Decomposition

magnet

magnetism

magnetic

magnetize

magnificent

No decomposition

magnetize

magnolia

magnetic

magnet

magnetism

magnificent

Etc…
Same vs. similar

TEACHER vs. TEACH

BROTHEL vs. BROTH

SORCERY vs. MAGIC
Morphological decomposition

- TEACH ER vs. TEACH
- BROTHEL vs. BROTH
- SORCERY vs. MAGIC
Alternative(?): “emergent morphology”

- Morphology is similarity at the extreme.
- Effects of morphology should reduce to combined effects of semantic and phonological/formal similarity.  
  
  (Seidenberg and Gonnerman, 2000)

![Diagram](image)

Figure 1. A connectionist framework for lexical processing. The large arrows depict inputs and outputs of the system.

Gonnerman and Plaut (2000)
To test the theories:

• What are the effects of phonological and semantic similarity?

• Do effects of morphology reduce to combined effects of semantic and phonological similarity?
Morphology and the internal structure of words

Joseph T. Devlin†‡, Helen L. Jamison†, Paul M. Matthews†, and Laura M. Gonnerman§

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![Diagram](image)

<table>
<thead>
<tr>
<th>Condition</th>
<th>Relation</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Unrelated</td>
<td>[-orth, -sem]</td>
<td>award-MUNCH</td>
</tr>
<tr>
<td>2. Orthographic</td>
<td>[+orth, -sem]</td>
<td>passive-PASS</td>
</tr>
<tr>
<td>3. Semantic</td>
<td>[-orth, +sem]</td>
<td>sofa-COUCH</td>
</tr>
<tr>
<td>4. Morphological</td>
<td>[+orth, +sem]</td>
<td>hunter-HUNT</td>
</tr>
<tr>
<td>5. Pseudoword</td>
<td></td>
<td>casino-HODER</td>
</tr>
<tr>
<td>6. Consonants</td>
<td></td>
<td>lather-FRLNK</td>
</tr>
</tbody>
</table>
Form priming (passive - PASS)

Semantic priming (sofa - COUCH)

Morphological priming (hunter - HUNT)
• In masked priming

1. Transparent
   CLEANER - clean: PRIMING

2. Pseudoaffixed
   CORNER - corn: PRIMING

3. Form
   BROTHEL - broth: NO PRIMING

➢ Fast morphological parsing of orthographical forms.
Semantic, phonological and morphological priming in MEG
Crossmodal priming (materials adapted from Gonnerman (1999))

- **SOA:** Duration of prime
- **Task:** Lexical decision
- **21 subjects**

<table>
<thead>
<tr>
<th></th>
<th>Auditory prime</th>
<th>Visual target</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Phonological</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(onset-matching)</td>
<td>spinach</td>
<td>spin</td>
</tr>
<tr>
<td><strong>Phonological</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(non-onset-matching)</td>
<td>teacher</td>
<td>reach</td>
</tr>
<tr>
<td><strong>Semantic</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(synonyms)</td>
<td>idea</td>
<td>notion</td>
</tr>
<tr>
<td><strong>Morphological</strong></td>
<td>teacher</td>
<td>teach</td>
</tr>
</tbody>
</table>
Phonological similarity: behavioral inhibition

• In longer SOA priming words tend to be harder to recognize when they are preceded by similar sounding words (e.g. Soto-Faraco, Sebastián-Gallés & Cutler, 2001)

  slower when preceded by
  SPINACH
  SPIN
  than when preceded by
  MUFFLER
Phonological similarity: behavioral inhibition

Because SPIN is one of the representations that must be inhibited from recognition when we’re processing SPINACH?

slower when preceded by SPINACH
Inhibited activation

![Diagram showing the process of inhibited activation with time on the x-axis, activation level on the y-axis, and various labels such as SPIN, SPINACH, SUPPRESSION, INHIBITED ACTIVATION, and DELAYED REACTION TIME. The diagram includes arrows indicating the PRIME and TARGET stages.]
Alternative: Inhibited recognition

**Diagram Description:**
- **Activation Level** is plotted on the vertical axis, with **Time** on the horizontal axis.
- Two curves represent **SPINACH** and **SPIN**.
- **Prime** is indicated by a vertical arrow from the prime to the curve.
- **Target** is indicated by a vertical arrow from the target to the curve.
- **Competition** and **Inhibited Recognition** are shown with arrows pointing downwards.
- **Delayed Reaction Time** is indicated with a hand icon.
Mechanisms of recognition

• **Inhibited activation:**
  – Mismatching candidates are suppressed below their resting level

• **Inhibited recognition:**
  – Mismatching candidates are rejected simply because they receive *less excitation* from the input

• **BUT:** make similar behavioral predictions
Timing of activation

INHIBITED ACTIVATION

INHIBITED RECOGNITION

activation level

activation level

activation
M350: a tool for investigating inhibitory mechanisms

INHIBITED ACTIVATION

activation level

time

spinach

spin

SPIN

activation

activation level

time

spinach

spin

SPIN

activation

SPIN

SPIN

SPIN

SPIN
Materials

- Two types of phonological similarity (embedded in a larger experiment):

  1. **ONSET-MATCHING**
     - **AUDITORY PRIME**: spinach
     - **VISUAL TARGET**: SPIN
     - **AUDITORY PRIME**: muffler
     - **VISUAL TARGET**: SPIN

  2. **NON-ONSET-MATCHING**
     - **AUDITORY PRIME**: teacher
     - **VISUAL TARGET**: REACH
     - **AUDITORY PRIME**: ocean
     - **VISUAL TARGET**: REACH

Similarity-induced inhibition in RT
Materials

- Two types of phonological similarity (embedded in a larger experiment):

  1. ONSET-MATCHING
     - **AUDITORY PRIME**
       - spinach
       - muffler
     - **VISUAL TARGET**
       - SPIN

  2. NON-ONSET-MATCHING
     - **AUDITORY PRIME**
       - teacher
       - ocean
     - **VISUAL TARGET**
       - REACH

- Would the M350 show inhibition or priming?
- If inhibition, activation is inhibited.
- If priming, RT inhibition originates in competition.
Materials

- Two types of phonological similarity (embedded in a larger experiment):

1. **ONSET-MATCHING**
   - **AUDITORY PRIME**: spin a ch
   - **VISUAL TARGET**: SPIN

2. **NON-ONSET-MATCHING**
   - **AUDITORY PRIME**: m u f f l e r
   - **VISUAL TARGET**: SPIN

Would the 2 types of targets pattern the same with respect to M350 priming?
Results

n=21

(Pylkkänen, Stringfellow & Marantz, submitted)
Results

n=21

(Pylkkänen, Stringfellow & Marantz, submitted)
Results

n=21

- RT
- M350-latency
- M350-amplitude

(Pylkkänen, Stringfellow & Marantz, submitted)
Results

n=21

- RT  □ M350-latency ■ M350-amplitude

![Graph showing priming measures for spinach-spin and teacher-reach](image)

Onset-matching

- spinach-spin
  - Time = 332 [msec]

- muffer-spin
  - Time = 316 [msec]

Non-onset-matching

- teacher-reach
  - Time = 332 [msec]

- ocean-reach
  - Time = 350 [msec]

(Pylkkänen, Stringfellow & Marantz, submitted)

(Pylkkänen, Stringfellow & Marantz, submitted)
Results

n=21

Onset-matching

Non-onset-matching

(Pylkkänen, Stringfellow & Marantz, submitted)
Same behavior but different neurophysiological effects

(Pylkkänen, Stringfellow & Marantz, submitted)
Same behavior but different neurophysiological effects

→ Not all competitors are treated the same
→ Some undergo complete deactivation

(Pylkkänen, Stringfellow & Marantz, submitted)
Semantic similarity

- Behaviorally facilitory
  NURSE primes DOCTOR

- Would the M350 show semantic priming?
Results

- **M350 = First component affected by semantic relatedness**

(Pylkkänen, Stringfellow, Gonnerman, Marantz, in prep.)
Phonological and semantic relatedness affect the same component, the M350

Consistent with recent ERP results showing that phonological and semantic relatedness affect the same ERP component, the N400 (Radeau et al. 1998)
So far:

- Onset matching phonological similarity and semantic similarity have opposite effects:

**Spinach – Spin**
Inhibition in M350 and RT.

**Ideal – Notion**
Priming in M350 and RT.
What about TEACHER-TEACH?

Decomposition view:
- Relationship is one of identity.
  - TEACHER contains TEACH

Morphemes are emergent (e.g. Seidenberg and Gonnerman 2000):
- Relationship is one of similarity.
  - TEACHER and TEACH are only semantically and phonologically similar
What about TEACHER-TEACH?

Decomposition view:
- Relationship is one of identity.
  - M350 & RT should show repetition priming

Morphemes are emergent (e.g. Seidenberg and Gonnerman 2000):
- Relationship is one of similarity.
  - M350 & RT should show added effects of phonological and semantic similarity
Materials (crossmodal)
(part of previous experiment)

<table>
<thead>
<tr>
<th>RELATED</th>
<th>AUDITORY PRIME</th>
<th>VISUAL TARGET</th>
</tr>
</thead>
<tbody>
<tr>
<td>teacher</td>
<td>teach</td>
<td></td>
</tr>
<tr>
<td>UNRELATED</td>
<td>ocean</td>
<td>teach</td>
</tr>
</tbody>
</table>
Results

Repetition priming
(Pylkkänen et al 2000)

spinach-spin  idea-notion

dog-dog
Results: like repetition priming, not additive similarity effects
What about TEACHER-TEACH?

Decomposition view:

• Relationship is one of identity.
  ➢ M350 & RT should show repetition priming

Morphemes are emergent (e.g. Seidenberg and Gonnerman 2000):

• Relationship is one of similarity.
  ➢ M350 & RT should show added effects of phonological and semantic similarity
Possible objection:

- Phonological similarity is only inhibitory in the absence of semantic similarity.
- Prediction: *ritzy* – *glitzy* should prime very much like morphologically related pairs.
Behavioral data from Gonnerman (1999)

<table>
<thead>
<tr>
<th>EXPERIMENT 1</th>
<th>Prime-target example</th>
<th>Priming</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Low sem, no morph:</td>
<td>spinach-spin</td>
<td>-19</td>
</tr>
<tr>
<td>2. Low sem:</td>
<td>corner-corn</td>
<td>-24</td>
</tr>
<tr>
<td>3. Mid sem:</td>
<td>dresser-dress</td>
<td>19*</td>
</tr>
<tr>
<td>4. High sem:</td>
<td>teacher-teach</td>
<td>40*</td>
</tr>
<tr>
<td>5. Hi sem, no phon:</td>
<td>idea-notion</td>
<td>13*</td>
</tr>
</tbody>
</table>

**EXPERIMENT 4**

<table>
<thead>
<tr>
<th>Psychology undergrads</th>
<th>Prime-target example</th>
<th>Priming</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. High sem &amp; phon:</td>
<td>ritz-y - glitz-y</td>
<td>-16</td>
</tr>
<tr>
<td>2. mid sem &amp; phon:</td>
<td>dismal-dismay</td>
<td>-12</td>
</tr>
<tr>
<td>3. low sem &amp; phon:</td>
<td>rankle-rank</td>
<td>12</td>
</tr>
<tr>
<td>4. High sem, no phon:</td>
<td>idea - notion</td>
<td>21*</td>
</tr>
<tr>
<td>5. Hi sem, no phon:</td>
<td>pumpkin-pump</td>
<td>-19</td>
</tr>
</tbody>
</table>

(Gonnerman, 1999, PhD thesis, USC)
Behavioral data from Gonnerman (1999)

<table>
<thead>
<tr>
<th>EXPERIMENT 1</th>
<th>Prime-target example</th>
<th>Priming</th>
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</thead>
<tbody>
<tr>
<td>1. Low sem, no morph:</td>
<td>spinach-spin</td>
<td>-19</td>
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<tr>
<td>2. Low sem:</td>
<td>corner-corn</td>
<td>-24</td>
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<tr>
<td>3. Mid sem:</td>
<td>dresser-dress</td>
<td>19*</td>
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<td>4. High sem:</td>
<td>teacher-teach</td>
<td>40*</td>
</tr>
<tr>
<td>5. Hi sem, no phon:</td>
<td>idea-notion</td>
<td>13*</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>EXPERIMENT 4</th>
<th>Prime-target example</th>
<th>Priming</th>
</tr>
</thead>
<tbody>
<tr>
<td>Honors students</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. High sem &amp; phon:</td>
<td>ritz - glitzy</td>
<td>24*</td>
</tr>
<tr>
<td>2. mid sem &amp; phon:</td>
<td>dismal-dismay</td>
<td>-5</td>
</tr>
<tr>
<td>3. low sem &amp; phon:</td>
<td>rankle-rank</td>
<td>19</td>
</tr>
<tr>
<td>4. High sem, no phon:</td>
<td>sorcery-magic</td>
<td>54*</td>
</tr>
<tr>
<td>5. Hi sem, no phon:</td>
<td>pumpkin-pump</td>
<td>-39*</td>
</tr>
</tbody>
</table>

(Morphological priming exceeds semantic priming)

(Gonnerman, 1999, PhD thesis, USC)
Brief article

Neural correlates of the effects of morphological family frequency and family size: an MEG study

Liina Pylkkänen\textsuperscript{a,*}, Sophie Feintuch\textsuperscript{b,c}, Emily Hopkins\textsuperscript{b,c}, Alec Marantz\textsuperscript{b}

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\textsuperscript{b}Department of Linguistics and Philosophy, KIT/MIT MEG Laboratory, Massachusetts Institute of Technology, Cambridge, MA 02139, USA
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Received 6 February 2003; revised 2 July 2003; accepted 19 September 2003
Cumulative root frequency effects

• High frequency words are processed faster than low frequency words.

• Decomposition predicts:
  – The frequencies of the derivational variants of a root should add to the frequency of the root.
Cumulative morpheme frequency

Decomposition

\[ \text{magnet} \]

\[ \text{magnet} \quad \text{ism} \]

\[ \text{magnet} \quad \text{ic} \]

\[ \text{magnet} \quad \text{ize} \]
Cumulative morpheme frequency

Decomposition

magnet

magnet ism

magnet ic

magnet ize
Cumulative morpheme frequency

Decomposition

magnet

magnet ism

magnet ic

magnet ize
Cumulative morpheme frequency

Decomposition

magnet

magnet ism

magnet ic

magnet ize
Cumulative morpheme frequency

Decomposition

- magnet
  - magnet ism
  - magnet ic
  - magnet ize

No decomposition

- magnetize
- magnolia
- magnetic
- magnet
- magnetism
- magnificent
- Etc...
Cumulative morpheme frequency

Decomposition

- magnet
  - magnetism
  - magnetic
  - magnetize

No decomposition

- magnetize
- magnolia
- magnetic
- magnet
- magnetism
- magnificent

Etc…
Cumulative morpheme frequency

Decomposition

- magnet
  - magnet ism
  - magnet ic
  - magnet ize

No decomposition

- magnetize
  - magnetic
  - magnetism
  - magnificent
  - magnolia

Etc…
Behaviorally:

- The frequencies of the morphological derivatives of a noun do not affect lexical decision times (Schreuder & Baayen, 1997).

  ➢ No morphological decomposition?
Possibility:

- An early effect of high cumulative frequency might not be observable in behavioral reaction times because of a counteracting factor, such as competition between highly frequent morphological family members.
Hypothesis

- High morphological family frequency is associated with:

  - M350
    - speed-up due to cumulative root frequency
  - later
    - slow-down due to competition from highly frequent family members

= null behavioral effect
Materials:
2 categories of singular nouns

High frequency derivatives

- ist –ize –ism

Same number of derivates

terror

Low frequency derivatives

- ic –ize –ism

magnet

Matched for surface frequency

- Task: Lexical decision
- 15 subjects
Simultaneous manipulation of cumulative morpheme frequency and phonotactic probability

- Six categories of 70 stimuli:

<table>
<thead>
<tr>
<th></th>
<th>High cumulative morpheme frequency</th>
<th>Low cumulative morpheme frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Word</td>
<td>DANGER</td>
<td>COTTON</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>High probability</th>
<th>Low probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Word</td>
<td>BELL, LINE</td>
<td>PAGE, DISH</td>
</tr>
<tr>
<td>Nonword</td>
<td>MIDE, PAKE</td>
<td>JIZE, YUSH</td>
</tr>
</tbody>
</table>
MEG recording and source modeling

- 146 channel magnetometer (BTi)
- Multi-dipole modeling
  - The averaged response to all words is used in source modeling. This solution is kept constant across conditions.
    1. Localization of activity time window by time window.
    2. All sources are introduced into a multi-dipole model.
Example
Visual M100 (bilateral)
M170, bilateral
“M250” (three dipoles)
Late activity: “M420”
Multidipole model
All sources (15 subjects)

Visual M100  M170  M250  M350  “M420”
All sources (15 subjects)

source of auditory M100
Behavioral data, cumulative frequency
M350 data, cumulative frequency

Single subject

M350 Latency (n=15)
M350 data, cumulative frequency

Single subject

M350 Amplitude (n=15)
M350 data, cumulative frequency

- Inhibition, not facilitation, at the M350.

- Morphological competition occurs at the M350?

M350 Amplitude (n=15)

*
M350 data, cumulative frequency

- Inhibition, not facilitation, at the M350.

- Morphological competition occurs at the M350?

- Competition between morphological relatives precedes competition between phonological relatives?

(Pylkkänen, Stringfellow, Marantz, *Brain and Language*, 2002)
Phonotactic probability results (n=15)

<table>
<thead>
<tr>
<th>RT and M350 Latency</th>
<th>M350 Amplitude</th>
</tr>
</thead>
</table>

* *
Cumulative frequency summary

• Contra to our predictions:
  – High cumulative morpheme frequency has an inhibitory effect on the M350.
  – Competition between morphological relatives (magnet and magnetism) precedes competition between phonological neighbors (line and lime).
  – Why? Is this consistent with decomposition?
Early decomposition (Taft 1979)

• Decomposition is obligatory and early.
  – Recognition of grammatical morphemes precedes recognition of morphological roots.

The boys picked up the blender from the supplier
Early decomposition

- Early morphological parsing/segmentation
  - Morphological competition effects
- Lexical access
  - Phonological competition effects
Challenge for the ‘no decomposition’ hypothesis

- Why should competition between morphological relatives (magnet and magnetism) precede competition between phonological neighbors (line and lime) if magnet and magnetism stand in a qualitatively similar relation to each other as line and lime?
Conclusion

- Effects of morphology ≠
  Combined effects of phonological and semantic similarity
- Even though morphological relatives involve identity, they compete. However, the time course of this competition differs from purely similarity-based competition in a way that behavioral measurements do not show.