Division of Labor in the Triangle Model of Visual Word Recognition

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in the Triangle Model of Visual Word Recognition

Division of Labor
Orthography, phonology and semantics are interconnected.

The same computational principles apply to all mechanisms of the model (as opposed to rule application versus lexical lookup).

Information is summed from different sources (as opposed to gating, or race)

Activation is spread between representations in a smooth and gradual manner.

Semantic and phonological representations are distributed features which are interconnected.

Core Principles

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 (orthophonology—sem) activation of meaning?
- What happens when feedback on phonology is dramatically reduced?
- How can we account for studies suggesting phonological mediation dominates the DOL?
- What is the influence of word frequency, regularity, homophony, and network skill level on this DOL?
Simulation Overview

- Initial phon–sem pretrained prior to read.
- Distributed semantics, phonology.
- Continuous-time learning.
- 6,300 monosyllabic words.

Implementation of framework from Seidenberg and McClelland (1989).

- Orthography
- Phonology
- Semantics
Effect of Skill Level

Initially, DOL is driven by phonological mediation: orthophonology is closer. Over time, direct ortho-semantic grows in importance due to error from homophones, and homophone is slower, and homophones are ambiguous. Orthophonology is much more regular than ortho-phonology is limited; it is intact. Initially, DOL is driven by phonological media-
High frequency items recognized better by orth than orth → phonology → sem.

Low frequency items show much more equal DOL.

Effect of Frequency by Semantics, by Phonology

Percent Correct

To Semantics, by Frequency
Effect of Regularity

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

Over time, relative effect of Imageability increases. Relative effect of Regularity decreases. Relative effect of Imageability increases, and Regularity decreases.

Plotted difference in z-score for measured size of Imageability effect and Regularity effect, for early point in training (50K presentations) and late (1500K presentations) for high and low Imageable items, and regular and exception items. Regressed out effect of frequency. Computed z-scores of model for Imageability and Regularity.
Effect of Homophony

Homophone pairs were divided into high frequency and low frequency members. The high frequency member (e.g., use) and low frequency member (e.g., ewes) are typically recognizable by phonology. Hence, low frequency members of homophone pairs must be read by ortho-sem. Homophone pair must be homophone (To Semantics)
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!
ACounter View: Phonology is First!

Meaning proceeds direct ortho-semantically. Because these effects emerge early in processing, with little orthographic effect, it has been argued that phonological access of homophone and pseudohomophone confusions in semantic categorization (Van Orden, 1987; 2).

- Homophone and pseudohomophone confusions in semantic categorization (Van Orden, 1987; 2).
- Homophone foils prime naming of semantically related items (e.g., TOWED primes FROG; LeCroy & Pollatsek, 1993).

Briefly presented stimuli have strong phonological effects.

Becausetheseeffectsariseearlyinprocessing,withlittleorthographiceffect,ithasbeenarguedthatphonologicalaccessof
Van Orden (1987) found false positives on a semantic task ("is it an animal?" DOUGH).

Therefore, it was argued phonologically.

Evidence From Homophone Confusions:

Duration of Stimuli

Mean False Positives

- Long presentation, more errors on visually similar distractors (BEACH/BEECH) than dissimilar.
- At short presentation, no effect of visual similarity.
- Therefore, it was argued phonologically.
- Similar similarity.

Data From Van Orden (1987)
Can the Model Account for Van Orden 87?

- Found same pattern of results.
- Presented the model with items from Van Orden (1987) and measured semantic activation in the long and short presentation for homophone items (e.g., MEET -> foodstuff).
- Measured semantic activation for homophone item (e.g., MEET -> foodstuff).

<table>
<thead>
<tr>
<th>Duration of Stimuli</th>
<th>Mean Semantic Activation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short</td>
<td>0.02</td>
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<tr>
<td>Long</td>
<td>0.08</td>
</tr>
</tbody>
</table>

Presented items from Van Orden (1987) minus polysyllabic items.
Why?

Phonology is more resilient to orthographic disruption than semantics.

- Orthography is less intercorrelated.
- Phonology is more internally redundant, resonant.
- Semantics is very sparse, less intercorrelated.
- Hence, phonology is better able to perform pattern completion... and better able to retain activation.
Bomb / Balm Under Masked Conditions

- Process bias.
- Interference not present in normal.
- Masking the input yields homophone.
  - Spurious activation.
  - When masked, "substance" receives.
  - When masked, "weapon".
  - Network presented with BOMB.

Semantic Features (for BOMB)

Masking - Spurious Semantic Activation

Network presented with BOMB.

- Substance - Masked
- Substance - No Mask
- Weapon - Masked
- Weapon - No Mask

Under normal conditions, no spurious.

When masked, "substance" received.

BALM ("substance") and homophonous pair.

Network presented with BOMB.
### Phonology - Masked vs. Semantics - Masked

- Average error in semantics rises sharply when stimuli masked.
- Phonology much more resilient to effect of masking the input.

### Phonology - No Mask vs. Semantics - No Mask

- Sum squared error measured over conditions.
- Average error in semantics rises sharply when stimuli masked.
- Phonology much more resilient to effect of masking the input.

**How General Is That?**
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. The error rate was higher in the foil condition than in the exemplar condition. 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 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.

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Broadly, yes.
The effect of foil frequency is straightforward: HF foils are quickly recognized by ortho—semantics. But partial activation for the foil of ortho—sem is enough to counter it. However, if the exemplar is LF, then ortho—phon—sem is weak. Partial activation for the foil of ortho—sem will kill the false positives. As a strong ortho—sem will kill the foil, the foil must become very strong to counter it. So during learning, the foil’s ortho—sem must become very strong to counter it. A strong ortho—sem will kill the foil. So why should their frequency matter? But, the subjects never see the exemplars! So why should their recognized by ortho—semantics.

Why?
Evidence from brief exposure pattern masking studies is questionable:

- Critically assumes that mask halves 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.


Summary: It’s Not All Phonology.
What if feedback on phonology is withheld during training?

It has been argued by educational policy theorists (e.g., Smith, 1971) that phonological feedback can be debilitating for development. There are many words with irregular ortho-phon!

Homophones become ambiguous.

Two-stage conversion to meaning.

Homophones become ambiguous.
Modeling Reduced Feedback on Pronunciation

- Much slower acquisition of items.
- Much reduced reliance on phonology.
- Much slower acquisition.
- Much lower reliance on phonology.
- Model does not exhibit huge phonological error once phonological error is produced on 1% of the trials.
- Same architecture and regime except for reduced feedback.

To Semantics

By Phon

By Sem

Intact
Whole language model shows impaired exception and nonword reading. Orthosem is much more difficult to master than orthophon; takes many more iterations to reach competent reading.

Whole language model shows impaired exception and nonword reading.
<table>
<thead>
<tr>
<th>Point in Training</th>
<th>0.00</th>
<th>0.20</th>
<th>0.40</th>
<th>0.60</th>
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<td>Early</td>
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Like the normal model, imageability effect increases in the whole language model, indicating increased reliance on semantic reading. The proportional size of effect is greater than in the normal model, suggesting increased reliance on semantic reading.
In normal models, 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.

In normal models, pronunciation is an important early source of information that drives learning.
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.

The Division of Labor is complicated, with many factors...