# Division of Labor
# in the Triangle Model of Visual Word Recognition

Michael W. Harm

CNBC

Carnegie Mellon University

Mark S. Seidenberg

Neuroscience Program

University of Southern California

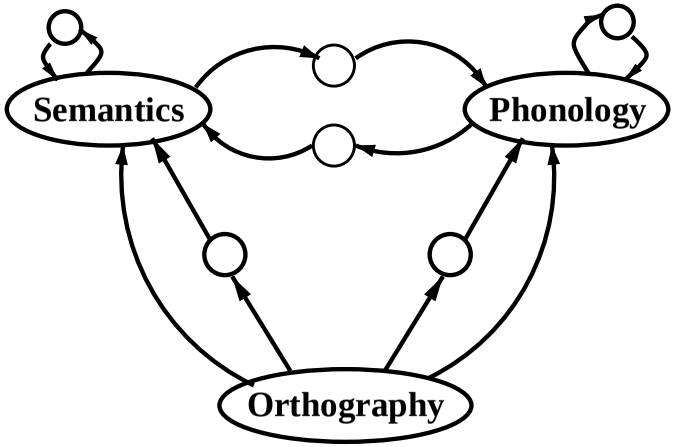
# Core Principles

- Orthography, phonology and semantics are interconnected.
- Semantic and phonological representations are distributed features which are computed (as opposed to accessing stored representations).
- Activation is spread between representations in a smooth and gradual manner.
- Information is *summed* from different sources (as opposed to gating, or a race model).
- The same computational principles apply to all mechanisms of the model (as opposed to rule application versus lexical lookup).
- Hence, differences in the strength of different pathways is a function of experience and item characteristics, not a priori architectural decisions.

# Central Research Questions

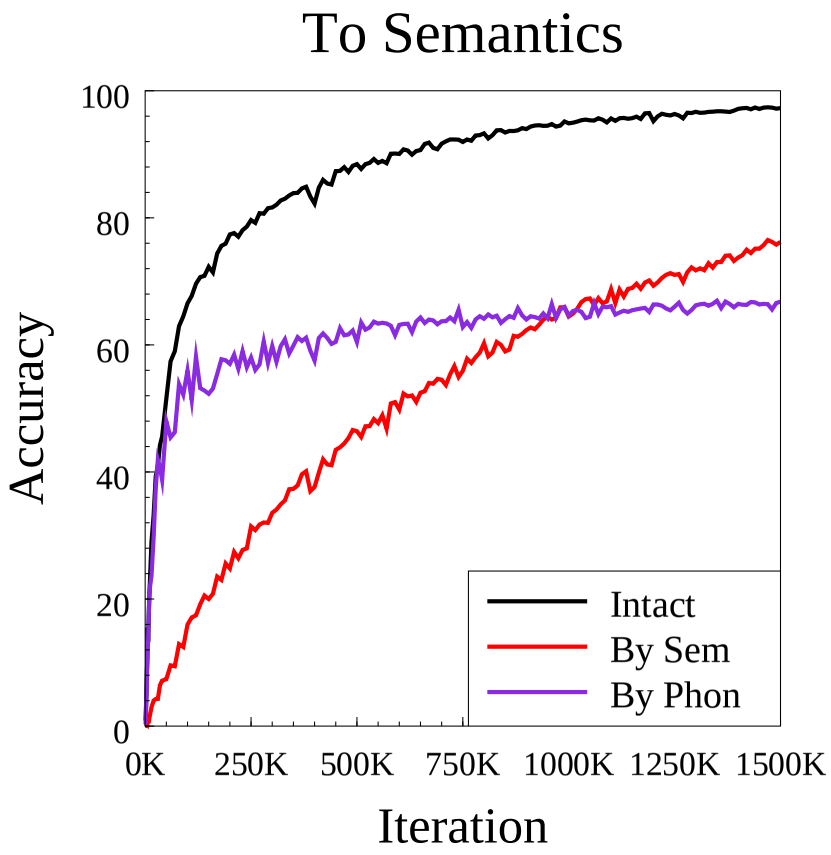
- What is the division of labor (DOL) between direct (orth→sem) and phonologically mediated (orth→phonology→sem) activation of meaning?
- What is the influence of word frequency, regularity, homophony, and network skill level on this DOL?
- How can we account for studies suggesting phonological mediation dominates the DOL?
- What happens when feedback on phonology is dramatically reduced?

# Simulation Overview



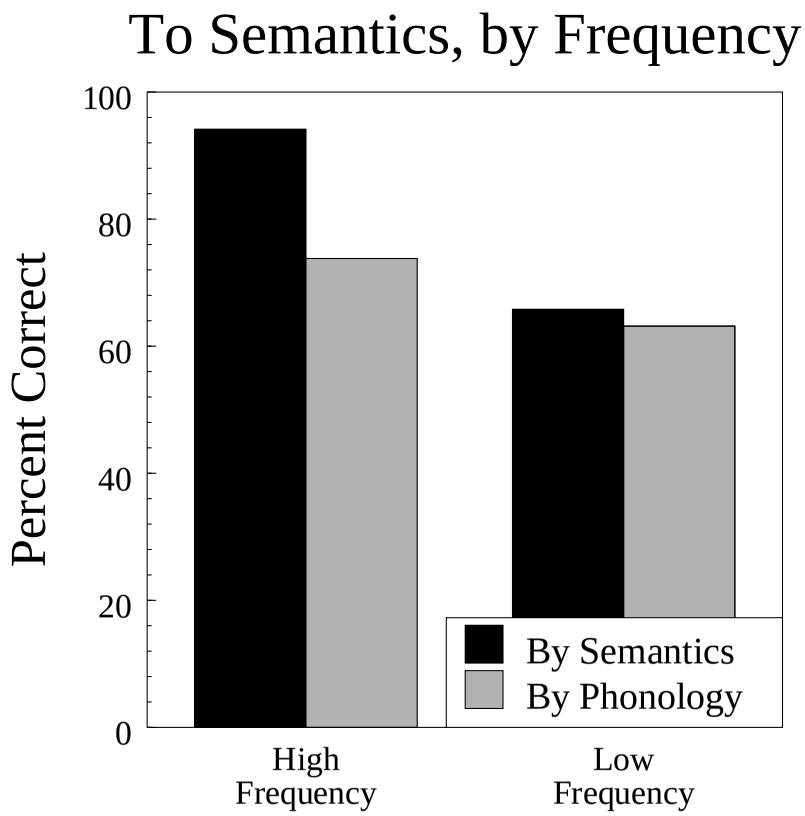

- Implementation of Framework from Seidenberg and McClelland (1989).
- 6,300 Monosyllabic words.
- Continuous-time Learning.
- Distributed Semantics, phonology.
- Phon–Sem pretrained prior to reading.

# Effect of Skill Level



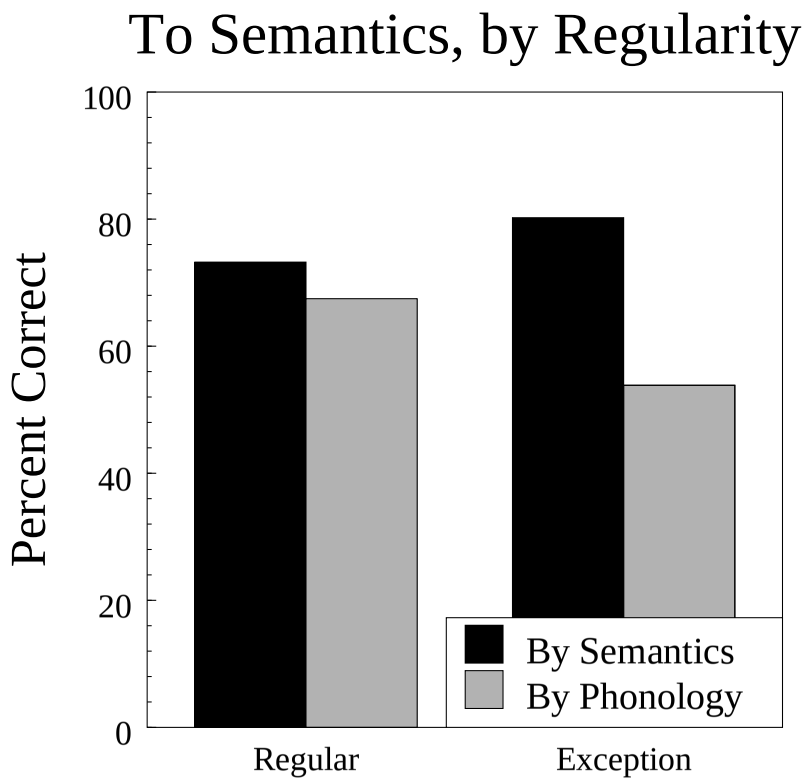

- Initially, DOL is driven by phonological mediation: orth→phonology is much more regular than orth→semantics.
- orth→phonology is limited; it is slower, and homophones are ambiguous.
- Over time, direct orth→sem grows in importance due to speed pressure, error from homophones.

# Effect of Frequency



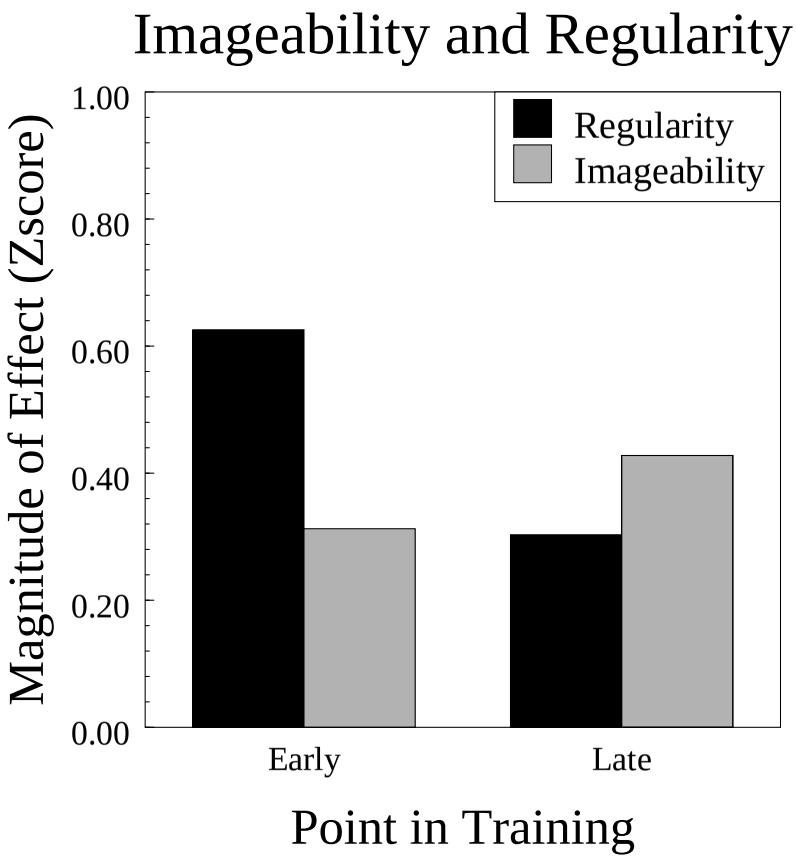

- High frequency items recognized better by orth→sem than orth→phonology→sem.
- Low frequency items show much more equal DOL.

# Effect of Regularity



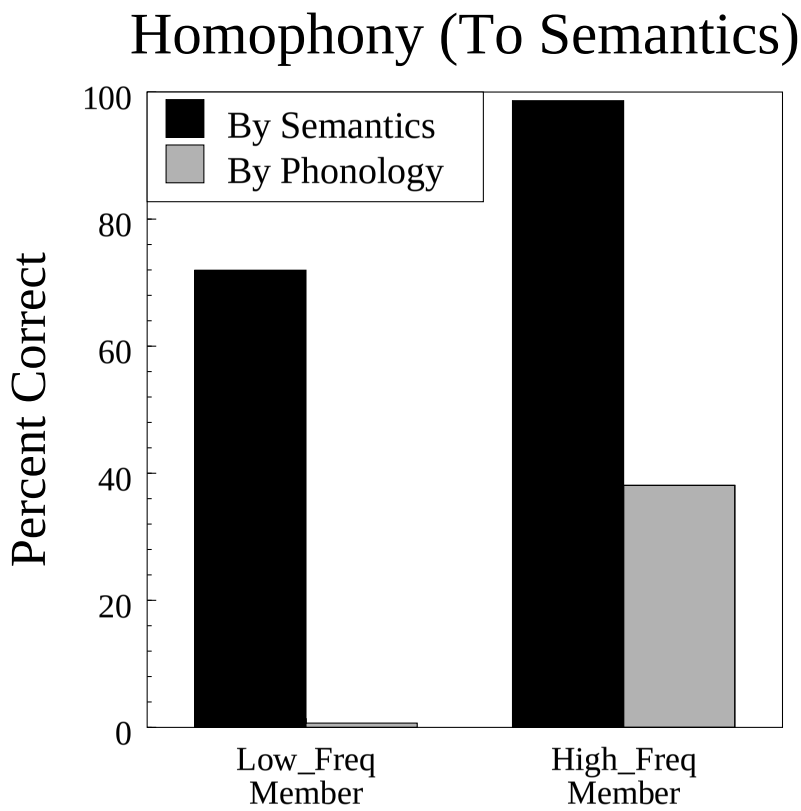

- Exceptions are recognized better by orth→sem than orth→phonology→sem.
- Regular items show more equal DOL.

# Imageability and Regularity




- Measured size of imageability effect and regularity effect, for early point in training (50K presentations) and late (1500K presentations).
  - Regressed out effect of frequency.
  - Computed zscores of model latencies on residuals.
  - Plotted difference in zscore for high and low imageable items, and regular and exception items.
- Over time, relative effect of imageability increases. Relative effect of regularity decreases.

# Effect of Homophony




- Homophone pairs were divided into high frequency member (e.g., *use*) and low frequency member (e.g., *ewes*).
- High frequency members are typically recognizable by phonology→sem.
- Hence, low frequency members of homophone pair must be read by orth→sem.

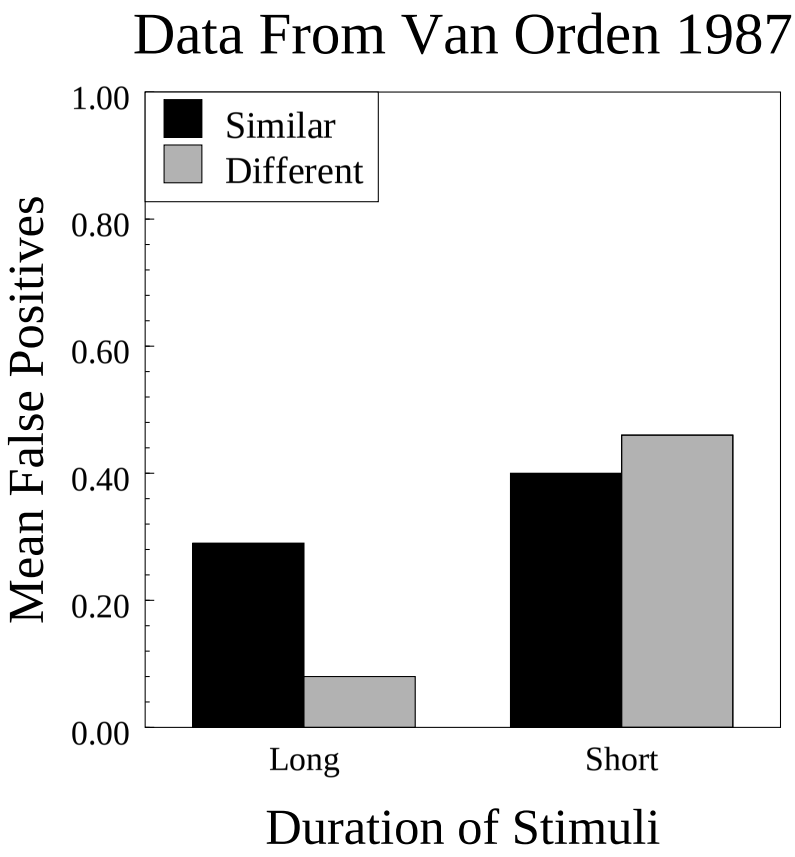
# Summary: Influences on DOL

- HF items rely on orth→sem more than low.
- Exceptions rely on orth→sem more than regulars.
- Homophones rely on orth→sem more than normal words.
- Reliance on orth→sem increases with skill level.
- *But both paths contribute to varying degrees for all items!*

# A Counter View: Phonology is First!

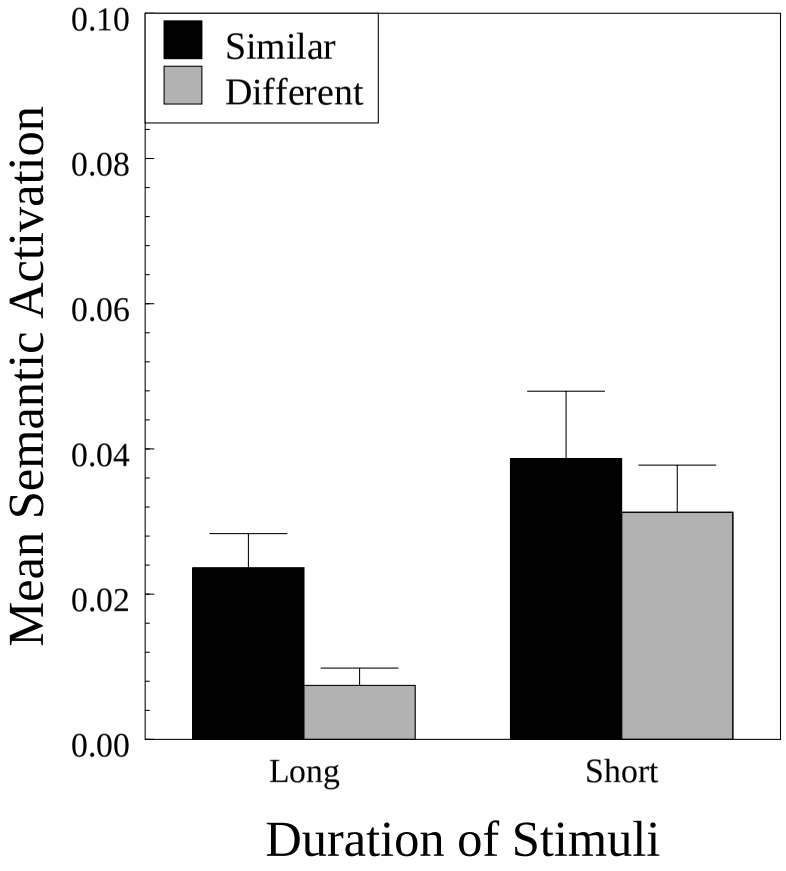
- Briefly presented stimuli have shown strong phonological effects.
  - Homophone and pseudohomophone confusions in semantic categorization (Van Orden, 1987; ?).
  - Homophone foils prime naming of semantically related items (e.g., TOWED primes FROG; Lesch & Pollatsek, 1993; Lukatela & Turvey, 1994).
- Because these effects arise early in processing, with little orthographic effect, it has been argued that phonological access of meaning *preceeds* direct orth$\rightarrow$semantics.

# Evidence From Homophone Confusions




- Van Orden (1987) found false positives on semantic task ("is it an animal?" DOUGH).
- At long presentation, more errors on visually similar distractors (BEACH/BEECH) than dissimilar (NOSE/KNOWS).
- At short presentation, no effect of visual similarity.
- Therefore, it was argued phonological activation of meaning preceeds direct visual disambiguation.

# Can the Model Account for Van Orden 87?

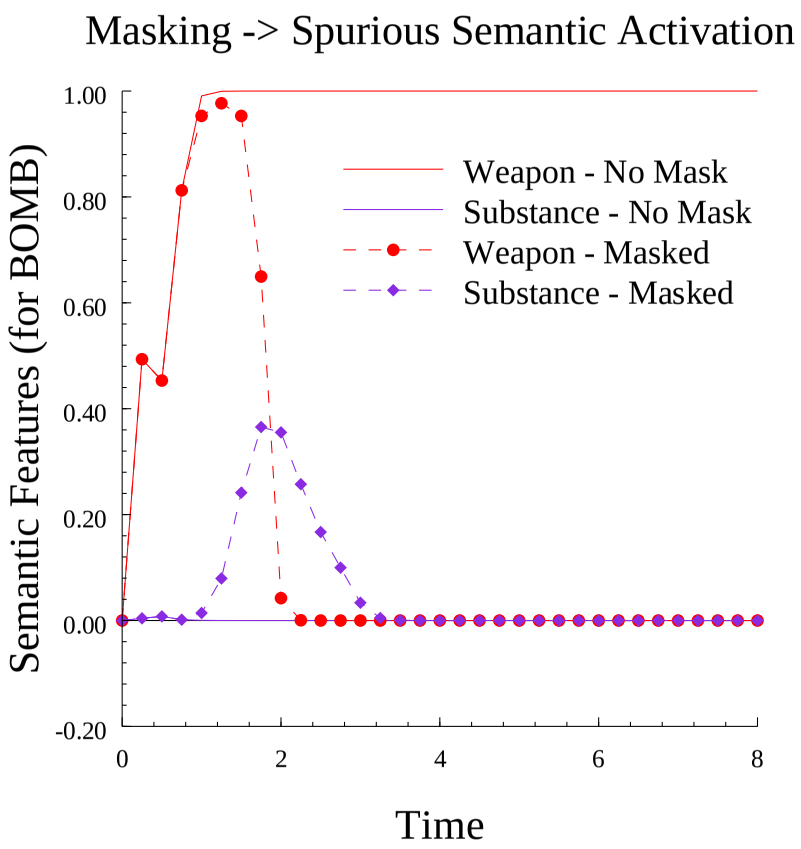



- Yes.
- Presented the model with items from Van Orden (1987) (minus polysyllabic items), at short and long presentation.
- Measured semantic activation for homophonous item (e.g., MEET -> “foodstuff”).
- Found same pattern of results.

# Why?

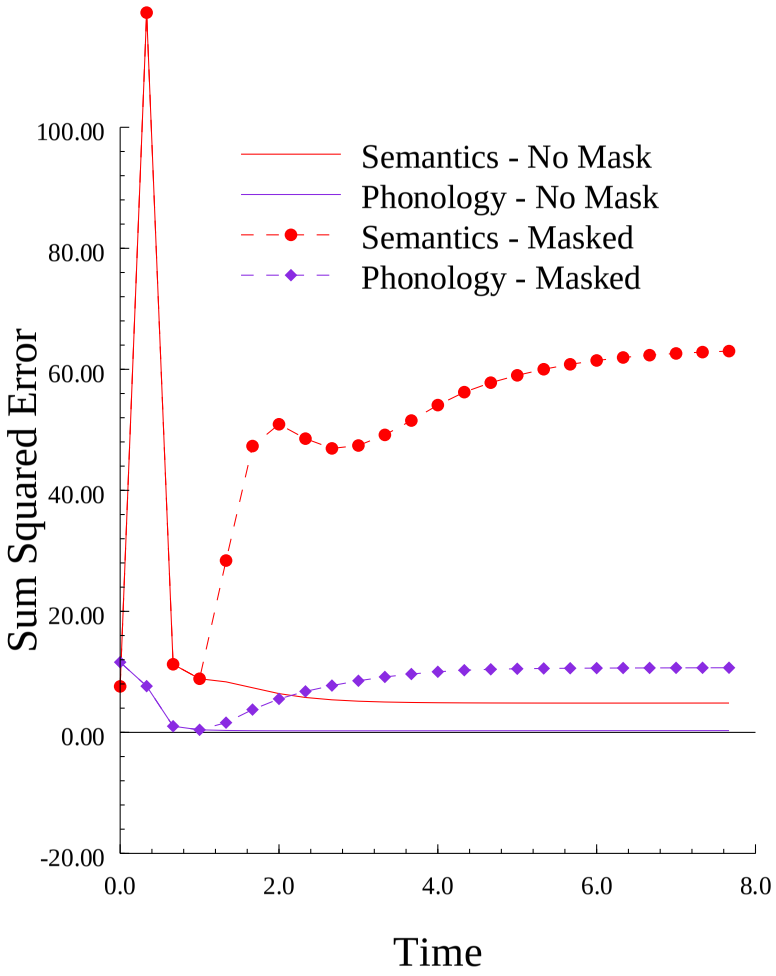
- Phonology is more resilient to orthographic disruption than semantics.
  - Orth$\rightarrow$phon more resonant, intercorrelated.
  - Phonology more internally redundant, dense.
  - Semantics very sparse, less intercorrelations.
- Hence, phonology is better able to perform pattern completion...
- ... and better able to retain activation.

# Bomb / Balm Under Masked Conditions



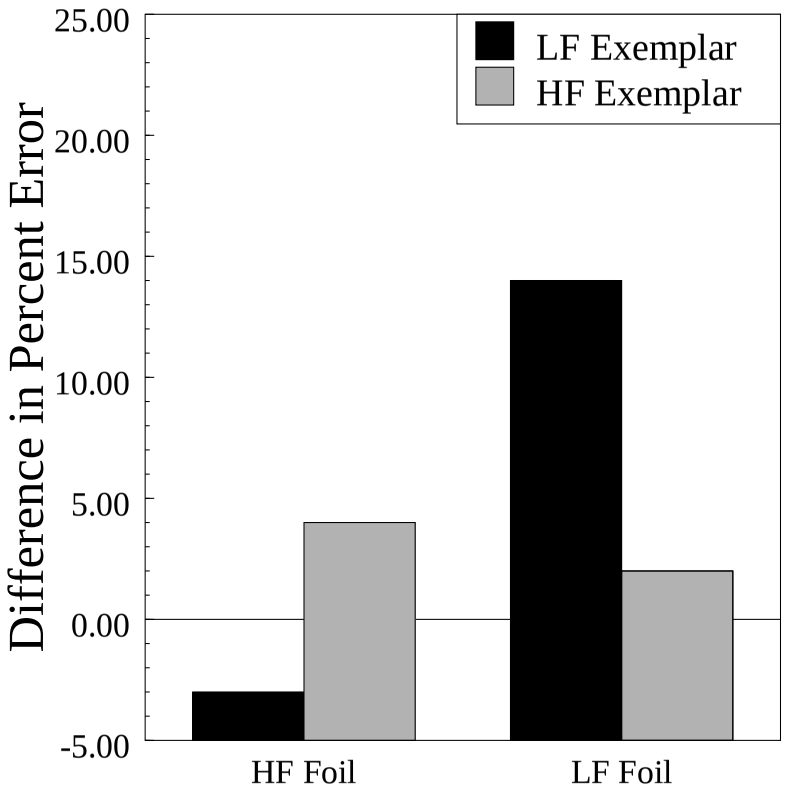

- Network presented with BOMB under normal and masked conditions. Semantic feature for BOMB ("weapon") and homophonous pair BALM ("substance") measured.
- Under normal conditions, no spurious activation of "substance".
- When masked, "substance" receives spurious activation.
- Masking the input yields homophone interference not present in normal processing.

# How General Is That?



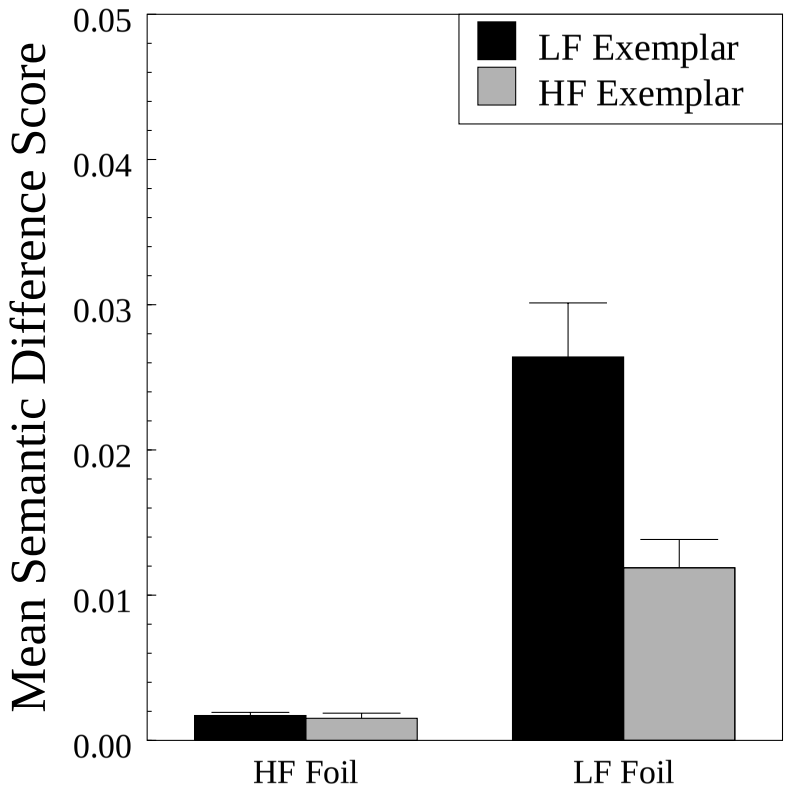

- Sem–phonology connections severed to examine each representation in isolation.
- All 6,000 training items presented to the model, in normal and masked conditions.
- Sum squared error measured over time for phonology and semantics.
- Average error in semantics rises sharply when stimuli masked.
- Phonology much more resilient to effect of masking the input.

# Evidence That It's Not All Phonology




- Jared and Seidenberg (1991) demonstrated phonological effects on semantic categorization, similar to Van Orden (1987).
- However, such effects were generally restricted to items where both the homophone and exemplar were low in frequency.
- Far fewer false positives when either exemplar or foil was high in frequency.

# Can The Model Replicate Jared and Seidenberg (1991)?




- Broadly, yes.
- We used items from Jared and Seidenberg (1991) (minus polysyllabic items) and measured spurious semantic activation for features appropriate to the exemplars.
- Low frequency foils of low frequency exemplars showed greatest false positive rate.

# Why?

- The effect of foil frequency is straightforward: HF foils are quickly recognized by orth→semantics.
- But, the subjects never see the exemplars! So why should *their* frequency matter?
- Answer: if the exemplar is HF, it strongly activates orth→phon→sem. So during learning, the foil's orth→sem must become very strong to counter it! A strong orth→sem will kill the false positives.
- However, if the exemplar is LF, then orth→phon→sem is weak. Partial activation for the foil of orth→sem is enough to counter it. But partial activation is more likely to yield false positives.

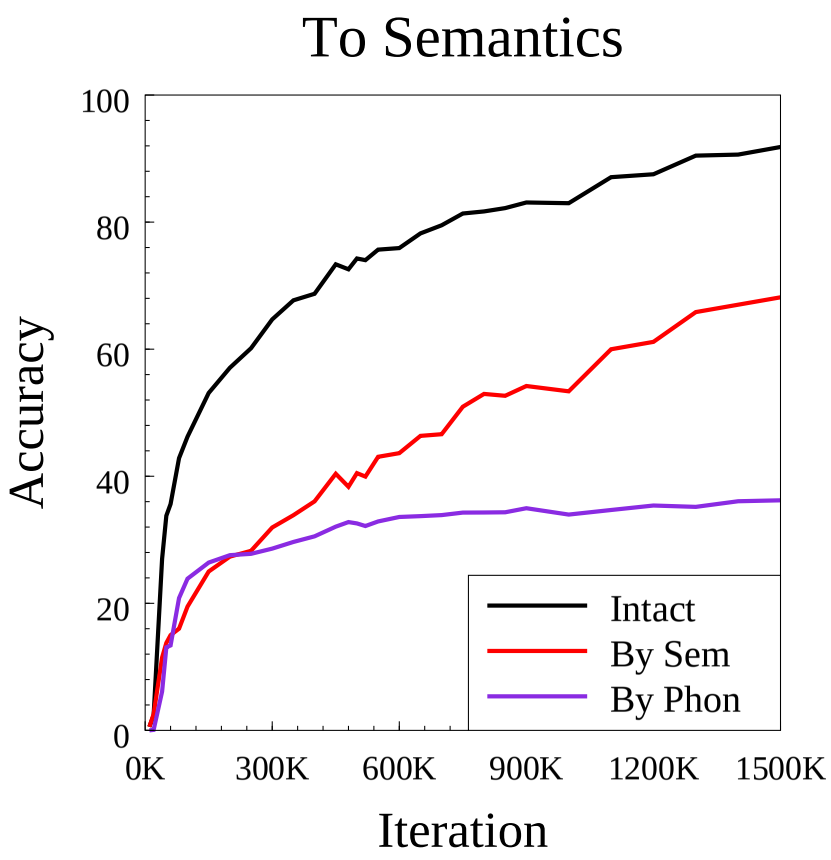
# Summary: It's Not All Phonology!

- Evidence from brief exposure pattern masking studies is questionable:
  - Critically assumes that mask halts processing of both pathways equally.
  - Simulations demonstrate that this assumption may not be warranted.
  - If mask affects semantics more than phonology, then masking will give an illusion of phonological dominance.
- Simulation accounts for masked presentation effects in Van Orden (1987).

# What if Feedback on Phonology is Withheld During Training?

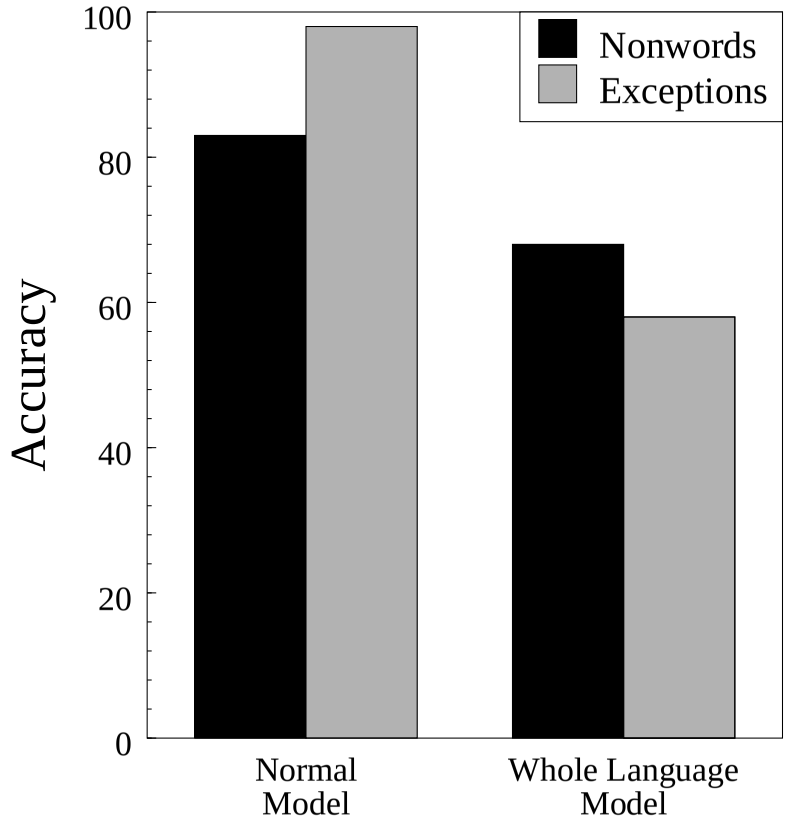
- It has been argued by educational policy theoreticians (e.g., Smith, 1971) that phonological feedback can be debilitating for development.
  - Homophones become ambiguous.
  - Two stage conversion to meaning.
  - There are many words with irregular orth→phon!
- Constructed model to investigate influence of "whole language" reading instruction on DOL.

# Modeling Reduced Feedback on Pronunciation



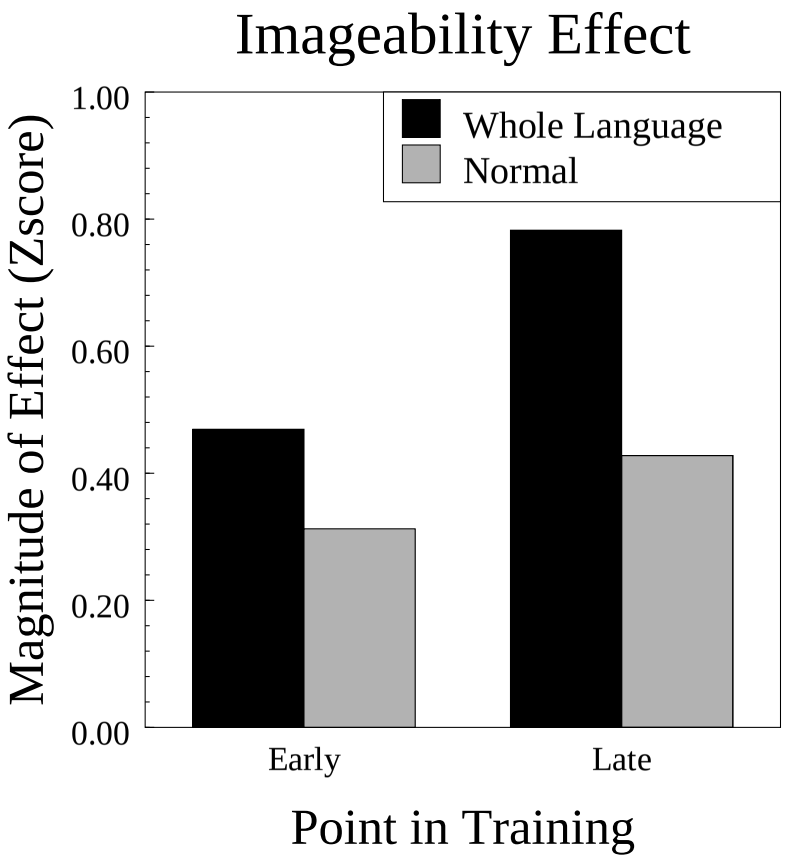

- Same architecture and regime as normal model, except phonological error only produced on 1% of the trials.
- Model does not exhibit huge initial reliance on phonology.
- Much slower acquisition of items.

# Impaired Nonword and Exception Reading in Whole Language Model




- Whole language model shows impaired exception and non-word reading.
- Orth→sem is much more difficult to master than orth→phon; takes many more iterations to reach competent reading.

# Greater Imageability Effect in Whole Language Model




- Like the normal model, imageability effect increases in whole language model.
- Proportional size of effect is greater than in normal model, indicating increased reliance on semantic reading.

# Whole Language Simulation: Summary

- In normal model, pronunciation is an important early source of information that drives learning.
- When this information is withheld, the model acquires items more slowly and generalizes more poorly.
- Such a training regime leads to an increased reliance on semantic reading.

# Conclusions

- The Division of Labor is complicated, with many factors influencing the relative contribution of the two different paths.
- Early claims that phonology is the sole initial, obligatory source of semantic activation in word reading are too strong.
- Counter claims that phonology has no useful role in reading instructions are also too strong.

# References


Jared, D., & Seidenberg, M. S. (1991). Does word identification proceed from spelling to sound to meaning? *Journal of Experimental Psychology: General*, *120*(4), 358-394.

Lesch, M. F., & Pollatsek, A. (1993). Automatic access of semantic information by phonological codes in visual word recognition. *Journal of Experimental Psychology: Learning, Memory and Cognition*, *19*(2), 285-294.

Lukatela, G., & Turvey, M. T. (1994). Visual lexical access is initially phonological: I. Evidence from associative priming by words, homophones, and pseudohomophones. *Journal of Experimental Psychology: General*, *123*(2), 107-128.

Seidenberg, M. S., & McClelland, J. L. (1989). A distributed, developmental model of word recognition and naming. *Psychological Review*, *96*(4), 523-568.

Smith, F. (1971). *Understanding reading.* New York: Holt, Rinehart and Winston.

Van Orden, G. C. (1987). A ROWS is a ROSE: Spelling, sound and reading. *Memory and Cognition*, *15*(3), 181-198.