

Using the N400 and P600 to Measure Prediction vs. Integration

Seminar on Language Prediction and Integration

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Two experiments

- 1) Delong, Urbach & Kutas (2005) Probabilistic word pre-activation during language comprehension inferred from electrical brain activity
- 2) Delong, Urbach, Groppe & Kutas (2011) Overlapping dual ERP responses to low cloze probability sentence completions

Outline

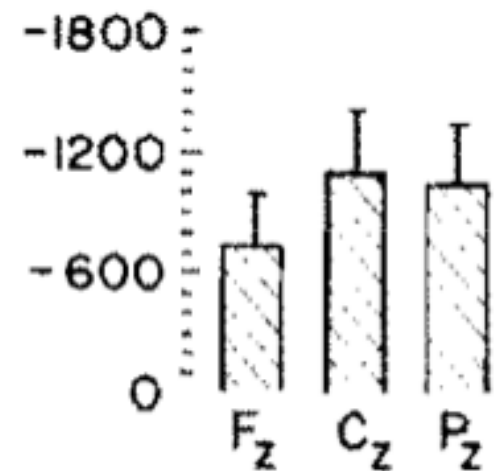
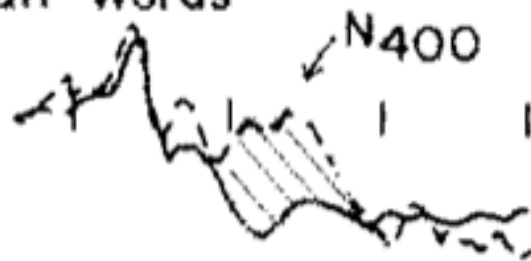
- Introduction
 - The N400
 - Prediction vs. Integration
- Evidence of prediction
 - Delong, Urbach & Kutas (2005)
 - Van Berkum et al. (2005)
- Costs of incorrect prediction
 - Federmeier & Kutas (2007)
 - Delong, Urbach, Groppe & Kutas (2011)
- Flies in the ointment: reinterpreting the N400 & P600

Kutas & Hillyard (1980)

- Congruous
 - “It was his first day at work.”
- Incongruous
 - “He spread the warm bread with socks.”

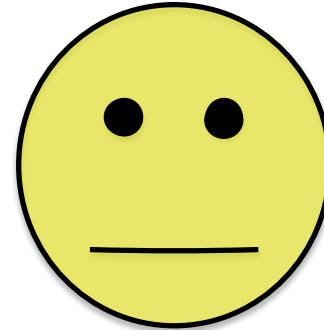
Semantic Deviation

Small Words



Prediction

“It was his first day at....”

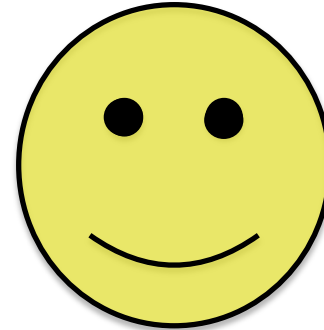


Prediction

“It was his first day at....”



“...work.”

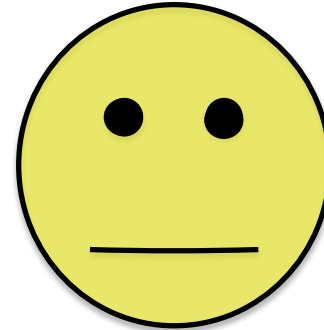


Prediction

“He spread the warm bread with....”



butter



Prediction

“He spread the warm bread with....”

butter

N400

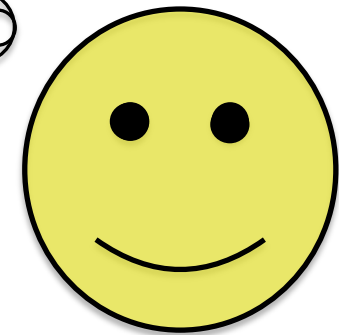
“...socks.”



Integration

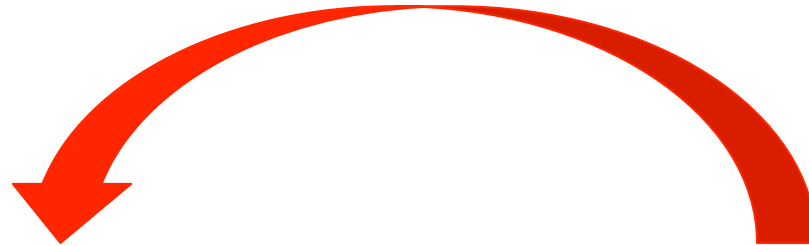


“It was his first day at... ..work.”

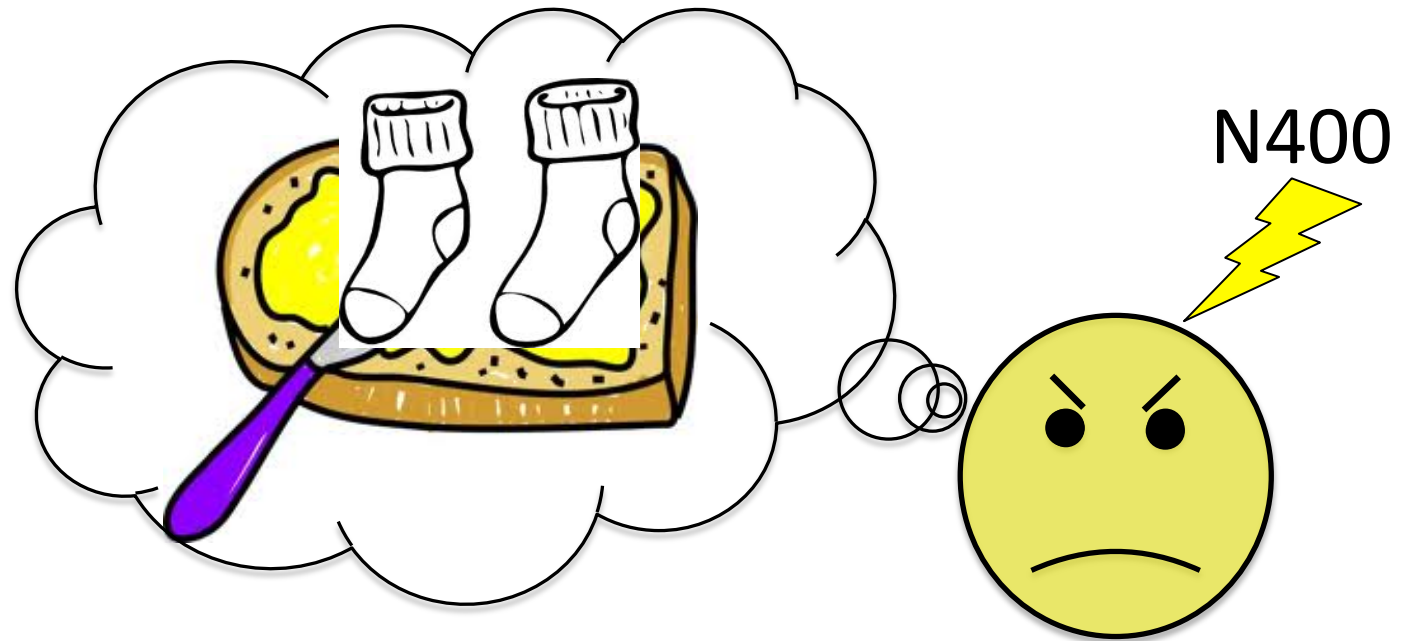


Kutas & Hillyard (1980)

Integration



“He spread the warm bread with... ..socks.”



Kutas & Hillyard (1980)

Prediction? Impossible!

- Noam Chomsky's Generative Grammar
- Creating the infinite from a finite set of symbols
- Possible to create sentences that have never been heard before:

“While listening to Katy Perry, Unicorns love to dance on... tables!”

Prediction? Impossible!

- Futile to try to predict the outcome of an entirely unique sentence
- Moreover, an incorrect prediction might create a cost
 - e.g. comprehension accuracy, reading time, and/or N400

DeLong, Urbach & Kutas (2005)

- Dissociating Integration from Prediction
- English phonological regularity:
 - ‘a’ precedes nouns beginning with consonants
 - ‘an’ precedes nouns beginning with vowels
- “The day was breezy so the boy went outside to fly...”
 - ...a kite ← cloze = 89%
 - ...an airplane

Integration

Cloze = 89%



“The day was breezy so the boy went outside to fly a...”

kite

Integration

Cloze = 8%*



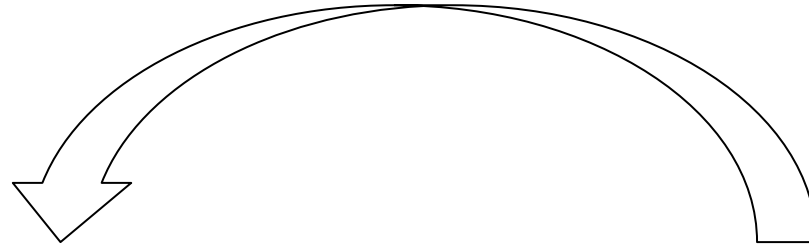
“The day was breezy so the boy went outside to fly an...”

airplane

*disclaimer: this is a made-up number, DeLong et al. (2005) did not provide a value

DeLong, Urbach & Kutas (2005)

Integration



“The day was breezy so the boy
went outside to fly a/an...”

kite > airplane

Integration

- 'a' and 'an' have the same semantic meaning
- Therefore no difference in their integration

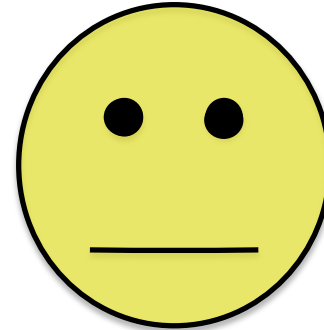
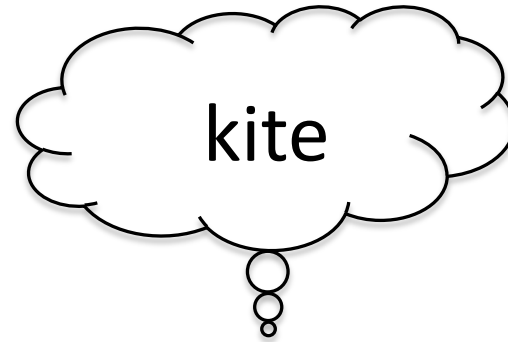


“The day was breezy so the
boy went outside to fly...”

a = an

Prediction

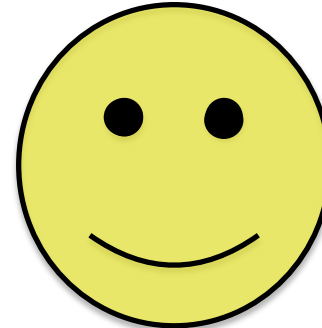
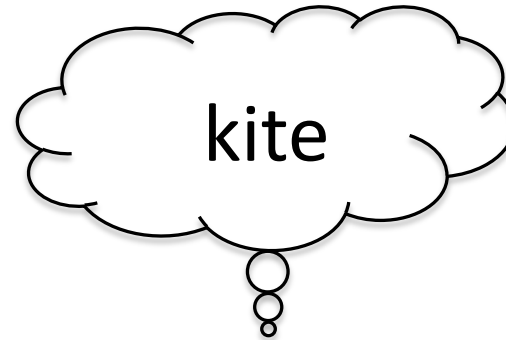
“The day was breezy so
the boy went outside
to fly.....”



Prediction

“The day was breezy so
the boy went outside
to fly.....”

“...a...”



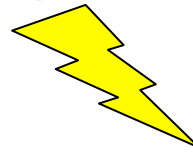
Prediction

“The day was breezy so
the boy went outside
to fly.....”

“...an...”



N400



Design

- 80 sentences with two possible target types:
 - relatively expected
 - and unexpected
- Targets were sentence medial
- 160 stimuli divided into two lists of 80 sentences, where each sentence context was used only once
- With an equal number of expected and unexpected targets

Design

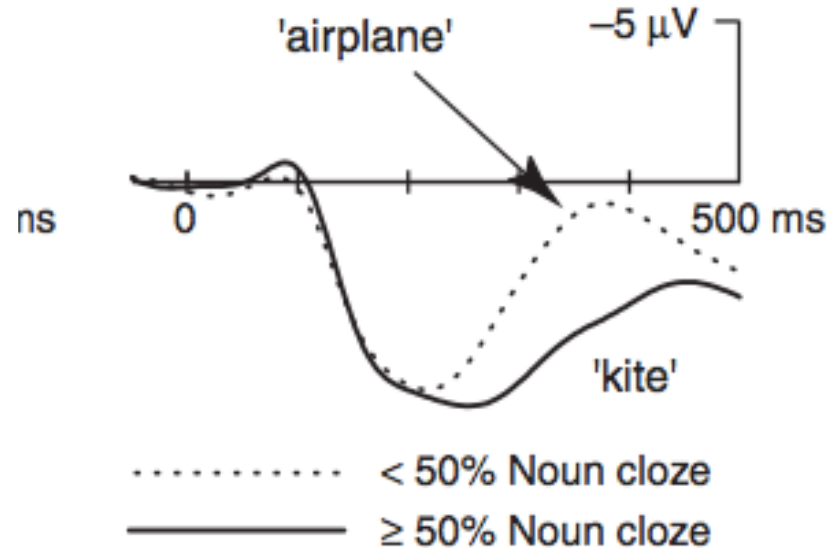
- One-quarter of the sentences followed by yes/no comprehension question
- Sentences were of varying constraint
- Target nouns ranging from highly probable to unlikely (based on offline cloze probability)
- Sorted into ten cloze probability bins from lowest (0-10%) to highest (90-100%)

Results

a

Vertex ERPs by median split on cloze probability,
e.g., 'The day was breezy so the boy went outside to fly ...'

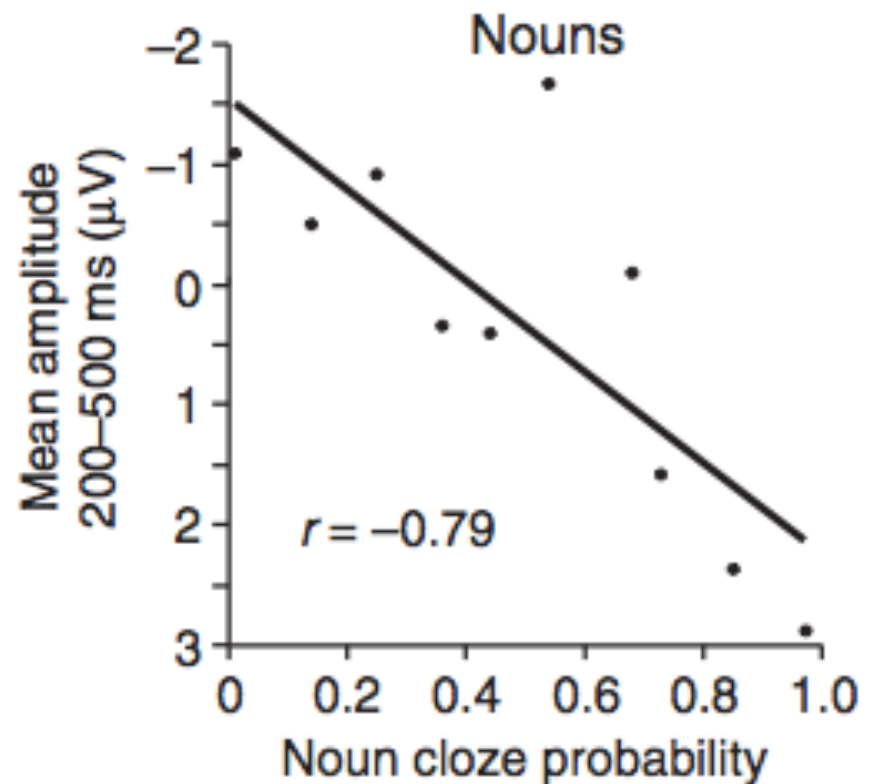
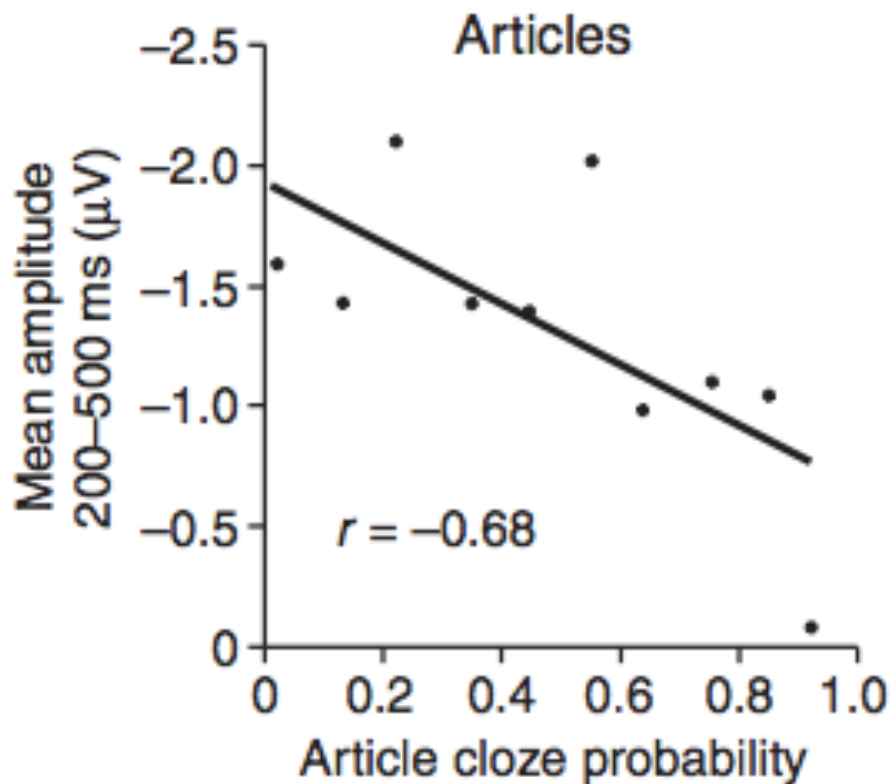
Nouns



Results

b

N400 x cloze probability correlations at vertex



Discussion

- The more contextually unexpected an indefinite article was, the greater the N400
- Not due to integration because 'a' and 'an' are grammatically and semantically congruent within the contexts
- Participants were anticipating the phonological form of a particular noun and therefore were expecting a particular article

Van Berkum et al. (2005)

- “The burglar had no trouble locating the secret family safe. Of course it was situated behind a...”
 - $\text{big}_{(\text{neu})}$ painting_(neu) (cloze = 86%)
 - $\text{big}_{(\text{com})}$ bookcase_(com) (cloze = 2%)
- N400 for bookcase > painting
- Positive deflection for $\text{big}_{(\text{com})} > \text{big}_{(\text{neu})}$ between 50-250ms after adjective inflection

Interim Summary

- Van Berkum et al. (2005) demonstrates expectancies of upcoming syntactic features
- Delong et al. (2005) demonstrates expectancies for specific words
- The N400 reflects the prediction of a specific noun and not integration

Federmeier et al. (2007)

Two different types of low cloze targets:

1) in strongly constraining contexts

- The children went outside to...
- ...play (cloze = 91%)
- ...look (cloze = 3%)

2) in weakly constraining contexts

- Joy was too frightened to...
- ...move (cloze = 35%)
- ...look (cloze = 3%)

Hypothesis 1

- The strength of the expectation matters
 - 1) “The children went outside to...”
 - Really expect that “play” comes next
 - 2) “Joy was too frightened to...”
 - Only somewhat expect that “move” comes next
- Hearing “look” violates a more strongly held expectation in sentence 1 than 2

Hypothesis 2

- Just generating the first sentence completion that comes to mind
- “The children went outside to...”
 - 93 of 100 participants pick “play”
 - 3 pick “look”
 - 4 pick something else
- “Joy was too frightened to...”
 - 35 of 100 participants pick “move”
 - 3 pick “look”
 - 62 pick something else
- Hearing “look” surprises 97 of 100 participants for both

Four types of sentences

- Strongly Constraining Expected (SC-E)
 - “The children went outside to play.” (cloze = 85.3%)
- Weakly Constraining Expected (WC-E)
 - “Joy was too frightened to move.” (cloze = 26.9%)
- Strongly Constraining Unexpected (SC-U)
 - “The children went outside to look.” (cloze = 3.1%)
- Weakly Constraining Unexpected (WC-U)
 - “Joy was too frightened to look.” (cloze = 3.1%)

Results

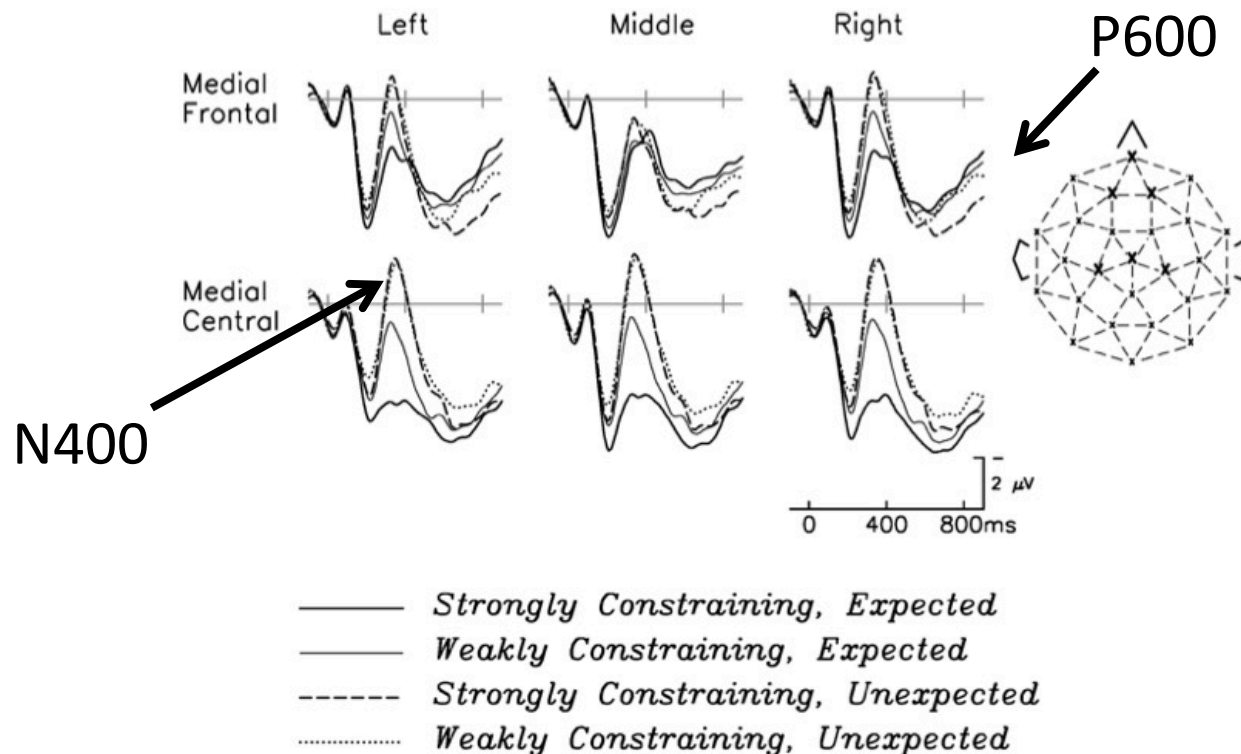


Fig. 2 – Close-up of the effects at six electrode sites, 3 over the central part of the head (showing the N400 effect pattern) and 3 over the front of the head (showing the frontal positivity to unexpected items in strongly constraining contexts). The small head diagram at right shows the positions (with X's) of the electrode sites.

Four types of sentences

- N400 inversely sensitive to cloze
 - SC-E < WC-E < SC-U = WC-U
 - 85.3% > 26.9% > 3.1% = 3.1%
- P600 effected by sentence constraint
 - SC-U > WC-U

Discussion

- N400
 - reflects the net benefit that contextual information provides for particular words, semantic features, and/or concepts
- P600
 - reflects the degree of mismatch between a strongly constraining sentence and an unrelated (although plausible) unexpected word
 - might reflect surprise and/or effort to override or suppress a strong prediction for a different word

DeLong, Urbach, Groppe & Kutas (2011)

- P600 = consequence of preactivating information that is later disconfirmed
- Is there a P600 to disconfirmed predictions in DeLong, Urbach & Kutas (2005)?
- For example, “The day was a breezy so the boy went outside to fly...” predicting ‘a kite’ but reading ‘an airplane’

Results

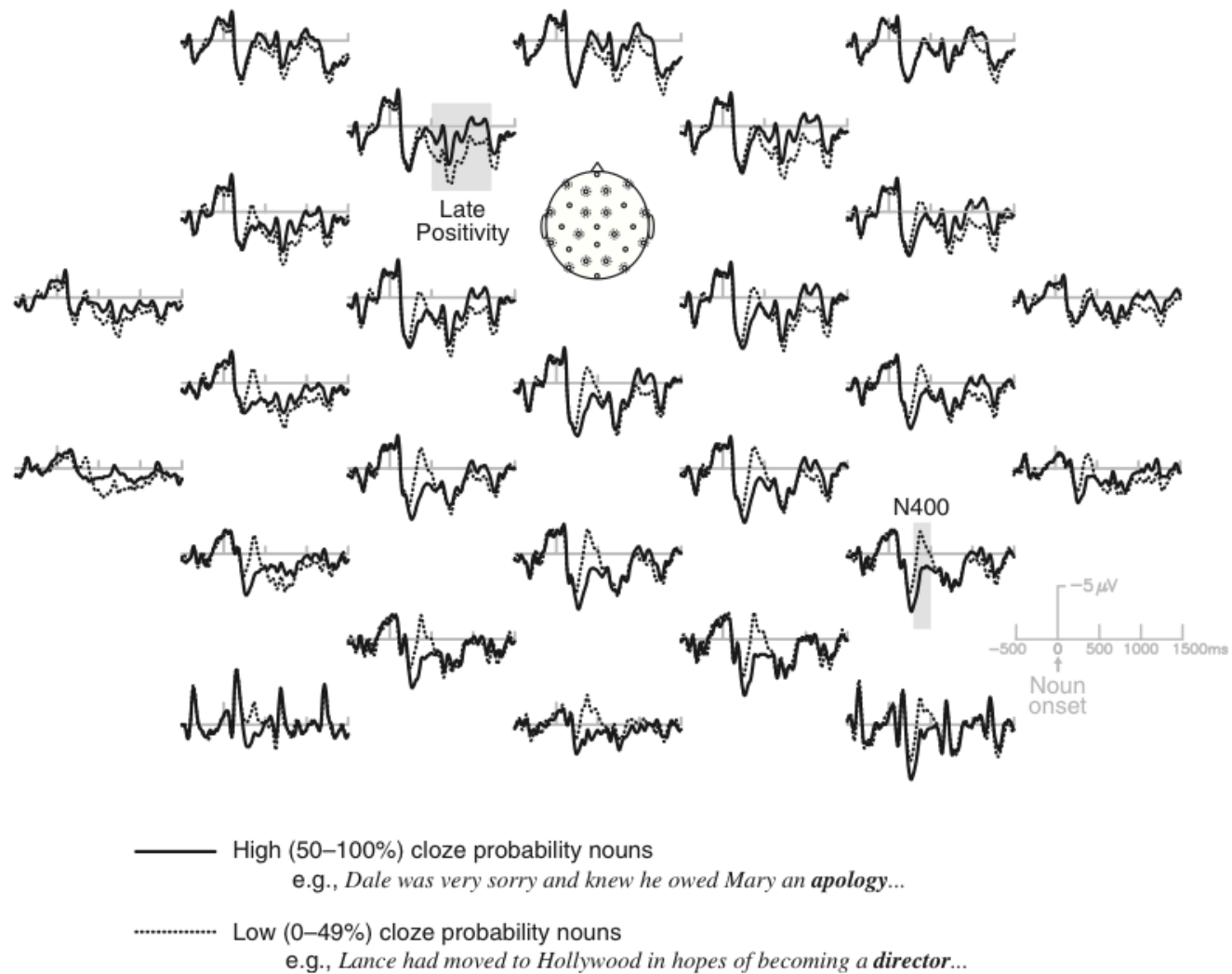


Figure 1. Grand average target nouns sorted on noun cloze probability over all 26 channels. N400 and LP time windows are highlighted over scalp locations where effects are prominent. The 16 electrodes used in distributional analyses are highlighted on the scalp map. ³⁶

Discussion

- Responses to low cloze nouns (e.g. airplane) were more positive than high cloze nouns (e.g. kite)
- Negatively correlated with cloze probability
 - i.e. increasing positivity with decrease cloze
- “Late Positivity” effect was strongest at anterior electrodes

Criticisms & Future Research

- Unlike Federmeier et al. (2007) contextual constraint was not directly manipulated
 - But was relatively high overall (mean = 71%)
- Different location from P600 to syntactic violations (posterior)
- Earlier than most other P600s
 - Less automatic, therefore less stable than N400?
 - Effect of the indefinite articles?
- No LP for the indefinite articles ‘a’ vs. ‘an’
 - “an enormous kite”

Reinterpreting the N400 & P600

- Traditional beliefs
 - N400: reflects either the integration of a word into the sentence context or the prediction of a word based upon the sentence context
 - P600: revision of a syntactic analysis

A few reviews:

- Brouwer, Fitz & Hoeks (2012)
- Van Petten & Luka (2012)

Flies in the ointment: N400

- Sensitive to shared semantic features
- Federmeier & Kutas (1999)
- “They wanted to make the hotel look more like a tropical resort. So along the driveway they planted rows of...”
 - palms (expected)
 - pines (within-category violation)
 - tulips (between-category violation)
- N400: palms < pines < tulips

Flies in the ointment: N400

- Insensitive to semantic illusions
- Brouwer, Fitz & Hoeks (2012)
- “The hearty meal was devouring...”
- “The fox that on the poacher hunted...”
- “For breakfast the eggs would eat...”
- Elicit P600 but not N400

Flies in the ointment: P600

- Sentences with long-distance *wh*-dependencies
 - (1) “Emily wonders *who* the performers in the concert imitate...”
 - (2) “Emily wonders *whether* the performers in the concert imitate...”
- Sentences with irony
 - “These artists are gifted.”
 - After either hearing a really good or really poor performance of a Bach sonata

Reinterpreting the N400 & P600

- N400
 - Retrieval of lexical information from memory
 - Higher the cloze reflects better sentential context
 - Greater preactivation of semantic features from the context → reduction in N400
- P600
 - Anterior: inhibition of disconfirmed predictions
 - Posterior: reprocessing costs (i.e. reviewing the previous context and determining what went wrong)

Thanks!

References

- Brouwer, H., Fitz, H., & Hoeks, J. (2012). Getting real about Semantic Illusions : Rethinking the functional role of the P600 in language comprehension. *Review Literature And Arts Of The Americas*, 6, 127-143. doi: 10.1016/j.brainres.2012.01.055.
- DeLong, K. A., Urbach, T. P., Groppe, D. M., & Kutas, M. (2011). Overlapping dual ERP responses to low cloze probability sentence continuations. *Psychophysiology*, 1-5. doi: 10.1111/j.1469-8986.2011.01199.x.
- DeLong, K. A., Urbach, T. P., & Kutas, M. (2005). Probabilistic word pre-activation during language comprehension inferred from electrical brain activity. *Nature Neuroscience*, 8(8), 1117-1121. doi: 10.1038/nn1504.
- Federmeier, K. D., & Kutas, M. (1999). A Rose by Any Other Name : Long-Term Memory Structure and Sentence Processing. *Journal of Memory and Language*, 495, 469 - 495.

References

Federmeier, K. D., Wlotko, E. W., Ochoa-dewald, E. D., & Kutas, M. (2007). Multiple effects of sentential constraint on word processing. *Science*, *46*, 75-84. doi: 10.1016/j.brainres.2006.06.101.

Kutas, M., & Hillyard, S. A. (1981). EVENT-RELATED BRAIN POTENTIALS TO SEMANTICALLY INAPPROPRIATE AND SURPRISINGLY LARGE WORDS Marta KUTAS and Steven A. HILLYARD. *Biological Psychology*, *11*(1980), 99-116.

Petten, C. V., & Luka, B. J. (2012). Prediction during language comprehension : Benefits , costs , and ERP components. *International Journal of Psychology*, *83*, 176-190. doi: 10.1016/j.ijpsycho.2011.09.015.

Van Berkum, J. J. A., Brown, C. M., Zwisterlood, P., Kooijman, V., & Hagoort, P. (2005). Anticipating Upcoming Words in Discourse : Evidence From ERPs and Reading Times. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *31*(3), 443- 467. doi: 10.1037/0278-7393.31.3.443.