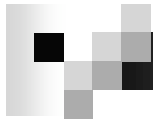




## How do sentences get their meanings?

- Given that we can produce and understand sentences we've never encountered before, sentence meanings must be composed from the meanings their constituents in some *fairly transparent way*.
- Frege's principle of compositionality:
  - **The meaning of an expression is a function of the meanings of its parts and the way they are syntactically combined.**



A **very** informal illustration of compositional interpretation, ignoring many aspects of sentence meaning (such as tense, for example).

*an event such that it is a seeing event and it has John as its Agent and the unique (contextually determined) individual such that it has the property of being heavy and a rock as its Theme*

*an event such that it is a seeing event and it has  $x$  as its Agent and the unique (contextually determined) individual such that it has the property of being heavy and a rock as its Theme*

*the unique (contextually determined) individual such that it has the property of being heavy and a rock*

*the property of being heavy and a rock*

**John**

**saw**

**the**

**heavy**

**rock**

*John*

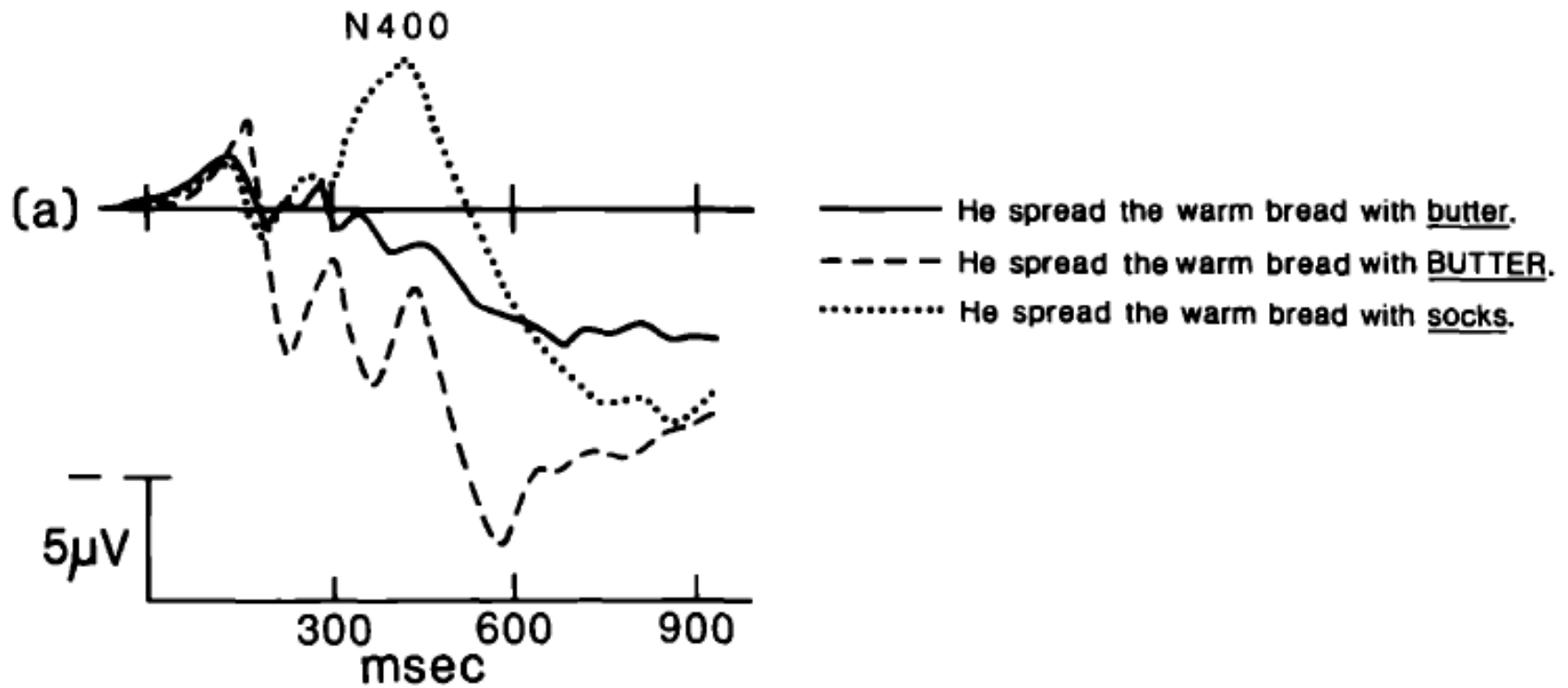
*an event such that it is a seeing event and it has  $x$  as its Agent and  $y$  as its Theme*

*the unique (contextually determined) individual such that it has the property  $X$*

*the property of being heavy*

*the property of being a rock*

# N400 (Kutas & Hillyard)



# N400 version of example

- What's the function of the N400?
  - **A wildly popular view: Semantic integration.**
    - In the context of the example below this would mean that forming the intersection of 'happiness' and 'rockness' is harder if no or few things are characterized by both of these properties (I.e., fall into the intersection).
  - **A less popular view: Lexical access.**
    - 'happy' sets up an expectation for a noun that describes an animate sentient individual. So lexical entries describing such entities are primed. Rock doesn't fit that description at all. Therefore, its access is delayed.

*the property of being  
happy and a rock*

**John**

**saw**

**the**

**happy**

**rock**

*John*

*an event such  
that it is a  
seeing event  
and it has  $x$  as  
its Agent and  $y$   
as its Theme*

*the unique  
(contextually  
determined)  
individual such  
that it has the  
property  $X$*

*the property of  
being happy*

*the property of  
being a rock*



# Predictions

- Semantic integration

- **The N400 should be modulated not just by plausibility but also by any factor that makes semantic composition harder.**

- Seeing whether this prediction is born out is the topic of our *next* class.

- Lexical access.

- **The N400 should be modulated by factors affecting lexical access.**

- **A sentential context should not be necessary for N400 effects.**



## N400 and lexical frequency

- Low frequency words elicit larger N400s than high frequency words.
  - **In a sentential context this interacts with position: frequency effect only obtained early on in the sentence.**

Refs:

- Van Petten, C. and Kutas, M. (1990) Interactions between sentence context and word frequency in event-related brain potentials. *Memory and Cognition* 18(4): 380-393.
- Smith, M. E., and Halgren, E. 1987. Event-related potentials during lexical decision: Effects of repetition, word frequency, pronounceability, and concreteness. *Electroencephalogr. Clin. Neurophysiol. Suppl.* 40: 417–421.



## N400 and semantic priming

- Semantically related targets (doctor - nurse) elicit smaller N400s than semantically unrelated targets.

### Refs:

- Bentin S, McCarthy G, and Wood CC (1985): Event-related potentials associated with semantic priming. *Electroencephalography and Clinical Neurophysiology* 60: 343-355.
- Holcomb PJ and Neville HJ (1990): Auditory and visual semantic priming in lexical decision -- a comparison using event-related brain potentials. *Language and Cognitive Processes* 5: 281-312.
- Holcomb, & Neville. (1991). Natural speech processing: An analysis using event-related brain potentials. *Psychobiology*, 19(4), Dec 1991.
- Kutas, M., Lindamood, T. E., & Hillyard, S. A. (1984). Word expectancy and event-related brain potentials during sentence processing. In S. Kornblum & R. J. (Eds.), *Preparatory states and processes* (pp. 217-237). Hillsdale: Erlbaum.



## N400 and phonological priming

- Phonologically related targets (e.g.: fame - lame) elicit smaller N400s than phonologically unrelated targets.

### Refs:

- Praamstra P, Meyer, AS, Levelt, WJM, 1994. Neurophysiological manifestations of phonological processing: latency variation of a negative ERP component time-locked to phonological mismatch. J. Cogn. Neuroscience.
- Praamstra P, Stegeman DF. Phonological effects on the auditory N400 event-related brain potential. Brain Res Cogn Brain Res 1993 Apr;1(2):73-86.
- Radeau M, Besson M, Fonteneau E, Castro SL. Semantic, repetition and rime priming between spoken words: behavioral and electrophysiological evidence. Biol Psychol. 1998 Jun;48(2):183-204.



# Is the N400 specific to words?

## The Search for “Common Sense”: An Electrophysiological Study of the Comprehension of Words and Pictures in Reading

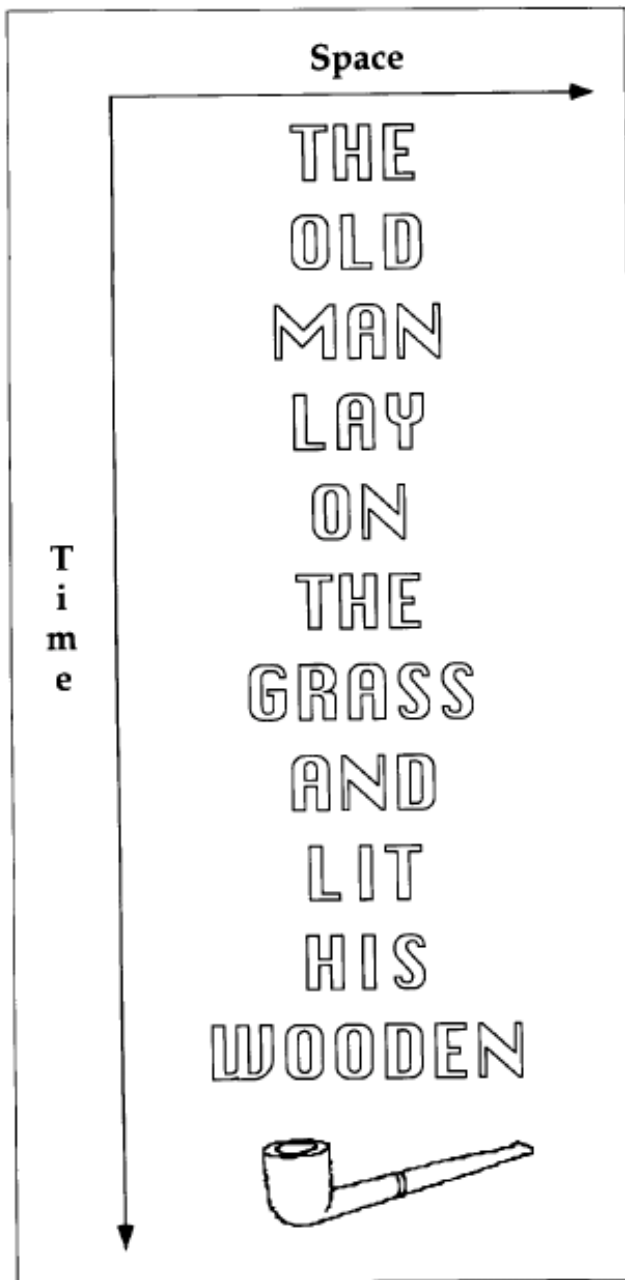
Giorgio Ganis, Marta Kutas, and Martin I. Sereno  
University of California, San Diego

### Abstract

■ Event-related brain potentials (ERPs) from 26 scalp sites were used to investigate whether or not and, if so, the extent to which the brain processes subserving the understanding of imageable written words and line drawings are identical. Sentences were presented one word at a time to 28 undergraduates for comprehension. Each sentence ended with either a written word (regular sentences) or with a line drawing (rebus sentences) that rendered it semantically congruous or semantically incongruous. For half of the subjects regular and rebus sentences were randomly intermixed whereas for the remaining half the regular and rebus sentences were presented in separate blocks (affording within-subject comparisons in both cases). In both presentation formats, words and line drawings generated greater negativity between 325 and 475 msec post-

stimulus in ERPs to incongruous relative to congruous sentence endings (i.e., an N400-like effect). While the time course of this negativity was remarkably similar for words and pictures, there were notable differences in their scalp distributions; specifically, the classic N400 effect for words was larger posteriorly than it was for pictures. The congruity effect for pictures but not for words was also associated with a longer duration (lower frequency) negativity over frontal sites. In addition, under the mixed presentation mode, the N400 effect peaked about 30 msec earlier for pictures than for words. All in all, the data suggest that written words and pictures when they terminate sentences are processed similarly, but by at least partially nonoverlapping brain areas. ■

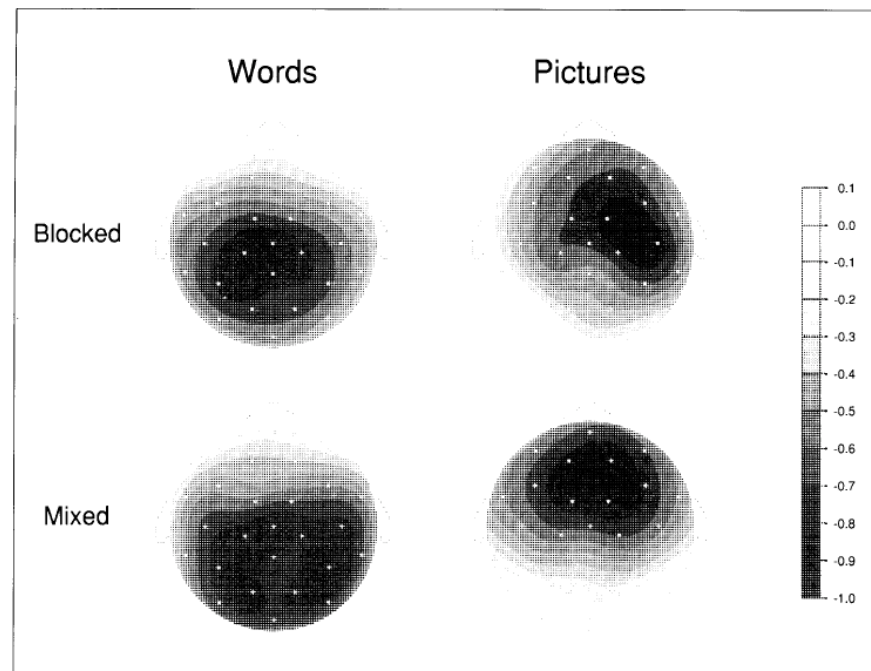
*Journal of Cognitive Neuroscience* 8:2, pp. 89–106



**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.

# Is the N400 specific to words?

- Both pictures and words elicited an “N400” but they had different topographies.
  - **The N400s of pictures and words must have different neural generators.**



**Figure 7.** Isopotential gray-scale maps of the normalized distribution of the N400 effect (mean amplitude of the difference waves between 525 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).



## **The N400**

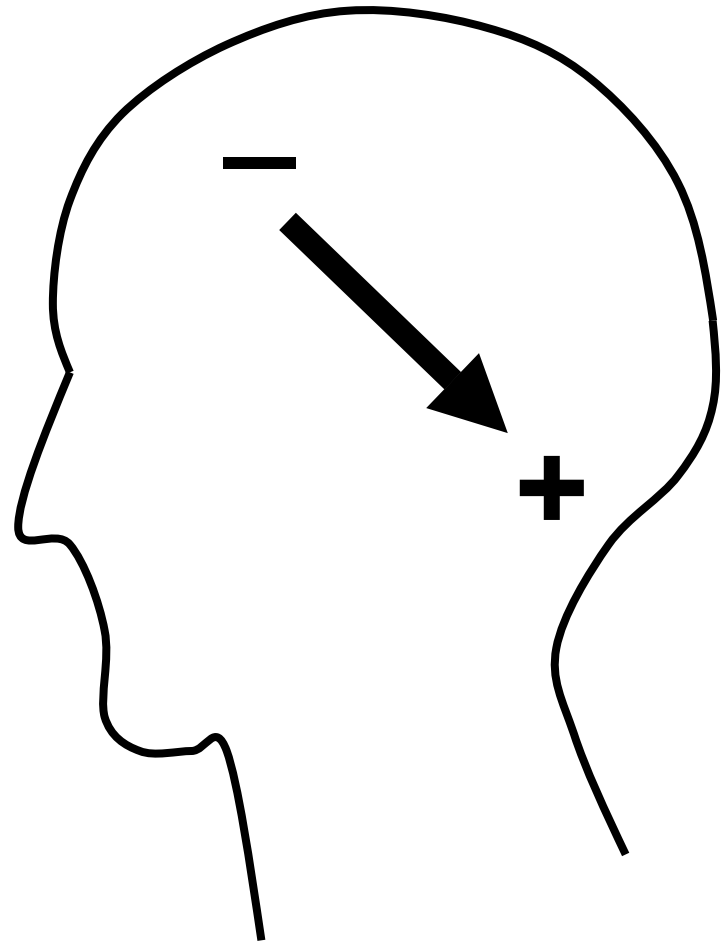
- Is elicited for all words (regardless of context)
- Shows lexical frequency and priming effects in a way consistent with the hypothesis that it indexes some aspect of lexical access.

**M350 = N400?**

# Polarity

---

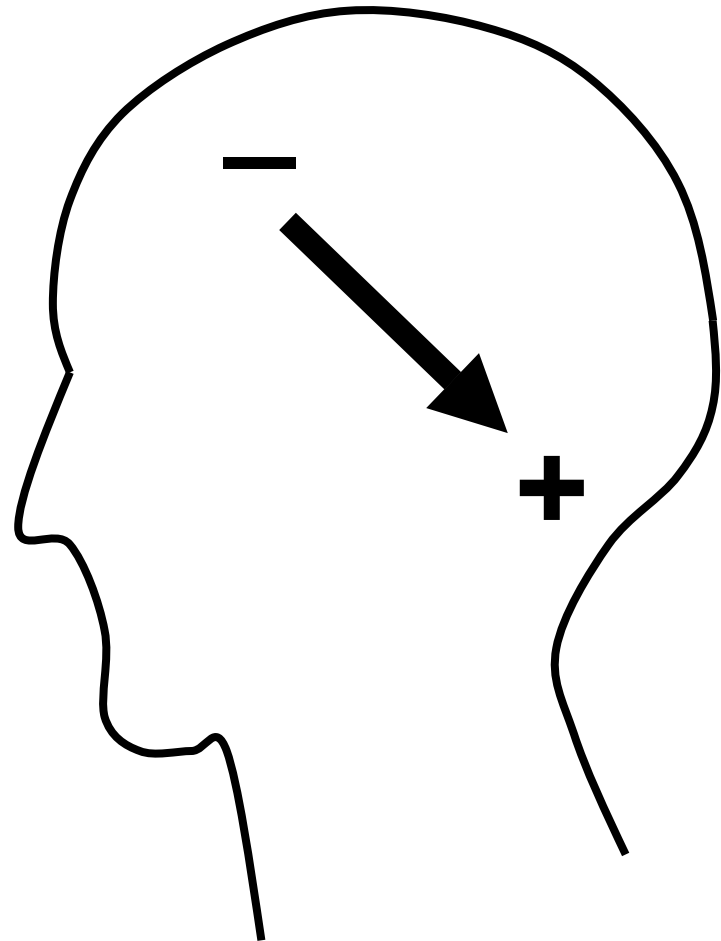
- **A typical M350 source should generate a negativity at the top of the head.**
- **N400 usually largest at central/midline electrodes.**



# Polarity

---

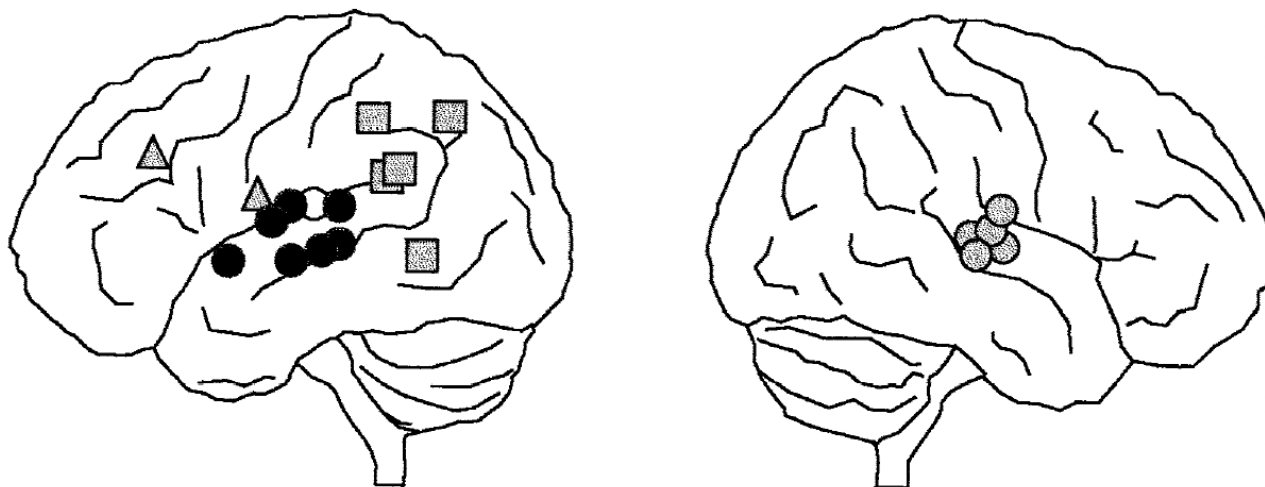
- **NB: The M350 is often bilateral.**
- **Both the LH and RL M350 sources contribute to the midline negativity.**
- **N400 sums over both hemispheres.**



# Localization of the N400 using MEG

---

- **Helenius et al 1999:**
  - **Classic N400 paradigm in MEG.**
  - **Sources of the N400 effect cluster in the vicinity of the auditory cortex (left-dominant).**

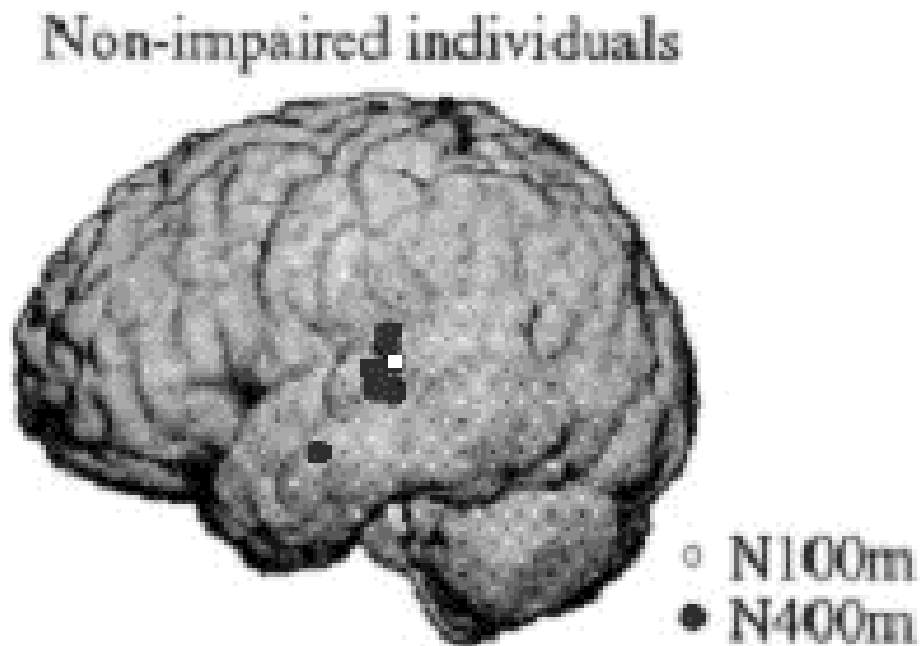


(Helenius, P, Salmelin, E, et al. 1998. Distinct time courses of word and context comprehension in the left temporal cortex. Brain, 121, 1133-1142. )

# Localization of auditory N400 using MEG

---

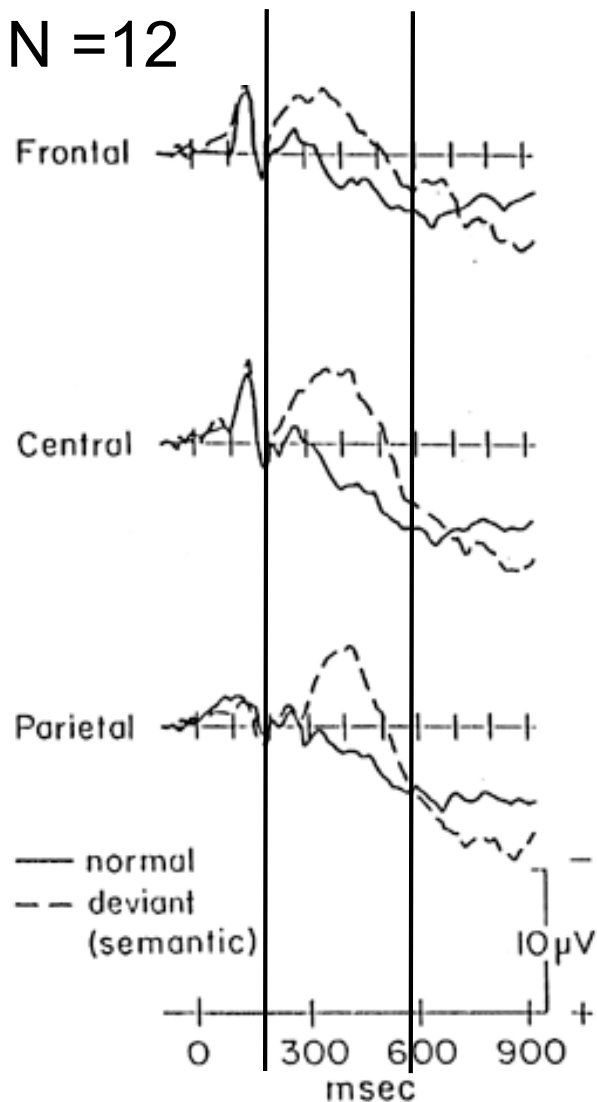
- **Helenius et al. (2002):**



(P Helenius, R Salmelin, E Service, JF Connolly, S Leinonen, and H Lyytinen, Cortical Activation during Spoken-Word Segmentation in Nonreading-Impaired and Dyslexic Adults J. Neurosci. 2002 22: 2936-2944. )

# Timing: N400

N = 12



- **Onset: ~250ms.**
- **Peak: ~400ms**
- **Offset: ~550-600ms.**
- **The duration of the M350 is in the order of 50ms.**

--- He spread the warm bread with SOCKS  
— He spread the warm bread with BUTTER

(Kutas and Hillyard, 1980)

**M350  $\neq$  N400**

**but the M350 is likely a  
subcomponent of the N400  
(the M250 might also be a  
subcomponent of the N400).**

# **Possible reasons for differences in waveform morphology in MEG and ERPs**

---

- 1. EEG picks up more activity than MEG.**
- 2. ERP data are usually grandaveraged.**
  - **Small latency differences may be lost.**
- 3. Summation over hemispheres in ERPs.**
  - **Differences between hemispheres may be lost.**

**Example illustrating the importance of being able to separate the hemispheres.**

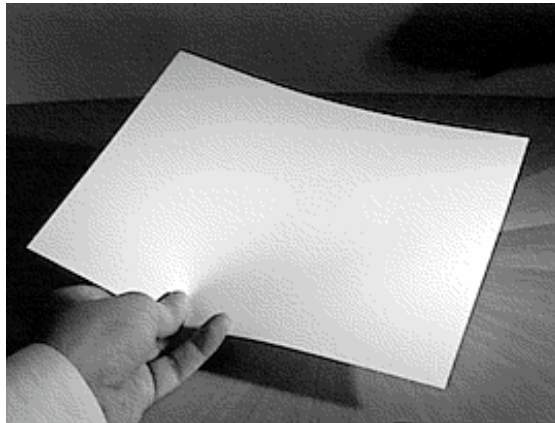
# **The Representation of Polysemy: MEG Evidence**

**Liina Pylkkänen<sup>1</sup>, Rodolfo Llinás<sup>2</sup>, and Gregory L. Murphy<sup>1</sup>**

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*Journal of Cognitive Neuroscience* 18:1, pp. 1–13

***paper***

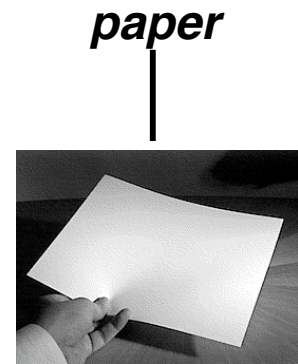


*Today's paper was depressing.*

*The paper went bankrupt.*

*Can I email you my paper?*

*We should paper these walls.*



- Flexibility of word meaning = ***Polysemy***
- Virtually all words are polysemous.
- Easy for humans but extraordinarily difficult for computers.

# Homonymy

---

- One pronunciation, two clearly different meanings

*savings bank*

*river bank*

# Intuitions not sufficient for pulling apart polysemy and homonymy!

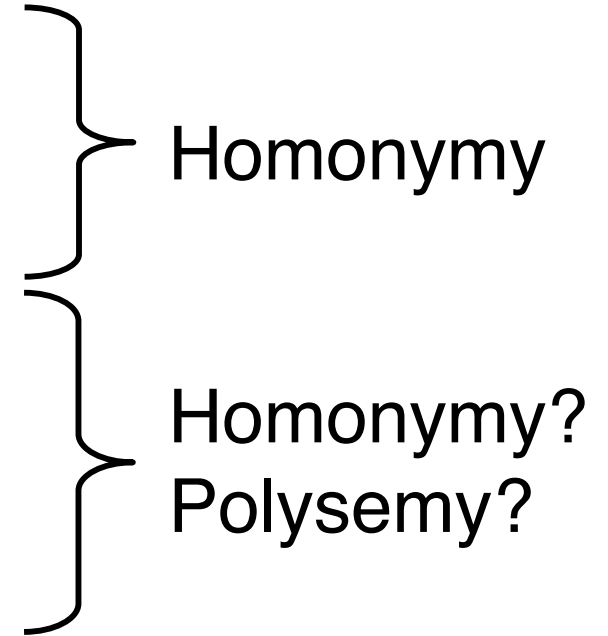
---

*I just ate a date.*

*Today's date is June 22nd.*

*I have a hot date tonight.*

*My date is dark and handsome.*



# Questions

---

- Are polysemy and homonymy qualitatively different phenomena?
- Does polysemy involve identity or similarity?

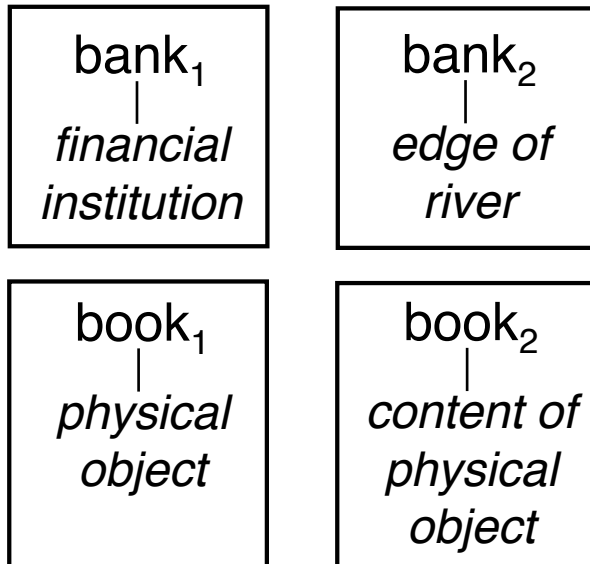
# A bit of terminology

---

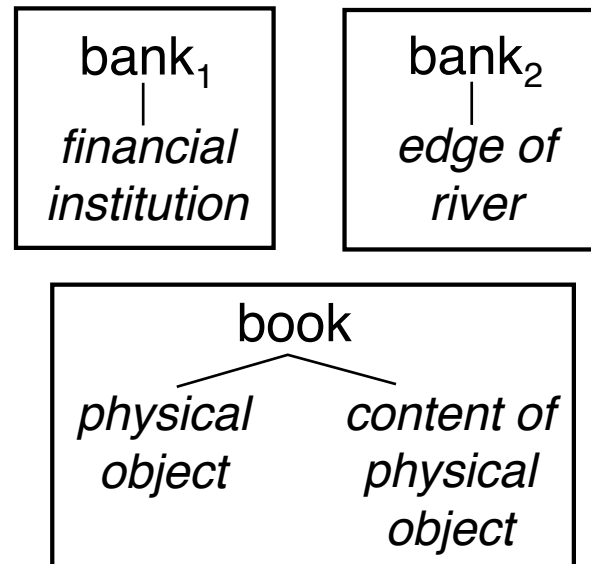
- Different but related meanings of a polysemous word:  
SENSES
- Different meanings of a homonymous word:  
MEANINGS

# Two hypotheses

**Polysemy is like homonymy: senses have their own lexical entries**



**Sense representations stored with roots**



# Predictions

**Polysemy is like homonymy: senses have their own lexical entries**

- Polysemy effects = effects of homonymy + semantic relatedness  
  
→ Cumulative effects of phonological and semantic relatedness

**Sense representations stored with roots**

- The relationship between polysemes and homonyms is qualitatively different  
  
→ Polysemy effects can be “special”

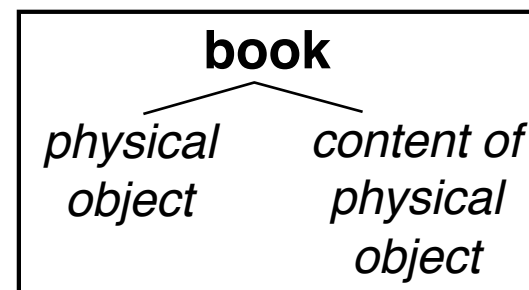
# Predictions

**Polysemy is like homonymy: senses have their own lexical entries**

- Polysemy effects = effects of homonymy + semantic relatedness
- Cumulative effects of phonological and semantic relatedness

**Sense representations stored with roots**

- Polysemy involves root *identity*.



# Stimuli

---

## HOMONYMY

RELATED

UNRELATED

## PRIME

broken bat

vast fortune

## TARGET

baby bat

baby bat

## POLYSEMY

RELATED

UNRELATED

## PRIME

green book

national bank

## TARGET

insightful book

insightful book

## SEMANTIC

RELATED

UNRELATED

## PRIME

interesting novel

national bank

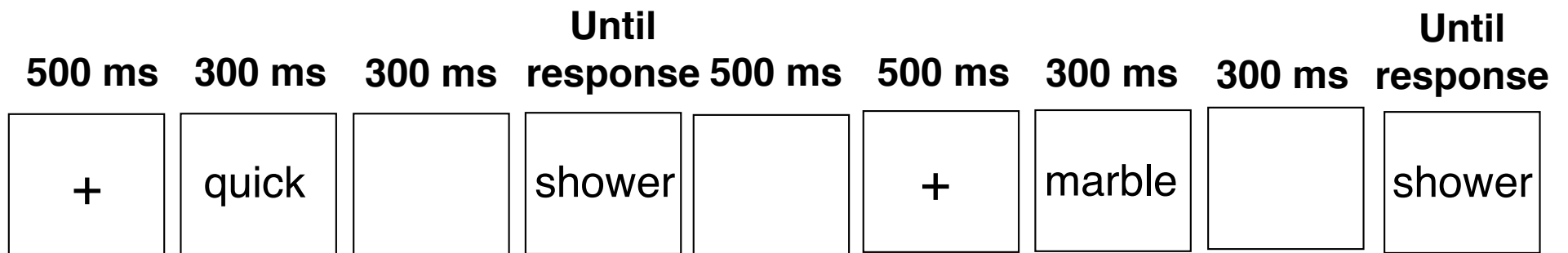
## TARGET

green book

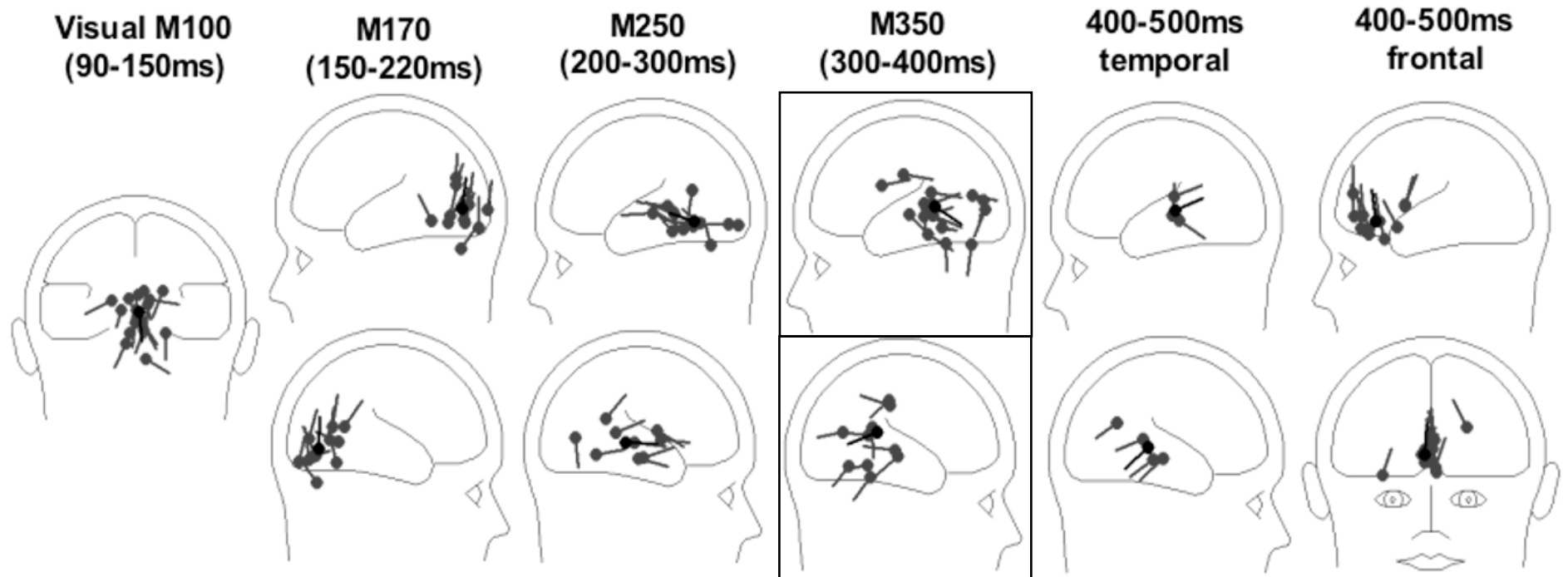
green book

# Sensicality judgment task

---

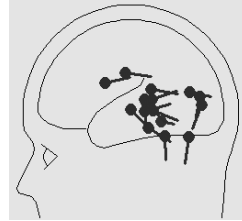


# MEG data: All sources (17 subjects)

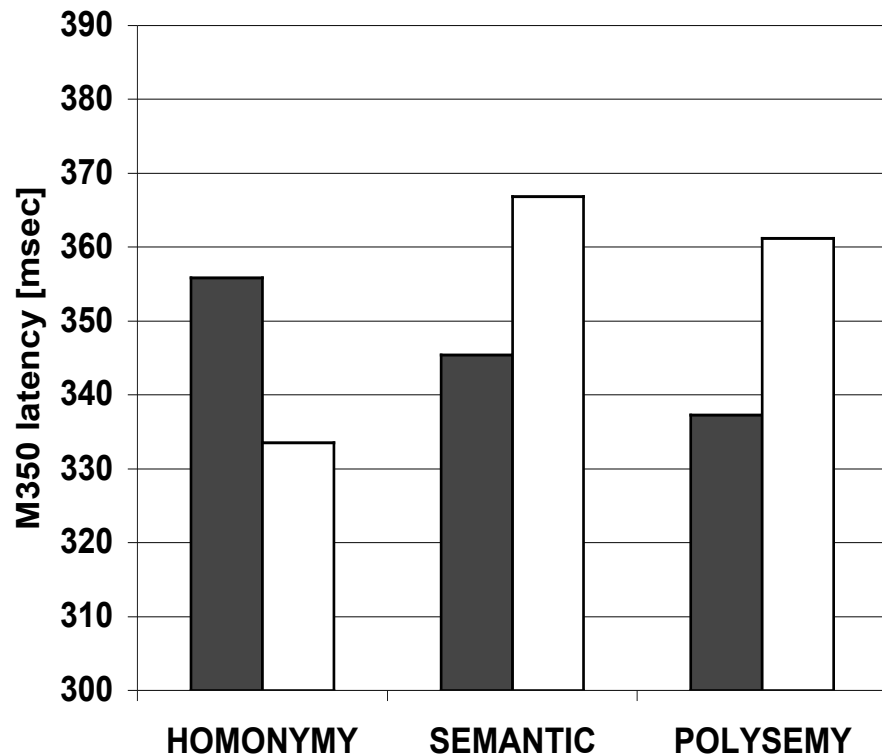


# Results: M350 latency

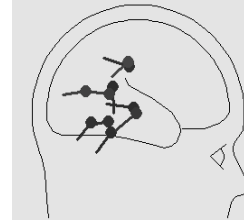
## LEFT



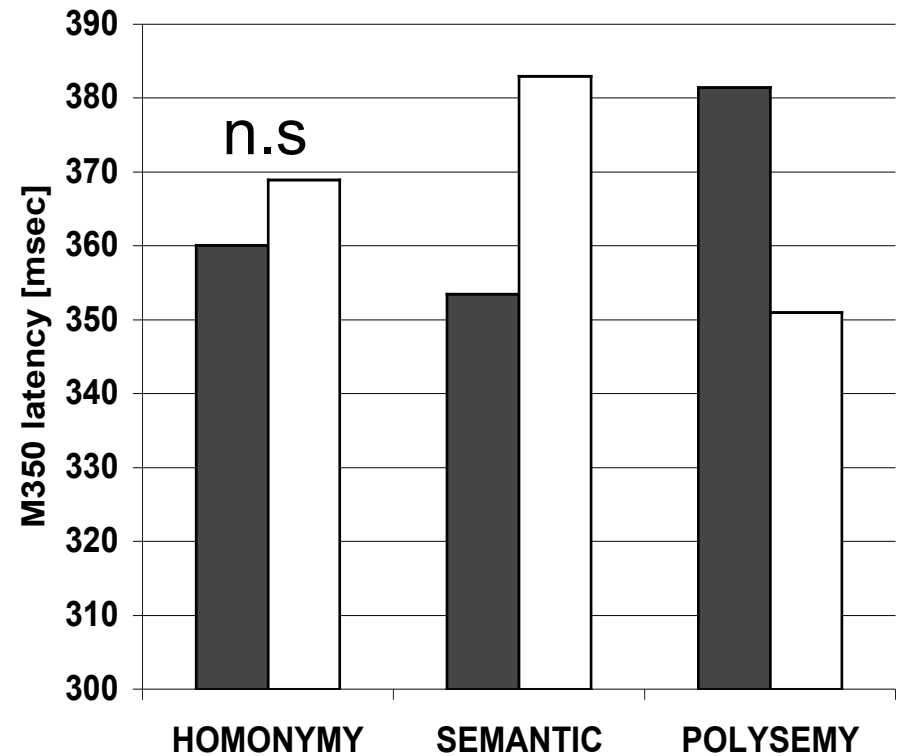
■ RELATED □ UNRELATED



## RIGHT

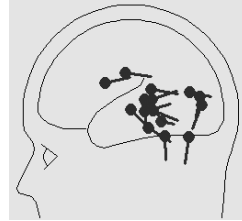


■ RELATED □ UNRELATED

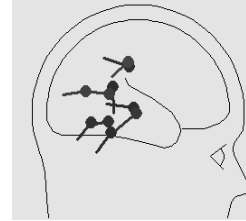
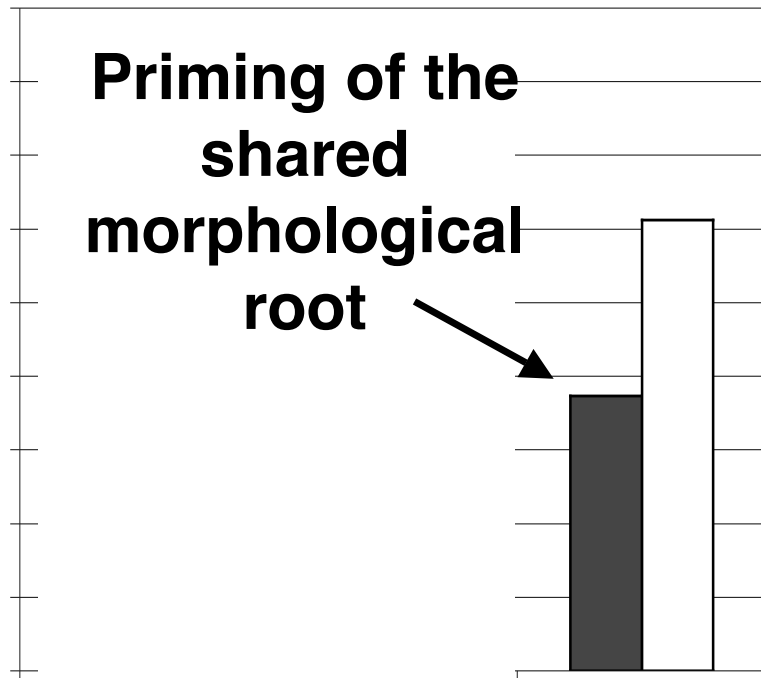


# Results: M350 latency

**LEFT**

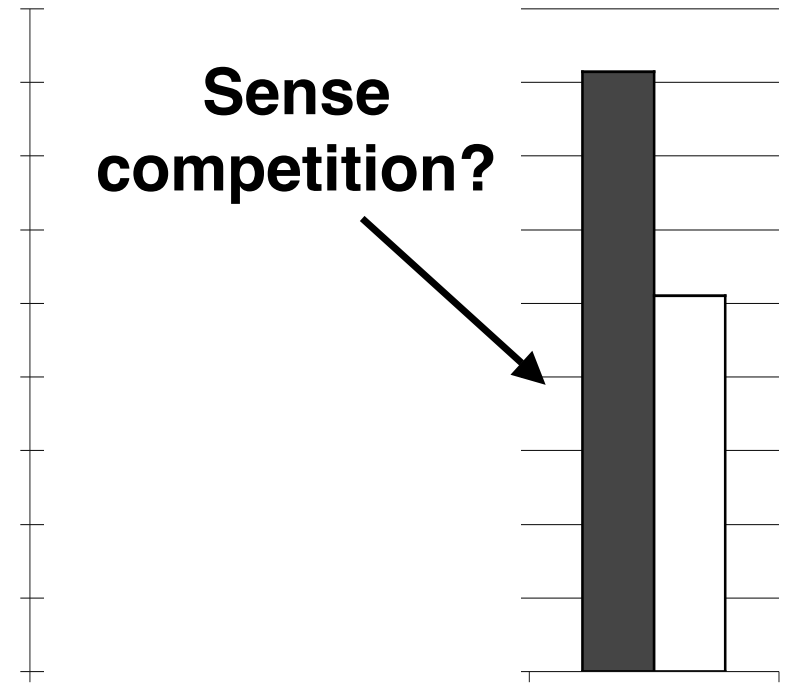
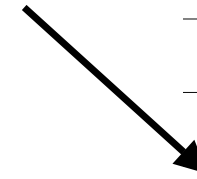


**Priming of the  
shared  
morphological  
root**



**RIGHT**

**Sense  
competition?**

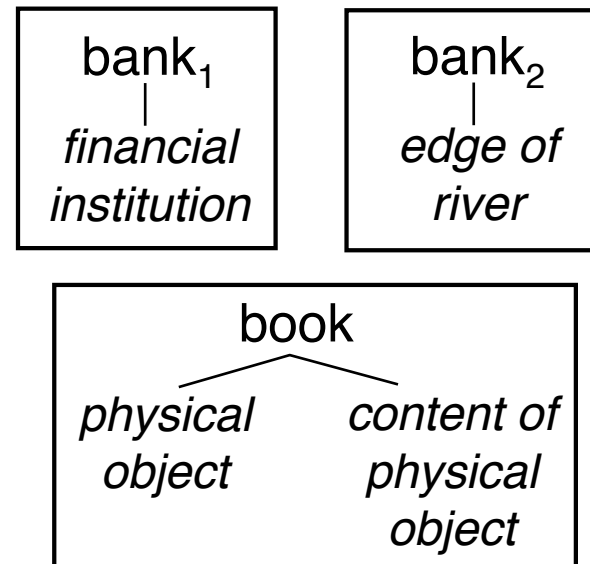


# Results: Summary

---

- Polysemy effects do not reduce to similarity effects.
- Polysemy involves identity.

## Sense representations stored with roots



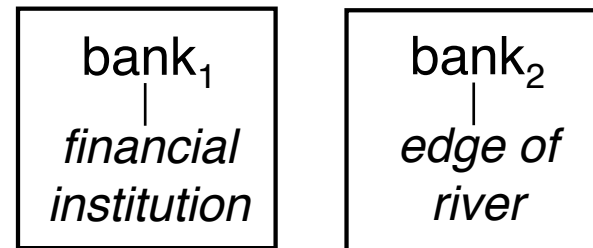
# Results: Summary

---

## Sense representations stored with roots

Homonymy:

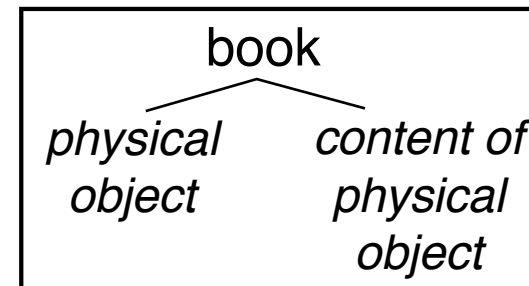
LH M350 delay (lexical competition)



Polysemy:

LH M350 speed-up (root priming)

RH M350 delay (sense competition)



# Polysemy and homonymy

- Elicit similar behavioral responses but *(near)opposite brain responses*.
  - The *combined* temporal and spatial accuracy of MEG allows drawing distinctions that are invisible to coarser measures.

# One sound - many meanings

- Polysemy:
  - Many meanings are represented as part of the *same* root morpheme
- Homonymy:
  - Many meanings, many roots