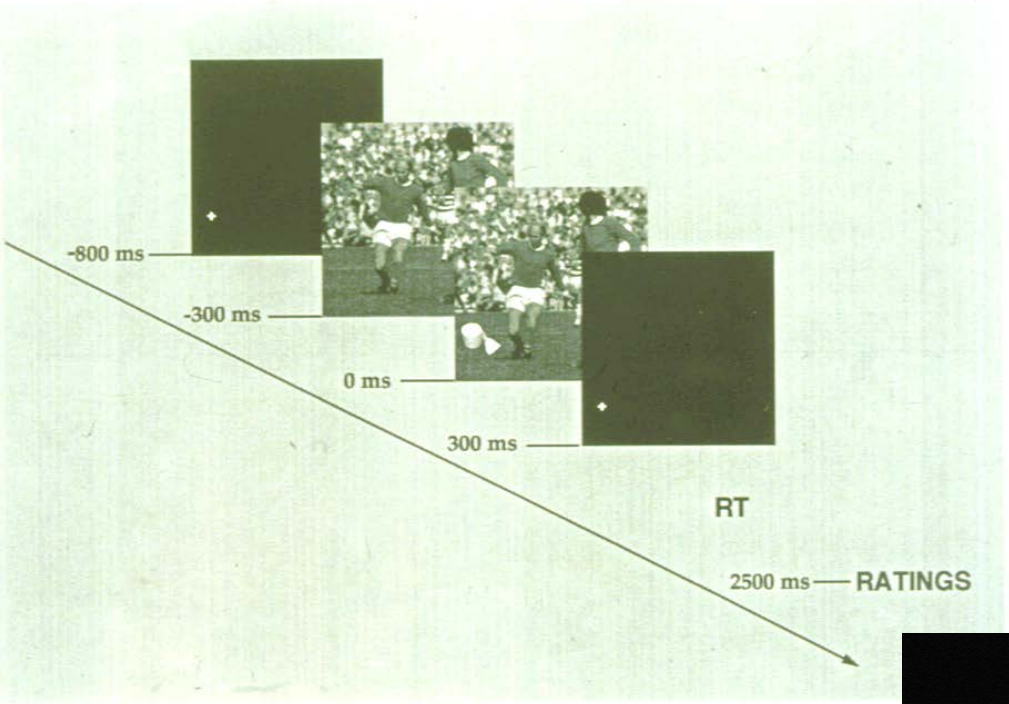
Figure 7. Isopotential gray-scale maps of the normalized distribution of the N400 effect (mean amplitude of the difference waves between 325 and 475 msec) in the blocked (top) and mixed (bottom) conditions for words (left) and pictures (right). The original scattered data (26 scalp sites) were interpolated with a spherical spline algorithm (Hassainia et al., 1994).

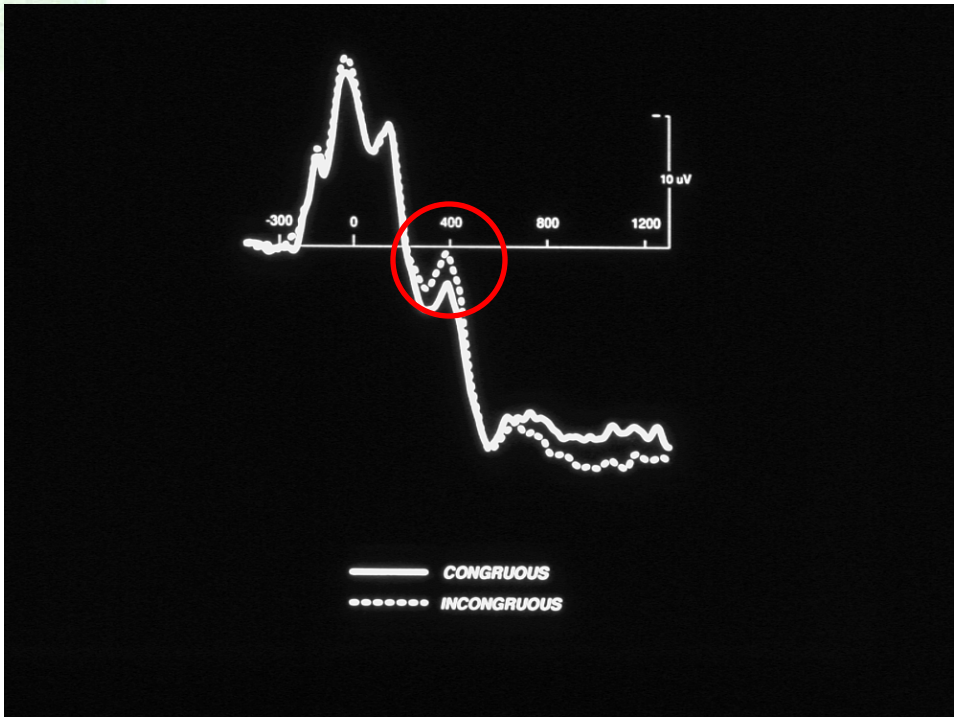
Ganis, Kutas,& Sereno



Ganis & Kutas

Congruent vs Incongruent Scenes





Ganis & Kutas

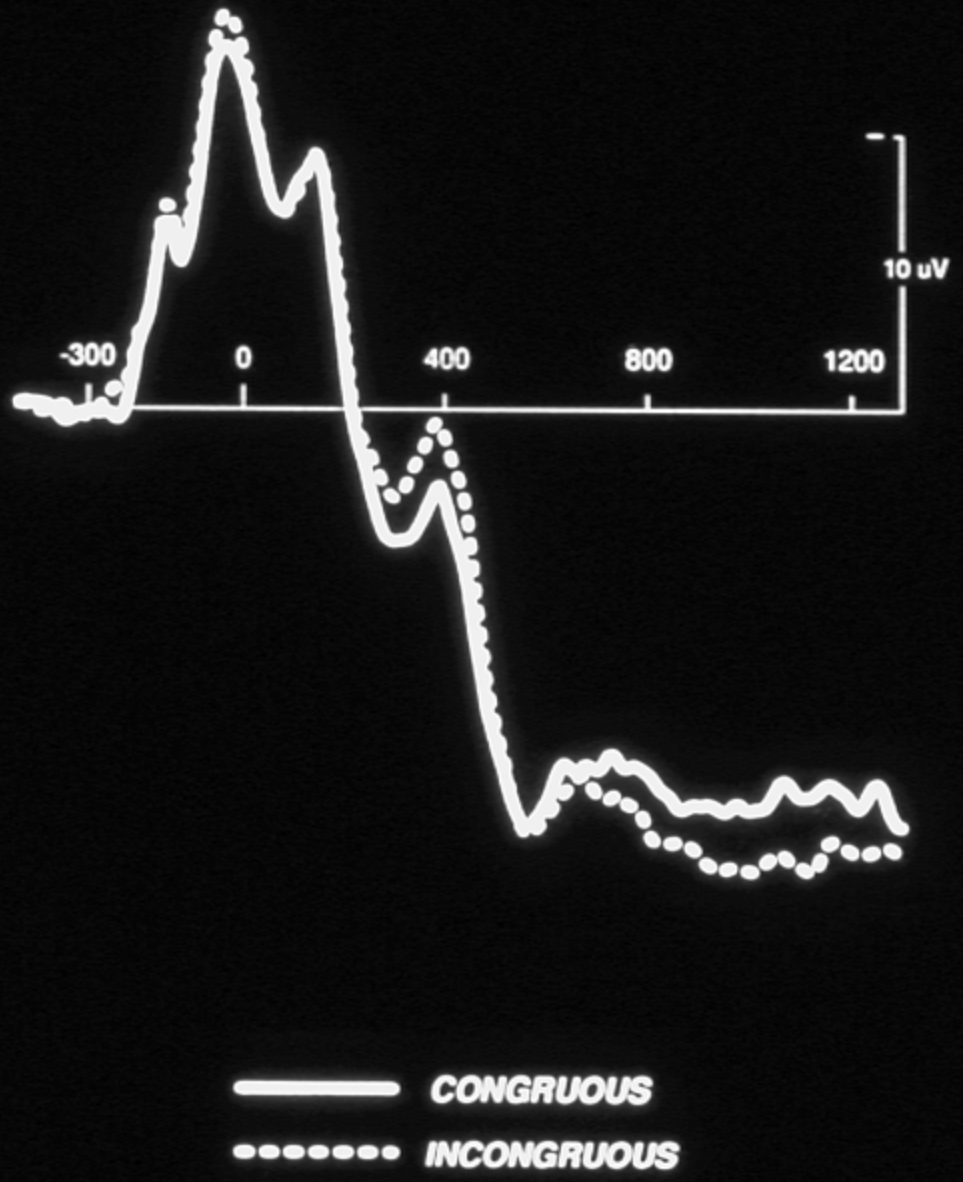

10 uV
-300
0
400
800
1200
CONGRUOUS
INCONGRUOUS

Fig. 1. Example of congruous and incongruous picture stories. The center column shows the series of pictures in a typical picture story. The bottom left frame shows the congruous final picture for this story and the bottom right frame shows the corresponding incongruous final picture for this story.

West & Holcomb, 2002

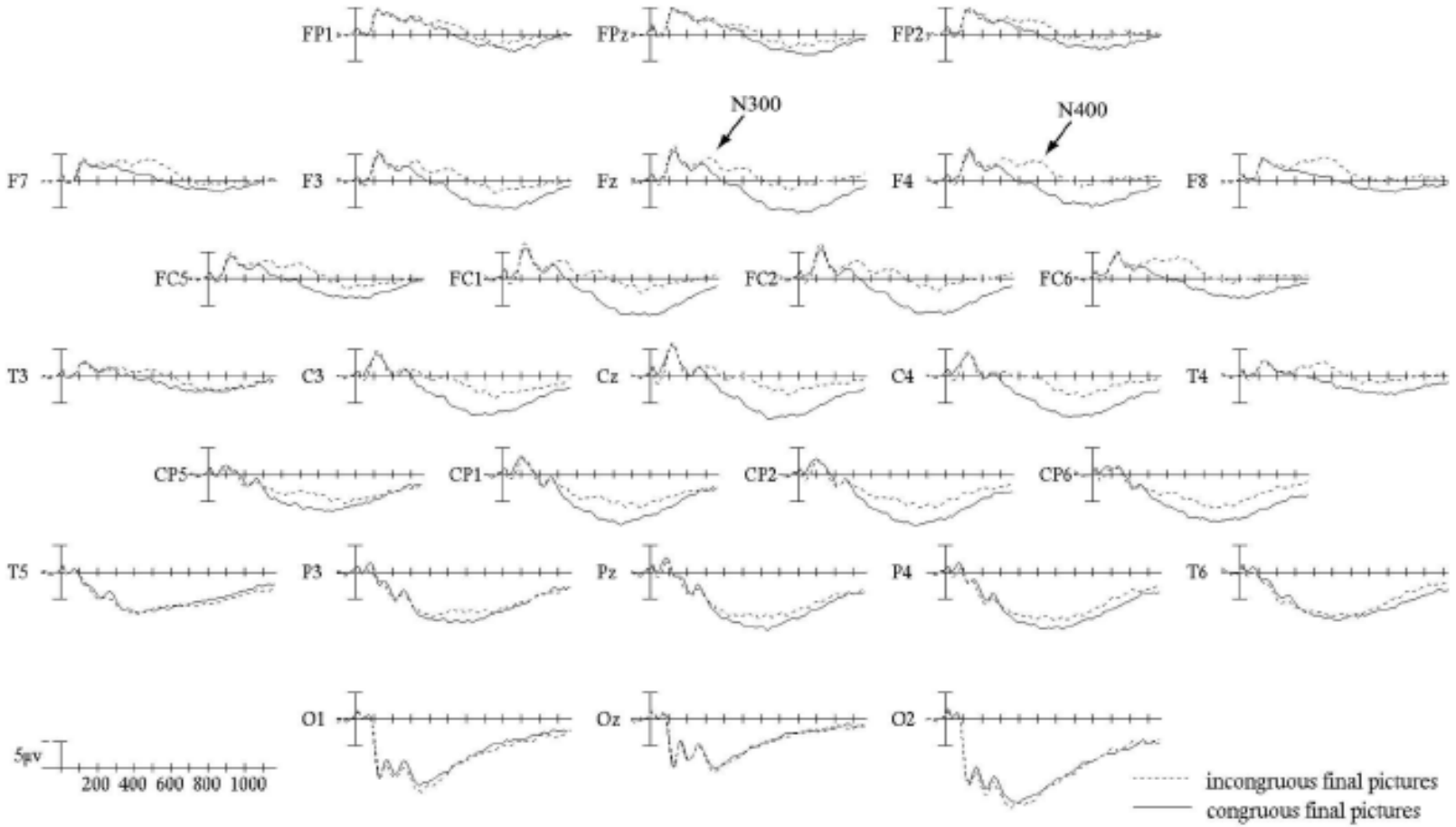


Fig. 3. Grand average ERPs elicited by congruous and incongruous final pictures.

In addition to an N400 effect, pictures sometimes elicit an N300 which some view as a mechanism specialized for processing pictorial or imagistic representations.

West & Holcomb, 2002

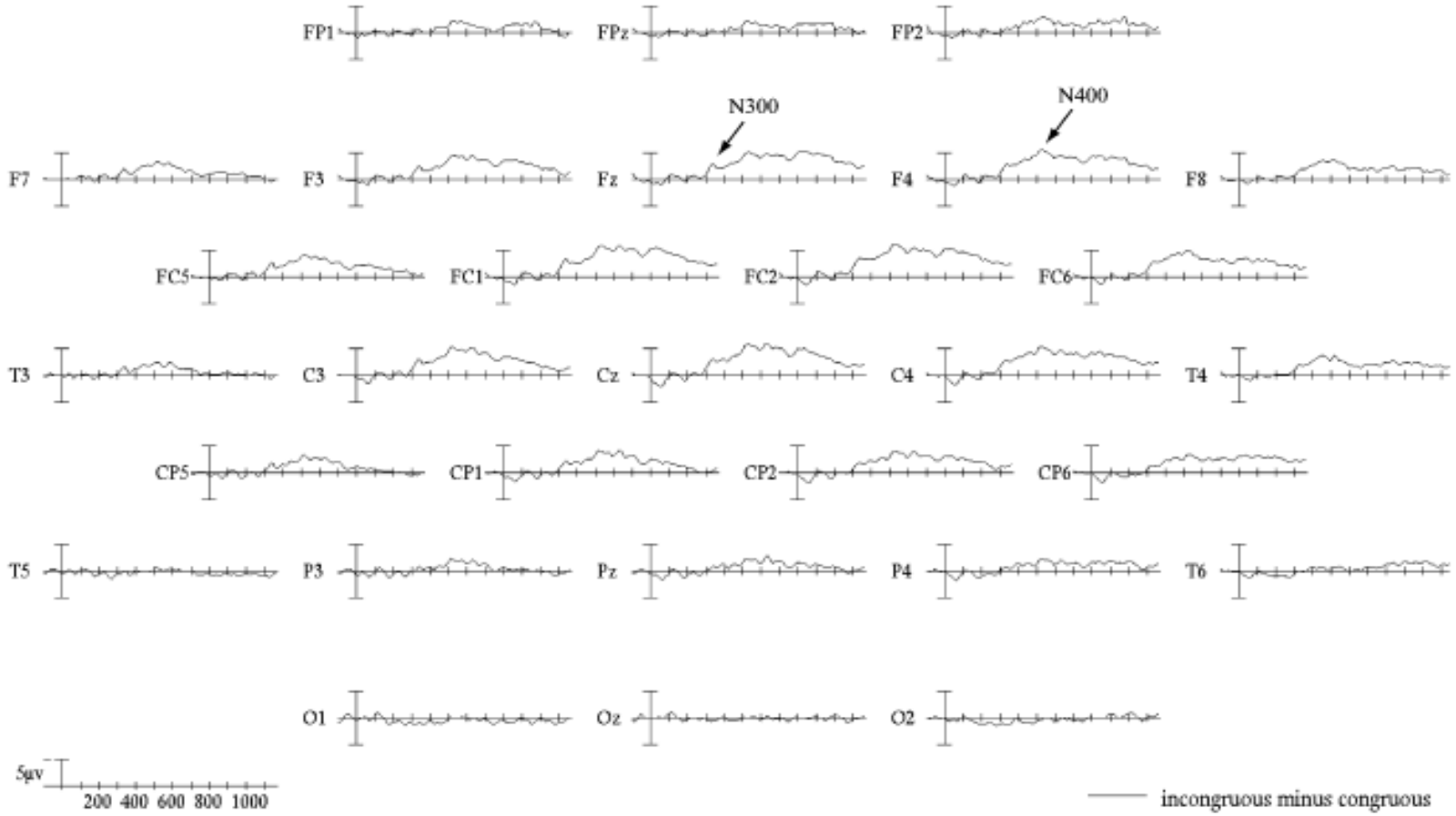


Fig. 4. Difference waves produced by subtracting the ERPs for congruous final pictures from the ERPs for incongruous final pictures.

West & Holcomb, 2002

N400s to events in video clips

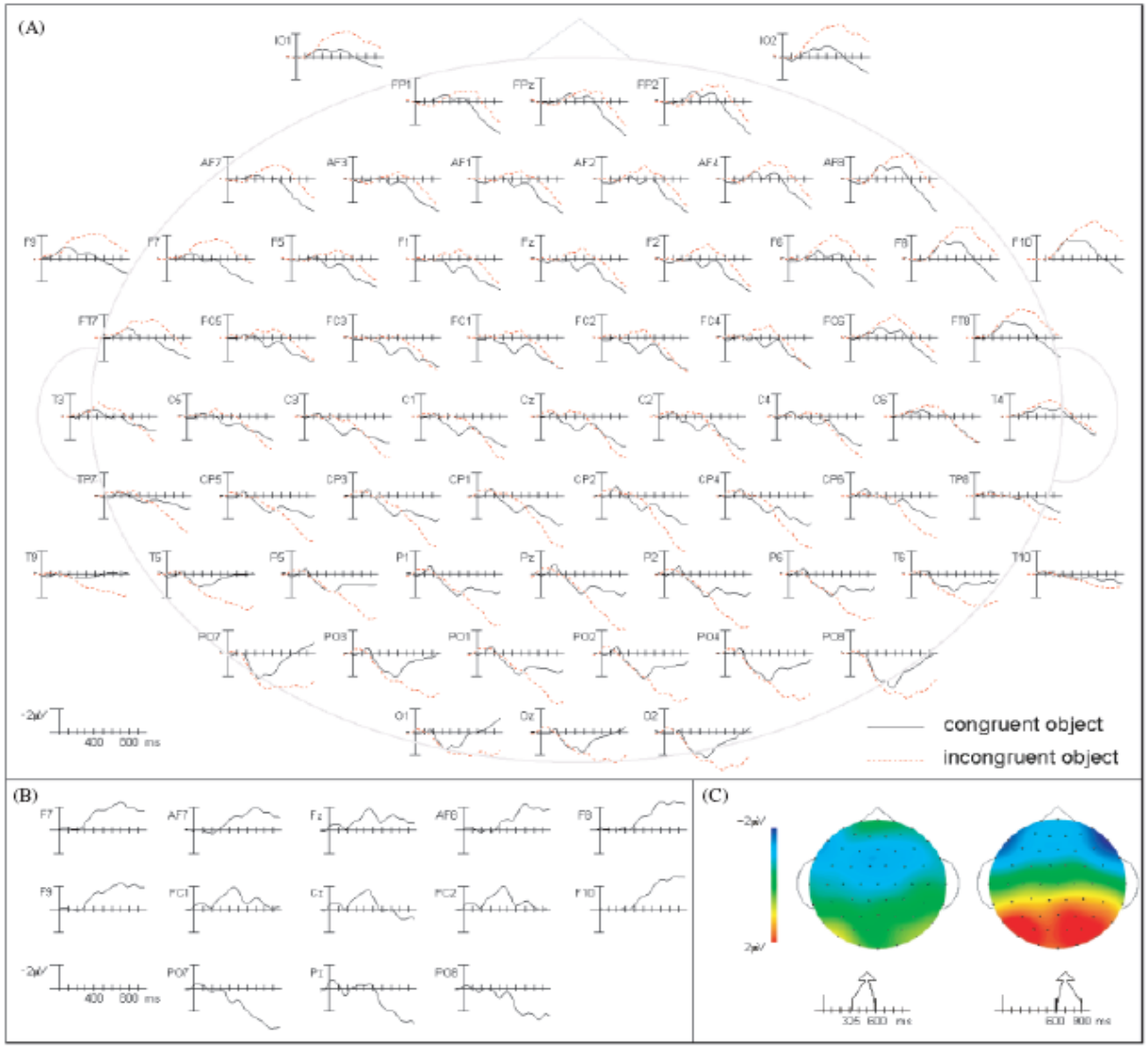
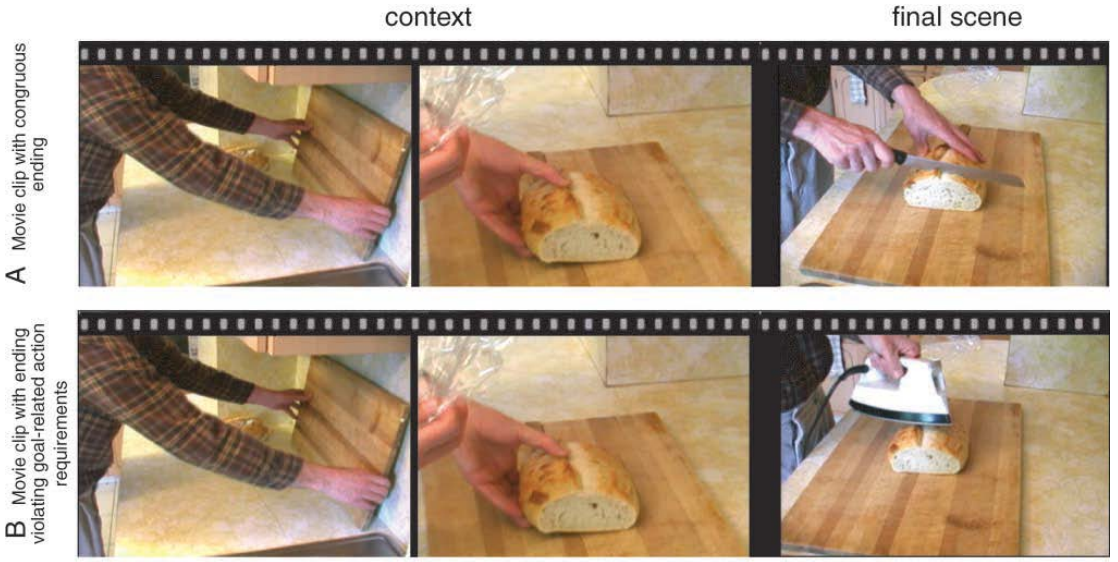


Figure 1. Average ERPs elicited by target objects in videos (A), difference waves obtained by subtracting incongruent from congruent condition at the selected electrode sites (B), and the corresponding voltage maps of the ERP differences in the N400 and LPC time windows (C).

e.g., person in mirror, face covered with shaving cream, shaving with razor or rolling pin.

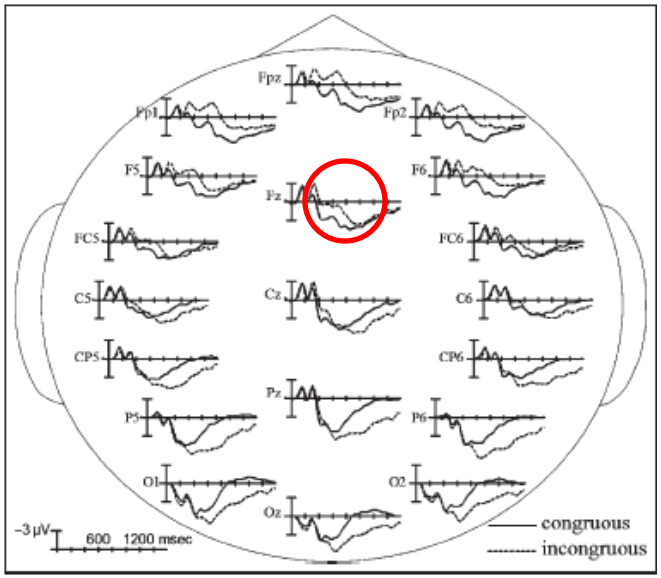
Sitnikova et al. 2003

Congruent
vs
Incongruent
Video clips



Two Neurocognitive Mechanisms of Semantic Integration during the Comprehension of Visual Real-world Events

Tatiana Sitnikova[1,2], Phillip J. Holcomb[3], Kristi A. Kiyonaga[3], and Gina R. Kuperberg[2,3]



LEXICO-SEMANTIC INCONGRUITY

CONGRUENT*:* *Die Kerze hat gebrannt (The candle has burned).*

INCONGRUENT: *Der Ball hat getraumt (The ball has dreamed).*

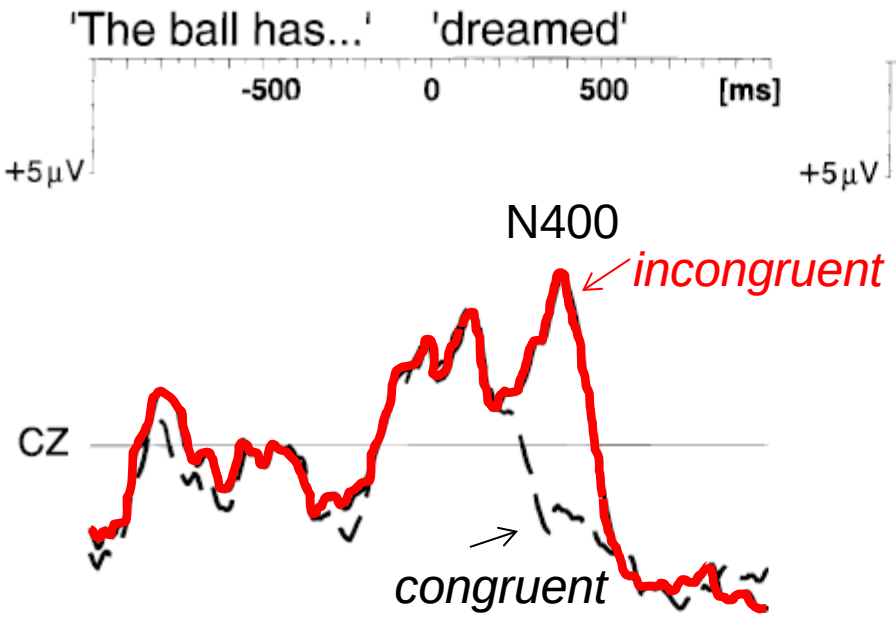
ARITHMETIC INCONGRUITY

CORRECT: 7 8 56 (7 x 8 = 56)

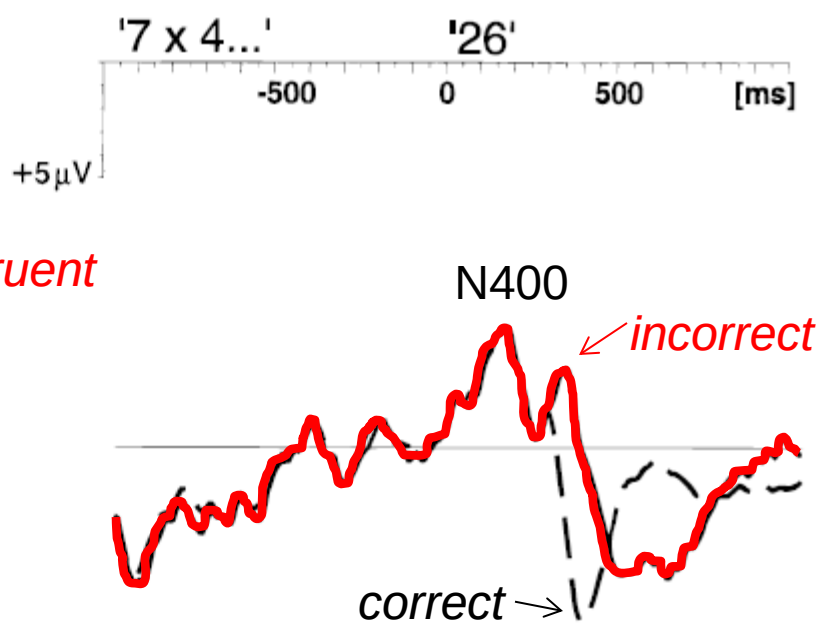
INCORRECT: 7 8 54 (7 X 8 = 54)

Nieddegen, Roesler & Jost, 1999

SEMANTIC/READING



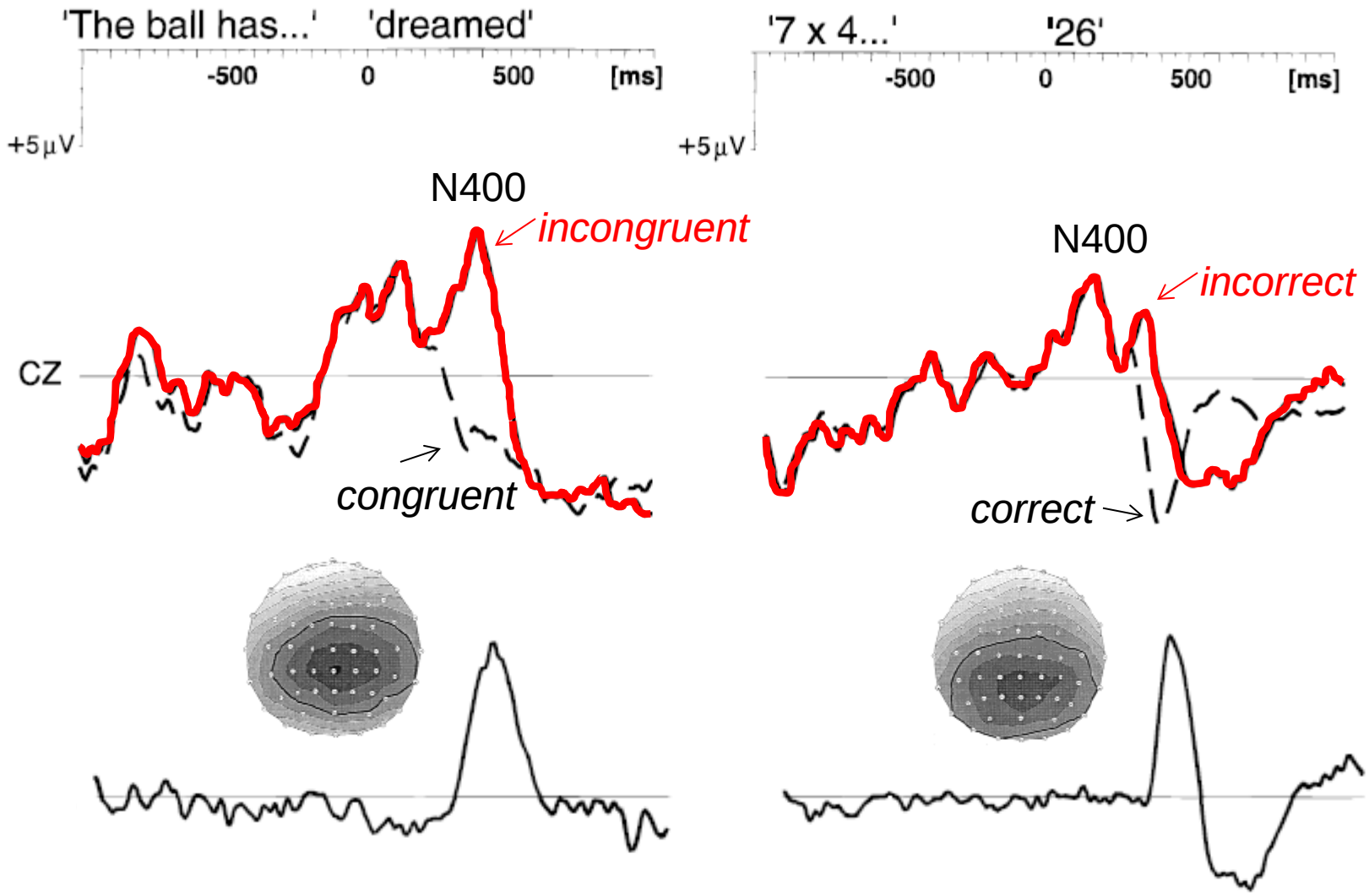
ARITHMETIC



Nieddegen, Roesler & Jost, 1999

SEMANTIC/READING

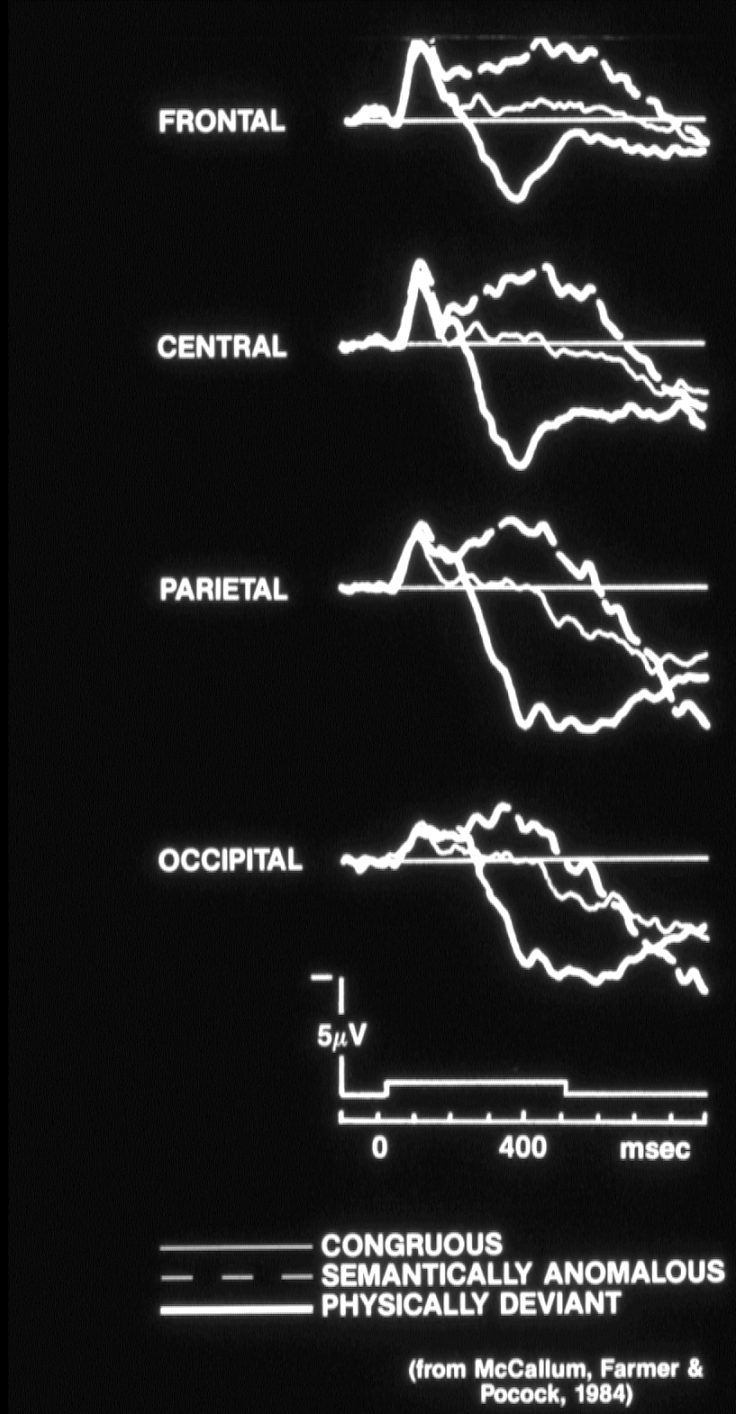
ARITHMETIC

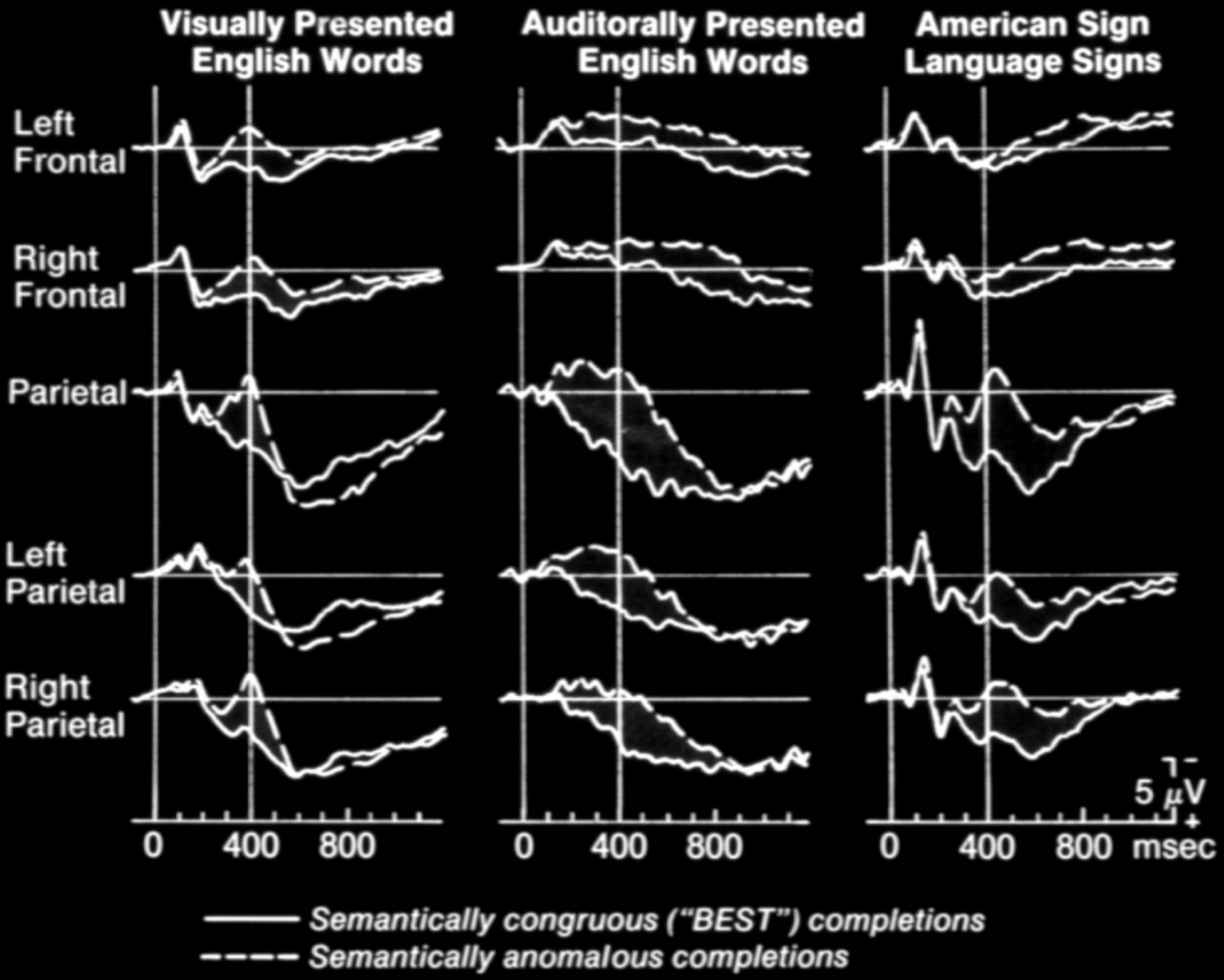


Nieddegen, Roesler & Jost, 1999

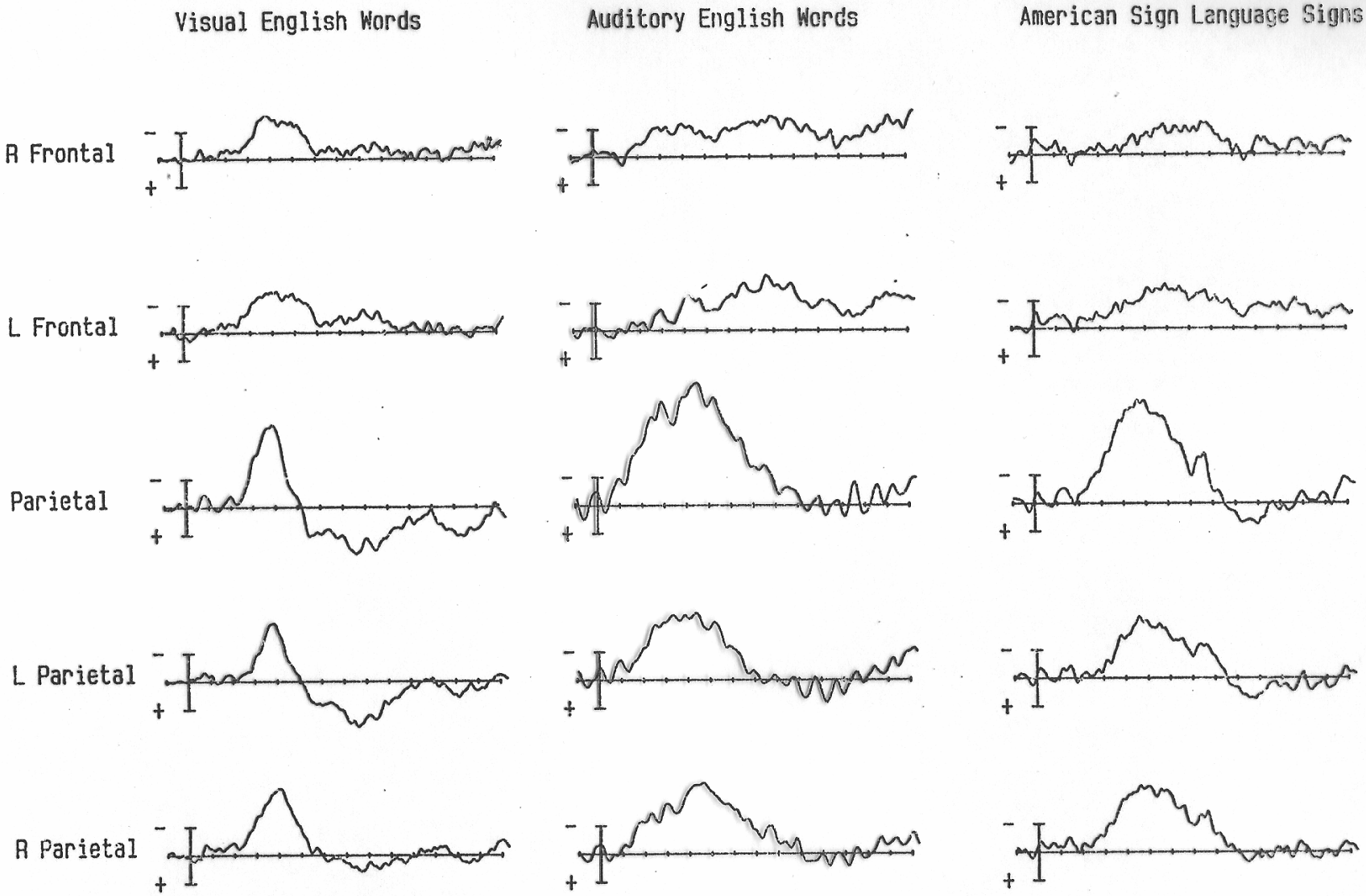
Is the N400 modality specific?

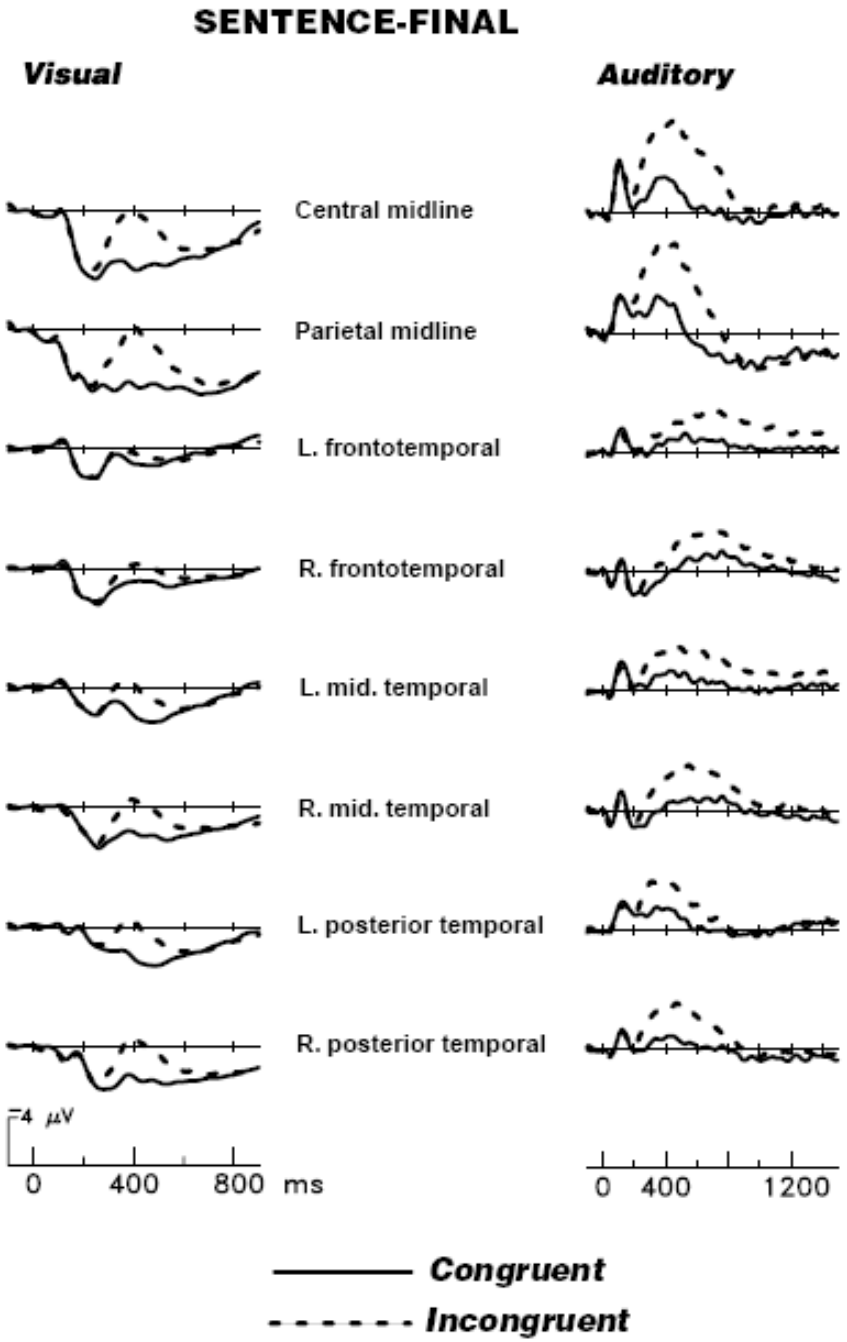
SEMANTIC and PHYSICAL VIOLATIONS in SPEECH




Visually Presented English Words
Auditorally Presented English Words
American Sign Language Signs
Left Frontal
Right Frontal
Parietal
Left Parietal
Right Parietal
5 μV
0
400
800
msec
Semantically congruous ("BEST") completions
Semantically anomalous completions

Monophasic negativity though varying in onset/peak latency, duration, and distribution





Van Petten Lab

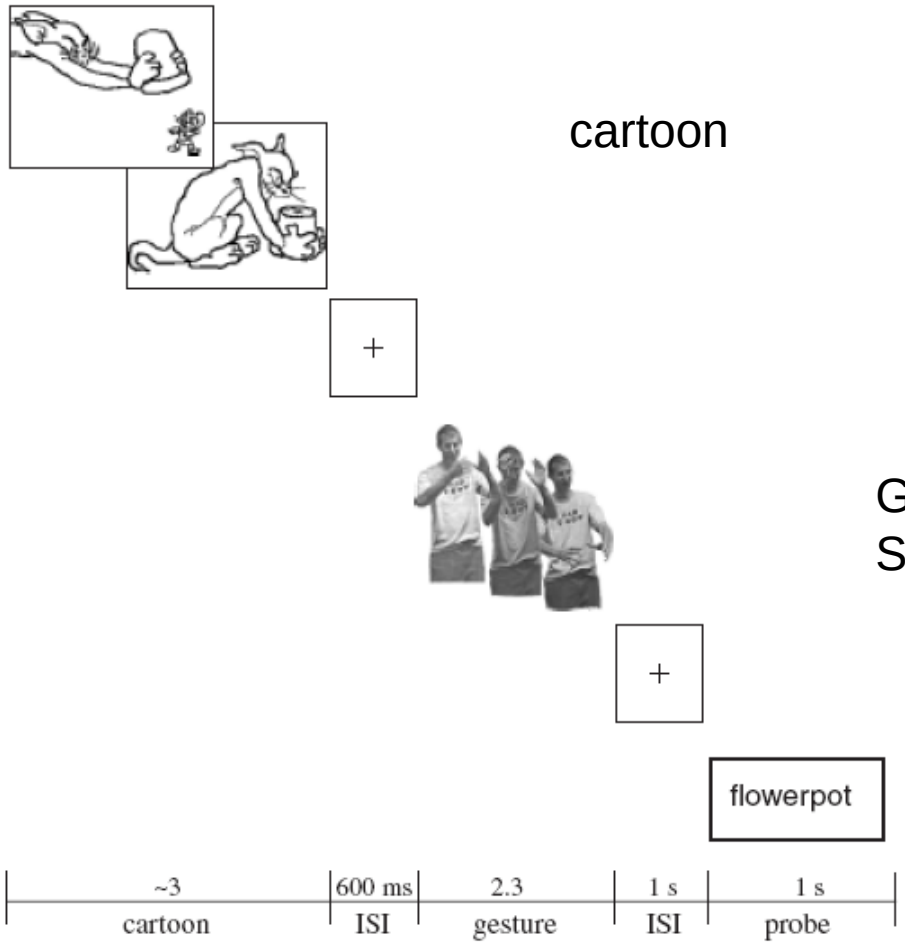


Figure 1. Sample trial: A short cartoon segment was followed by a congruent or incongruent gesture video and then a probe word.

Wu & Coulson, 2006

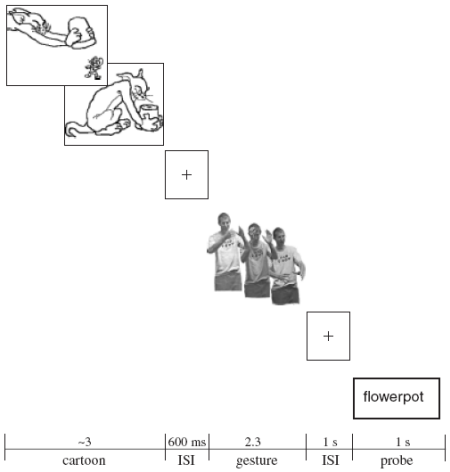
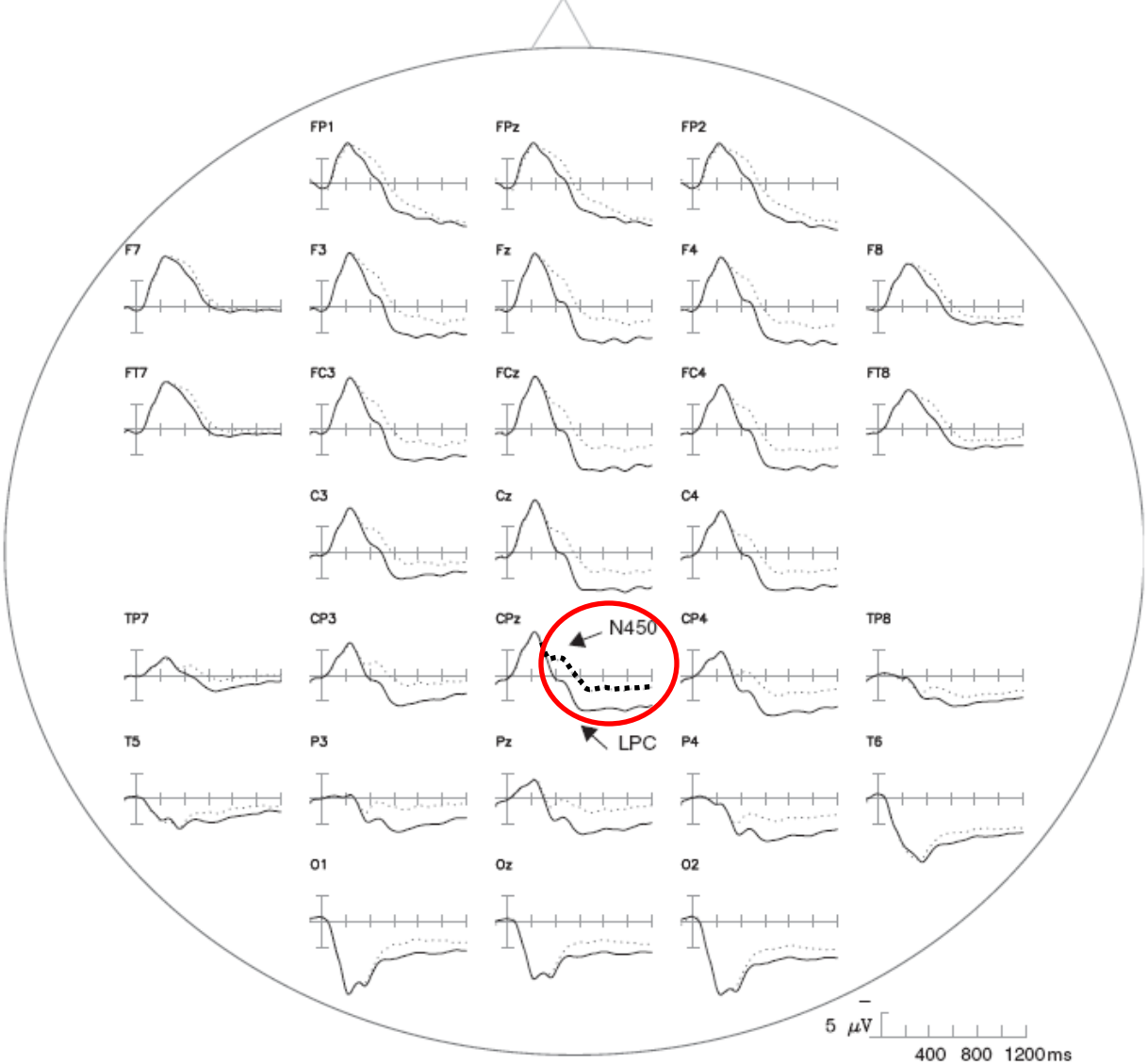
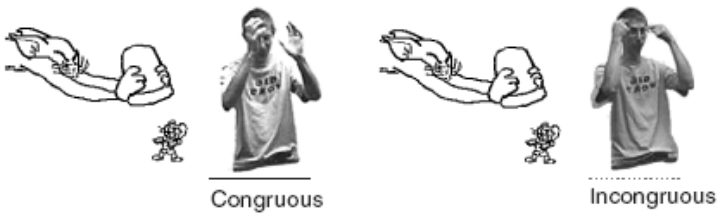


Figure 1. Sample trial: A short cartoon segment was followed by a congruent or incongruent gesture video and then a probe word.

Congruent versus Incongruent Gestures

Wu & Coulson





Clearly, the N400 is not specific to language.

But surely it is so large to semantic violations that it is a semantic violation detector. NO!!!!!!!!!!

A

hi/hi	He mailed the letter without a stamp.
hi/lo	The bill was due at the end of the hour.
med/hi	She locked the valuables in the safe.
med/med	Too many men are out of jobs.
med/lo	The dog chased our cat up the ladder.
lo/hi	There was nothing wrong with the car.
lo/lo	He was soothed by the gentle wind.

Hi/Hi = hi sentential constraint/hi final word cloze probability
Hi/Lo = hi sentential constraint/low final word cloze probability
Med/Lo= medium sentential constraint/low final word cloze probability
Lo/Lo = lo sentential constraint/low final word cloze probability

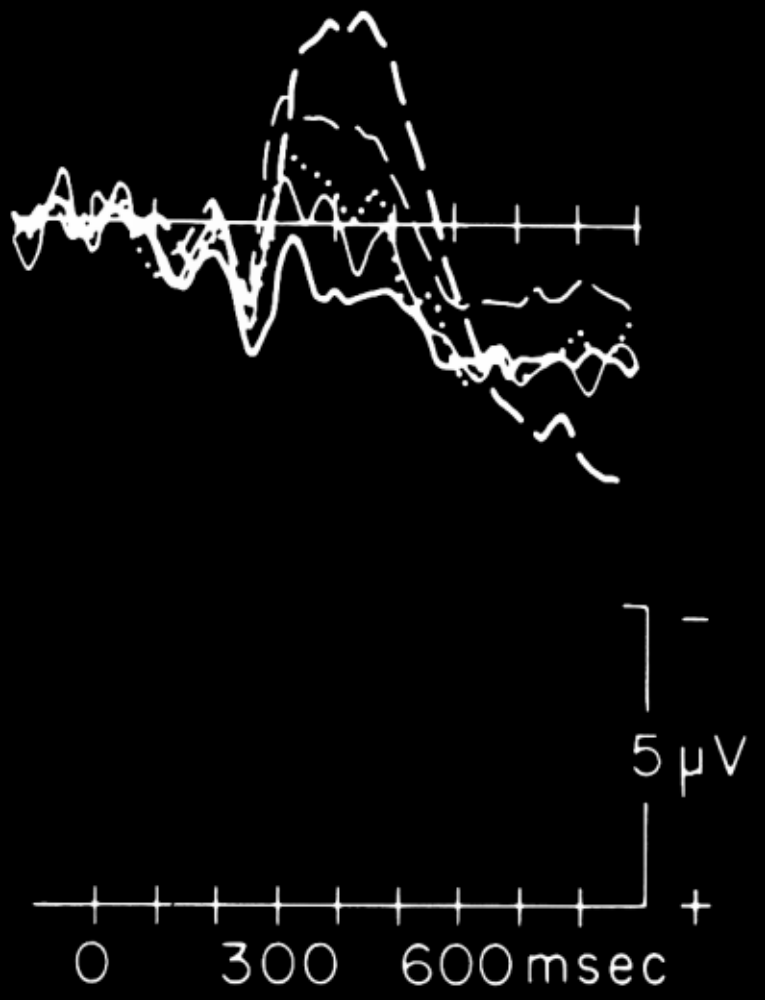
A

hi/hi	He mailed the letter without a stamp.
hi/lo	The bill was due at the end of the hour.
med/hi	She locked the valuables in the safe.
med/med	Too many men are out of jobs.
med/lo	The dog chased our cat up the ladder.
lo/hi	There was nothing wrong with the car.
lo/lo	He was soothed by the gentle wind.

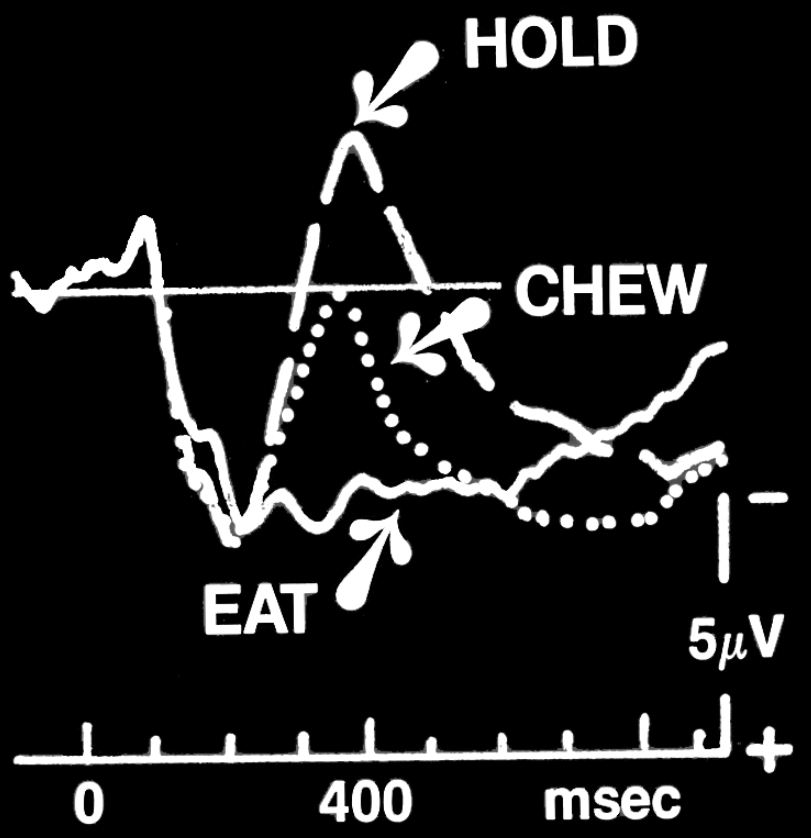
B

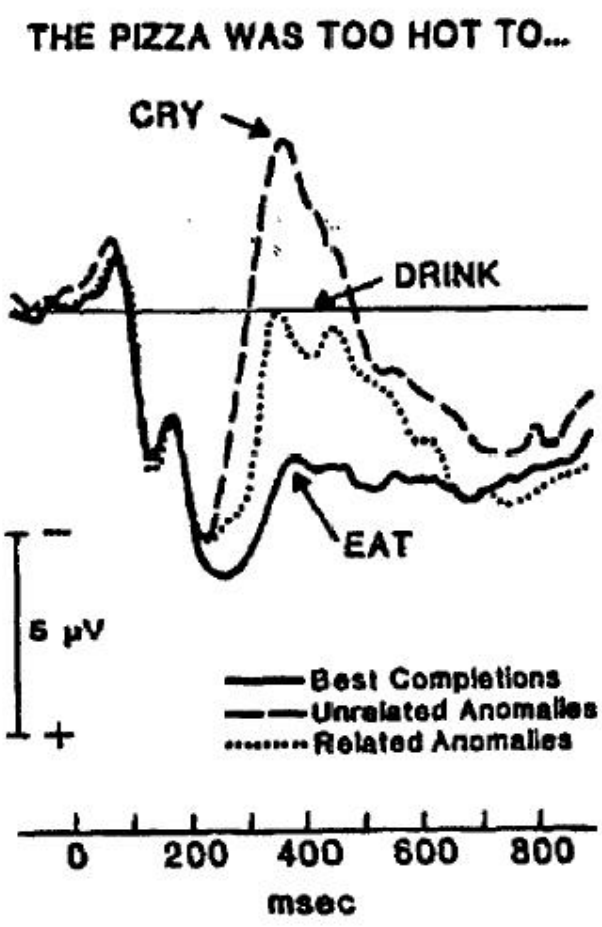
hi/hi	He mailed the letter without a stamp.
hi/lo	The bill was due at the end of the hour.
med/hi	She locked the valuables in the safe.
med/med	Too many men are out of jobs.
med/lo	The dog chased our cat up the ladder.
lo/hi	There was nothing wrong with the car.
lo/lo	He was soothed by the gentle wind.

C


−
5 μV
+
0
300
600 msec
cloze probability (p) > .7
p = .3 − .7
p = .1 − .3
p < .05

THE PIZZA WAS TOO HOT TO

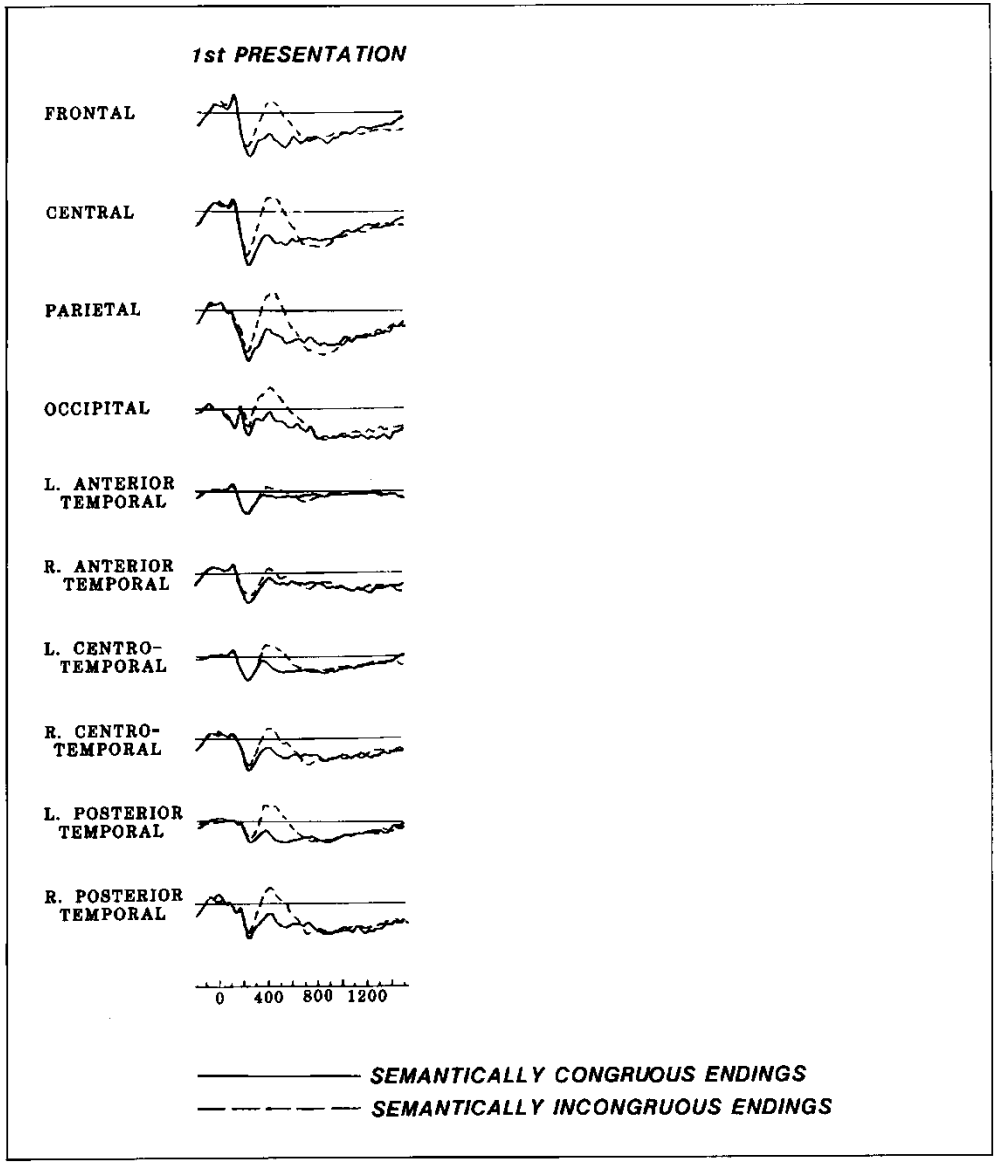



THE PIZZA WAS TOO HOT TO...
CRY
DRINK
EAT
5 μV
−
+
Best Completions
Unrelated Anomalies
Related Anomalies
0
200
400
600
800
msec

All else held constant, N400 amplitude is an inverse function of the degree to which an item is expected in semantic context – i.e., semantic expectancy, though this does not mean it reflects prediction/expectancy per se. Critically, it is not an index of the degree of semantic mismatch! It is not a semantic violation detector! In fact, an apparent lexico-semantic violation is neither necessary nor sufficient to elicit an N400.

Effect of repetition on N400 congruity effect

Figure 3. Grand average ERPs (N = 16) for semantically congruous and incongruous endings on first, second, and third presentations of the 192 sentences in Experiment 2.



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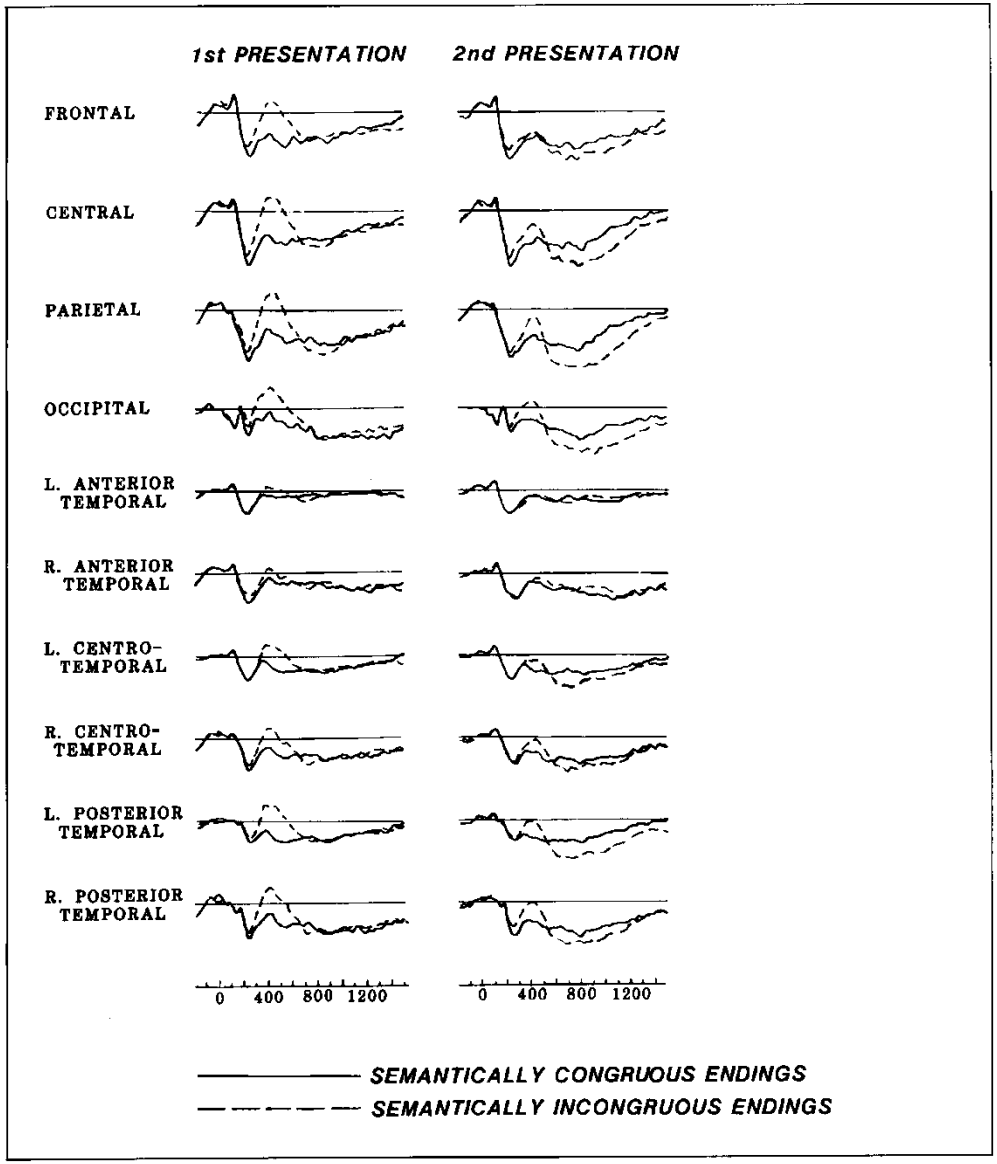

Effect of repetition on N400 congruity effect

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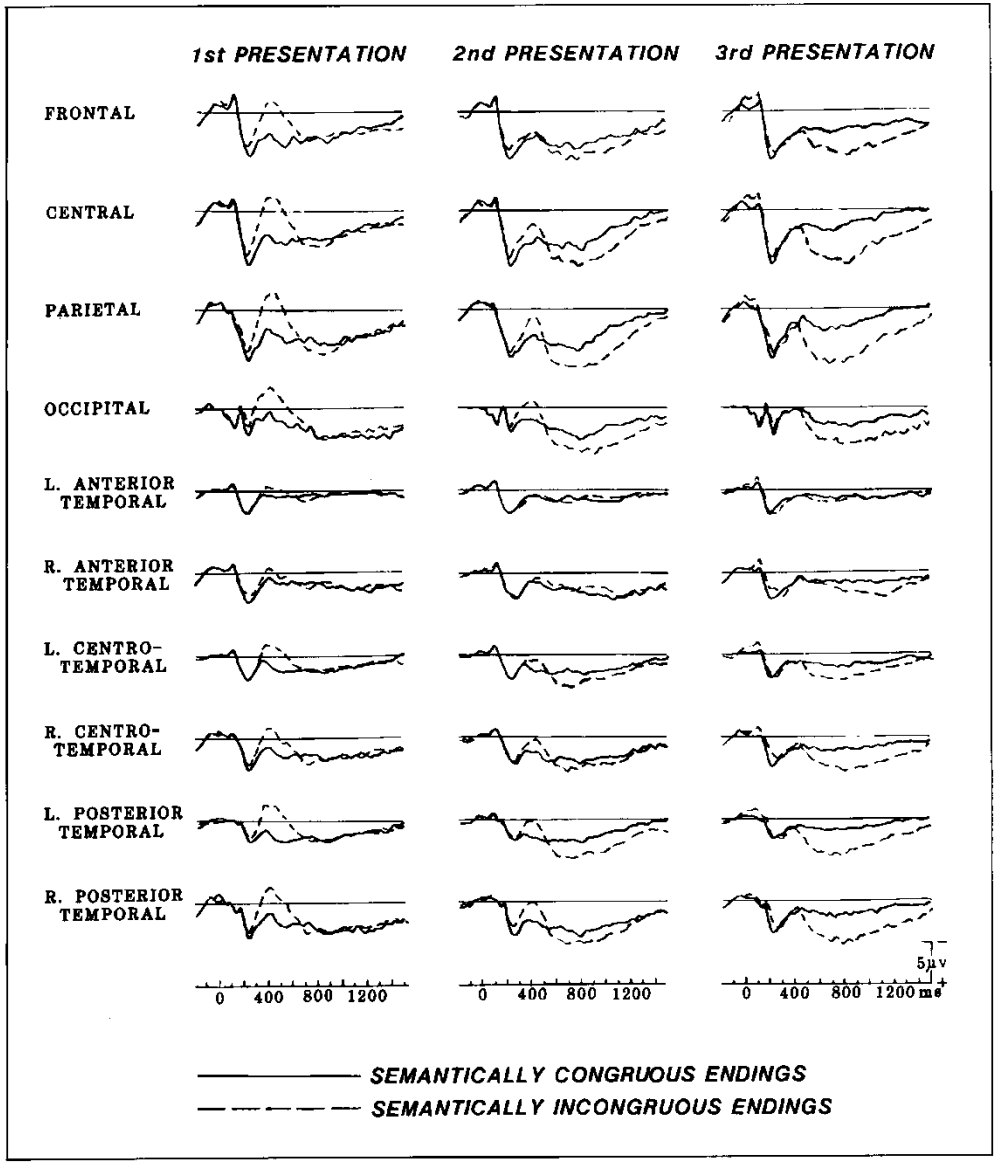
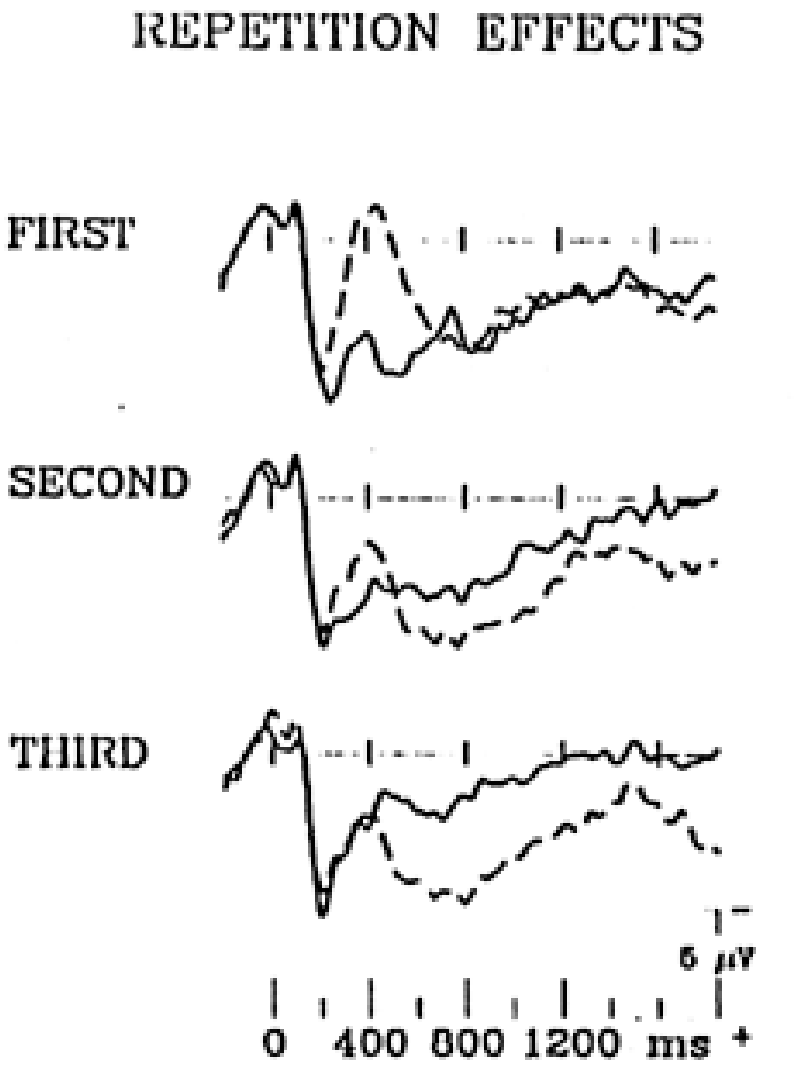


No N400 despite semantic incongruity on 3rd presentation of sentences



Since N400 is not a specific response to errors or violations, it might be a good way to examine language (and perhaps semantic processing) more generally.

N400 amplitude a linear function of word position in sentence