Computational models for the semantic bleaching of English intensifiers

Yiwei Luo  Dan Jurafsky  Beth Levin

{yiweil, jurafsky, bclevin}@stanford.edu
Department of Linguistics, Stanford University

First International Workshop on Computational Approaches to Historical Language Change, August 2, 2019
# The Phenomenon

<table>
<thead>
<tr>
<th>Manner meaning</th>
<th>Intensifier meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>wildly muttering</td>
<td>That recipe is <strong>wildly easy</strong>!</td>
</tr>
<tr>
<td>stupidly drunk</td>
<td>It’s <strong>stupidly sunny</strong> here in Florence.</td>
</tr>
<tr>
<td>terribly written</td>
<td>I’m not <strong>terribly interested</strong> in spending my money.</td>
</tr>
</tbody>
</table>
The Phenomenon

Basic meaning

De-adjectival adv = adj + -ly
‘in an adj manner’

Bleached meaning

Intensifying adv (intensifier)
‘very/really’

{ wild + -ly
    stupid+ -ly
    terrible+ -ly
}
What is bleaching?

- Bleaching is a process in which a word (or morpheme) loses certain semantic features while retaining others (Sweetser, 1989; Heine, 1991)

- Ex: Latin *ad* + *ripam* ‘to shore’
  > Vulgar Latin *arripare* ‘to come to shore’
  > Old French *ariver* ‘to come to land’
  > English *arrive* ‘to come to’
What is bleaching?

- Bleached terms have a wider range of collocates (Lorenz, 2002; Hopper and Traugott, 2003)
- Ex: adjectives modified by *terribly* in 1850 vs. 1990

<table>
<thead>
<tr>
<th></th>
<th>1850</th>
<th>1990</th>
</tr>
</thead>
<tbody>
<tr>
<td>terribly</td>
<td>deformed, diseased, broken, fatal, ...</td>
<td>deformed, diseased, broken, fatal, <strong>relieved</strong>, <strong>important</strong>, <strong>goodlooking</strong>, generous, ...</td>
</tr>
<tr>
<td></td>
<td>negative adjs only</td>
<td>negative <em>and</em> positive adjs</td>
</tr>
</tbody>
</table>

Bleached terms have a wider range of collocates (Lorenz, 2002; Hopper and Traugott, 2003). An example is adjectives modified by *terribly* in 1850 vs. 1990. In 1850, terms are mostly negative adjectives, while in 1990, terms include both negative and positive adjectives.
How does bleaching happen?

- Bleaching is the result of reanalysis, defined as a language user’s mapping of a form to a new meaning based on widening collocations (Bybee et al., 1994)
Some open questions

**Part I: Creating computational methods to operationalize the bleaching process**

- How similar in meaning are *terribly, stupidly, wildly*, etc. to a prototypical intensifier (e.g., *very*)?
- How much of their original meanings do they retain?
- How much have they grown in productivity?

**Part II: Using these methods to test a theory of reanalysis**

- What triggers the reanalysis of de-adjectival adverbs into intensifiers?
Part I

Methods for operationalizing bleaching

Verification of methods

Applying methods to test a theory of reanalysis
Part I

Methods for operationalizing bleaching

Verification of methods

Applying methods to test a theory of reanalysis
Method 1: SimVery

Q: How semantically similar is an adverb becoming to an intensifier?

SimVery: cosine similarity b/w bleaching adverb, \(a\), and “very”

\[ \text{SimVery}(a,t) = \text{sim}(a_t, \text{very}_t) \]
Method 2: SimLex

Q: How much does an adverb differ from its original meaning?

SimLex: cosine similarity between $a$ and lemmas ($L$) associated with its root meaning

$$SimLex(a,t) = \frac{1}{|L|} \sum_{l_k \in L} \text{sim}(a_t, l_{k_t})$$
### Method 2: SimLex

<table>
<thead>
<tr>
<th>Adverb</th>
<th>Lemmas from original semantic domain</th>
</tr>
</thead>
<tbody>
<tr>
<td>disgustingly</td>
<td>filthy, filth, repulsive, aversion</td>
</tr>
<tr>
<td>beautifully</td>
<td>elegance, elegant, style, gorgeous, beauteous</td>
</tr>
<tr>
<td>wildly</td>
<td>savage, rage, fierce, barbarian, uncivilized</td>
</tr>
<tr>
<td>remarkably</td>
<td>impact, stun, awe, wonder, amazement, terror</td>
</tr>
</tbody>
</table>

- Lemma sets are comprised of WN and thesaurus synonyms
- Eliminated lemmas undergoing semantic change (compared to set of highly stable lemmas of pronouns and numerals)
Method 3: TypeDiv

Q: How diverse are the adjectives modified by an adverb becoming?
Method 3: TypeDiv

Q: How diverse are the adjectives modified by an adverb becoming?

TypeDiv(a, t): number of unique adjective types modified by an adverb a at time t

Concern: an adverb might modify
• many highly similar (distinct) adjectives
• few semantically distant adjectives
Method 4: Breadth

Q: How semantically broad are the adjectives modified by an adverb becoming?
Method 4: Breadth

Q: How semantically broad are the adjectives modified by an adverb becoming?

**Breadth (B):** average weighted pairwise similarity among the adjectives (A_t) modified by a at time t
Method 4: Breadth

Q: How semantically broad are the adjectives modified by an adverb becoming?

**Breadth (B):** average weighted pairwise similarity among the adjectives \( (A_t) \) modified by \( a \) at time \( t \)
Method 4: Breadth

Q: How semantically broad are the adjectives modified by an adverb becoming?

Breadth (B): average weighted pairwise similarity among the adjectives ($A_t$) modified by $a$ at time $t$
Method 4: Breadth

Q: How semantically broad are the adjectives modified by an adverb becoming?

Breadth (B): average weighted pairwise similarity among the adjectives ($A_t$) modified by $a$ at time $t$

- Higher similarity $\rightarrow$ closer together $\rightarrow$ less broad
- Multiply Breadth by -1 so that greater density $\rightarrow$ more broad
Methods for operationalizing bleaching

Verification of methods

Applying methods to test a theory of reanalysis
## Data: Two sets of deadjectival adverbs

### 250 bleaching adverbs, including...

<table>
<thead>
<tr>
<th>enormously</th>
<th>immensely</th>
<th>abundantly</th>
<th>seriously</th>
<th>thoroughly</th>
</tr>
</thead>
<tbody>
<tr>
<td>strangely</td>
<td>abnormally</td>
<td>marvelously</td>
<td>absolutely</td>
<td>fully</td>
</tr>
<tr>
<td>brutally</td>
<td>terribly</td>
<td>abominably</td>
<td>insanely</td>
<td>entirely</td>
</tr>
</tbody>
</table>

### 178 frequency-matched control adverbs, including...

<table>
<thead>
<tr>
<th>abruptly</th>
<th>accordingly</th>
<th>frankly</th>
<th>privately</th>
<th>quietly</th>
</tr>
</thead>
<tbody>
<tr>
<td>ironically</td>
<td>locally</td>
<td>loudly</td>
<td>simultaneously</td>
<td>happily</td>
</tr>
<tr>
<td>nationally</td>
<td>newly</td>
<td>officially</td>
<td>neatly</td>
<td>originally</td>
</tr>
</tbody>
</table>
We want to test ...

- Changes in values in bleaching metrics over time (i.e., slope)

<table>
<thead>
<tr>
<th>Predicted slopes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>Bleaching adverbs</td>
</tr>
<tr>
<td>SimVery</td>
</tr>
<tr>
<td>Breadth</td>
</tr>
<tr>
<td>TypeDiv</td>
</tr>
<tr>
<td>SimLex</td>
</tr>
</tbody>
</table>
We test predictions using ...

• Linear Regression with:
  • ind. variable: time
  • dep. variable: each of SimVery, SimLex, etc.
• Use HistWords embeddings (Hamilton et al., 2016) to compute similarity metrics
• Use syntactic Google ngrams (Goldberg and Orwant, 2013) corpus for productivity metrics
Results: Bleaching and control adverbs both become more productive in TypeDiv
Results: Bleaching and control adverbs both become more productive in Breadth
Adjectives modified by *insanely, 1850...*
...vs. 1990
Found significant increases over time for both bleaching adverbs (expected) and control adverbs (not expected)

Likely due to increasing corpus size over time: #adjs found in corpus is increasing significantly for all adverbs

Relative increase for bleaching adverbs obscured
Results: Bleaching adverbs become more similar to “very” than controls
Results: Bleaching adverbs become less similar to their root meaning than control adverbs
### Examples of most and least bleached adverbs

<table>
<thead>
<tr>
<th>SimVery + W2V</th>
<th>Most bleached</th>
<th>Least bleached</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>extremely, terribly, awfully, remarkably, seriously</td>
<td>amply, vigorously, richly, heavily, furiously</td>
</tr>
</tbody>
</table>
Examples of most and least bleached adverbs

<table>
<thead>
<tr>
<th>Can they modify antonyms?</th>
<th>Most bleached</th>
<th>Least bleached</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>√ <strong>terribly</strong> good</td>
<td>? <strong>amply</strong> small</td>
</tr>
<tr>
<td></td>
<td>√ <strong>remarkably</strong> boring</td>
<td>? <strong>vigorously</strong> relaxed</td>
</tr>
<tr>
<td></td>
<td>√ <strong>seriously</strong> unimportant</td>
<td>? <strong>furiously</strong> happy</td>
</tr>
</tbody>
</table>
Interim summary

• Bleaching adverbs show decreasing SimLex whereas controls adverbs remain constant, as expected.

• Bleaching adverbs and controls show increasing SimVery, though this slope is significantly greater for bleaching adverbs.
  • A viable method when a (frequency-matched) control set is available as a benchmark.

• Breadth, TypeDiv do not distinguish bleaching adverbs from controls, likely due to increasing corpus size.
Methods for operationalizing bleaching

Verification of methods

Applying methods to test a theory of reanalysis
What is the context for intensifier reanalysis?

**beautifully picturesque ≈ very picturesque**  
(≈ beautiful)  

**beautifully asleep ≠ very asleep**  
(≠ beautiful)

**Hypothesis:** Modifying semantically similar adjectives (to the adverb’s root)
How do we test this hypothesis?

• $M'$ (reanalyzed meaning) becomes conventionalized over time due to regularly occurring “bridging contexts” that support the new interpretation (Bybee et al., 1994; Evans and Wilkins, 2000; Hopper and Traugott, 2003).

  beautifully picturesque ≈ very picturesque

• **Prediction:** the more an adverb modifies semantically similar adjectives, the faster it will be reanalyzed into an intensifier, i.e., undergo bleaching.
Testing a quantitative prediction of intensifier reanalysis

- **Prediction**: the more an adverb modifies semantically similar adjectives, the faster it will be reanalyzed into an intensifier, i.e., undergo bleaching.

adjs modified
Testing a quantitative prediction of intensifier reanalysis

- **Prediction:** the more an adverb modifies semantically similar adjectives, the faster it will be reanalyzed into an intensifier, i.e., undergo bleaching.

![Diagram showing the relationship between adjectives modified and adjectives](image)
Testing a quantitative prediction of intensifier reanalysis

- **Prediction:** the more an adverb modifies semantically similar adjectives, the faster it will be reanalyzed into an intensifier, i.e., undergo bleaching.

![Diagram](image-url)
Testing a quantitative prediction of intensifier reanalysis

- **Prediction**: the more an adverb modifies semantically similar adjectives, the faster it will be reanalyzed into an intensifier, i.e., undergo bleaching.

\[ \text{adjs modified} \]
Methods for operationalizing bleaching  
Verification of methods  
Applying methods to test a theory of reanalysis

awfully  
≈ adjs

dark

frightening

formidable

≈ adjs

content

happily

≈ adjs

t1

t2

t3
Rate of bleaching has (+) correlation with semantic overlap
Bleaching adverbs on average modify higher similarity adjectives
Summary

• Introduced 4 methods that operationalize features of bleaching
• Verified methods: large case study of English bleaching
  • 2 similarity methods successful: increasing similarity to target meaning; decreasing similarity to root meaning
  • 2 productivity methods less effective due to increasing corpus size
• Used methods to show importance of semantic overlap in reanalysis
Future work

• How well do these methods model other cases of bleaching? other languages?
• Within intensifier domain:
  • Improving productivity metrics:
    • different weightings
    • mitigate increasing corpus size
  • What other semantic factors can predict whether an adverb becomes an intensifier?
Thank You! Grazie!

Questions?
References

Bonus slides
## Intensifier data: Bolinger categories

<table>
<thead>
<tr>
<th>Root adjective type</th>
<th>Examples of derived intensifiers</th>
</tr>
</thead>
<tbody>
<tr>
<td>magnitude</td>
<td>enormously, vastly, immensely, hugely, abundantly</td>
</tr>
<tr>
<td>strength</td>
<td>overpoweringly, strongly, exuberantly</td>
</tr>
<tr>
<td>singularity</td>
<td>strangely, unusually, abnormally, mysteriously</td>
</tr>
<tr>
<td>evaluation</td>
<td>marvelously, brutally, dramatically, luxuriously, terribly, monstrously</td>
</tr>
<tr>
<td>irremediability</td>
<td>abominably, pathetically, disastrously</td>
</tr>
<tr>
<td>purity/veracity</td>
<td>unquestionably, thoroughly, absolutely, fully, entirely</td>
</tr>
</tbody>
</table>
Method details: Equations

**Breadth (B):** average weighted pairwise similarity between the adjectives \( (A_t) \) modified by \( a \) at time \( t \)

- \( B(a, t) = -\sum_{a_i \in A_t} \sum_{a_j \in A_t} \text{sim}(a_i, a_j) o(a_i) o(a_j), \) for \( i \neq j \)

  - \( o(a_k) \) is log odds of \( k \)th adjective being modified
Testing reanalysis: details

- Hypothesis: Rate of bleaching, \( \frac{d}{dt} (B(K, t)) \), is positively correlated with semantic similarity between an adverb and the adjectives that it modifies, \( SimAdjMod(K, t) \)

\[
\frac{d}{dt} (B(K, t)) = \frac{B(K, t + 10) - B(K, t)}{10}
\]

\[
SimAdjMod(K, t) = \frac{\sum_{a_i \in A_t} sim(K, a_i) o(a_i)}{|A_t|},
\]

\( o(a_i) \) is the odds of modifying \( a_i \)
<table>
<thead>
<tr>
<th>Intensifiers in bold are most or least bleached according to more than one metric. Intensifiers in italics are categorized as most bleached by one metric but least bleached by another.</th>
<th>Most bleached</th>
<th>Least bleached</th>
</tr>
</thead>
<tbody>
<tr>
<td>SimVery</td>
<td>extremely, terribly, truly, awfully, definitely, remarkably, absolutely, precisely, honestly, seriously</td>
<td>amply, vigorously, richly, heavily, violently, mysteriously, profusely, severely, furiously, miraculously</td>
</tr>
<tr>
<td>SimLex</td>
<td>entirely, decidedly, heavily, supremely, particularly, sorely, literally, deeply, especially, sharply</td>
<td>pleasantly, abundantly, enthusiastically, intensely, delightfully, definitely, furiously, curiously, evidently, profusely</td>
</tr>
<tr>
<td>Breadth</td>
<td>wholly, completely, particularly, deeply, evidently, distinctly, absolutely, extremely, perfectly, clearly</td>
<td>grievously, gorgeously, stupendously, surpassingly, outrageously, miraculously, deliciously, extravagantly, profusely, ludicrously</td>
</tr>
</tbody>
</table>
### Example adjectives modified in 1850 vs. 1990

<table>
<thead>
<tr>
<th></th>
<th>1850</th>
<th>1990</th>
</tr>
</thead>
<tbody>
<tr>
<td>abundantly</td>
<td>fat, large, flowing, fertile, rejoicing,</td>
<td>available, fraught, intelligible, loud,</td>
</tr>
<tr>
<td></td>
<td>grateful, ...</td>
<td>eager, familiar, ...</td>
</tr>
<tr>
<td>enormously</td>
<td>rich, large, high, long, great, fat,</td>
<td>popular, successful, important, complex,</td>
</tr>
<tr>
<td></td>
<td>wealthy, thick, ...</td>
<td>influential, difficult, helpful, ...</td>
</tr>
</tbody>
</table>