Simulation and evaluation of exemplar theoretic -t/-d deletion

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Outline

- t/-d deletion is the well known phenomenon of consonant cluster simplification
  - C{t,d} -> C

This talk is about possible representation and implementation of grammatical conditioning on -t/-d deletion
  - Exponential Model (Guy 1991a, 1991b)
  - Exemplar Model (Bybee 2002)
Grammatically Conditioned Variability

- Contextual Conditioning
  - Preceding segment
  - Following Segment
    - V < C

- Grammatical Conditioning
  - Past < Irregular Past < Monomorphemes

- Etc.
Grammatically Conditioned Variability

- **Representation:**
  - Decreasing functional load
    - Past > Irregular Past > Monomorphemes
    - Highly informed phonology
  - Variable Factor Weights
    - Past = .3; Irregular Past = .5; Monomorphemes = .7
    - Potentially arbitrary ranking
  - Connection to morphological structure
    - Exponential Model
Exponential Model (Guy 1991a, b)

- Single Variable Rule: Input p
- Cyclic application based on morphological structure
- Variation is based in phonological mechanics
**Exponential Model**

- Produces an exponential relationship across classes

<table>
<thead>
<tr>
<th>Level</th>
<th>Past</th>
<th>Irreg</th>
<th>Mono</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stem</td>
<td></td>
<td></td>
<td>50% td</td>
</tr>
<tr>
<td>Word</td>
<td></td>
<td>50% td</td>
<td>25% td</td>
</tr>
<tr>
<td>Post Lex</td>
<td>50% td</td>
<td>25% td</td>
<td>12.5% td</td>
</tr>
<tr>
<td>p</td>
<td>p^2</td>
<td>p^3</td>
<td></td>
</tr>
</tbody>
</table>
## Exponential Model

### Philadelphia Corpus; N = 1,555

<table>
<thead>
<tr>
<th></th>
<th>Past</th>
<th>Irreg</th>
<th>Mono</th>
</tr>
</thead>
<tbody>
<tr>
<td>Retention</td>
<td>$p = 76.6%$</td>
<td>55.6%</td>
<td>43.5%</td>
</tr>
<tr>
<td>Predicted</td>
<td>$p = 76.6%$</td>
<td>$p^2 = 56.6%$</td>
<td>$p^3 = 44.9%$</td>
</tr>
<tr>
<td>CI</td>
<td>2.4%</td>
<td>6.7%</td>
<td>1.7%</td>
</tr>
</tbody>
</table>

### Buckeye Corpus; N = 13,414

<table>
<thead>
<tr>
<th></th>
<th>Past</th>
<th>Irreg</th>
<th>Mono</th>
</tr>
</thead>
<tbody>
<tr>
<td>Retention</td>
<td>$p = 76.8%$</td>
<td>58.8%</td>
<td>46.7%</td>
</tr>
<tr>
<td>Predicted</td>
<td>$p = 76.8%$</td>
<td>$p^2 = 58.9%$</td>
<td>$p^3 = 45.3%$</td>
</tr>
<tr>
<td>CI</td>
<td>1%</td>
<td>2.5%</td>
<td>0.6%</td>
</tr>
</tbody>
</table>
Exponential Model

- Delivers:
  - A relationship between retention rates across classes
  - No need for direct morphological information in variable rule

- Dependant upon
  - Cyclicity
    - Lexical Phonology / Stratal OT (Bermuñez-Otero 2003)
  - Morphological composition
Exemplar Model

- Words are represented in phonetic detail
- Phonemic / Morphological categories are emergent (Pierrehumbert 2002, 2007).
- Variability is in the lexical representation (Bybee 2002).
Exemplar Model

- Variation could be introduced by the Production-Representation loop

Diagram:
- Representation
- Contextual Effects
- Production
- Storage Constraints
Exemplar Model

- Reduction is possible in production
- Over time, representations will “accrue more exemplars that are reduced” (Bybee 2002)
- More frequent words will go through this cycle more often, and will have more reduction

Diagram:
- Representation
- Contextual Effects
- Production
- Storage Constraints
Exemplar Model: Contextual Effects

- Effects of Preceding and Following Segment can be grounded in saliency
  - _V_: Audible burst, Formant Transitions
  - _C_: Obscured burst, Competing closures

- Differential contextual effect should affect words that vary in their distributions across contexts
Exemplar Model: Grammatical Differentiation

- Correlation between grammatical class’ \_V distribution and overall deletion (Bybee 2002)
Exemplar Model: Grammatical Differentiation

- The relationship between _V and overall deletion between corpora not the same
  - Possibly due to differences in nasal flap formation
Exemplar Model: Grammatical Differentiation

n -- n’t contraction

d -- Irregular Past tense

m -- Monomorphemes

p -- Past tense

From Buckeye
Exemplar Model: Grammatical Differentiation

- This model assumes that variable -t/-d deletion is a case of change.
  - Impossible to talk about accumulation of online reduction without this assumption
- Most formulations will produce rapid, complete reduction
Exemplar vs. Exponential

- Apparent exponential relationship between grammatical classes is coincidental
  - Emergent from variable contextual distributions
- Variation is located primarily in the representations, fed by the production-perception loop.
Exemplar Simulation

3 Factors of -t/-d deletion in Bybee 2002:
- -t/-d representation (proportion of t’s in the cloud)
- Contextual Retention (probability of retaining t)
- Distribution across contexts

Model
- Representation feeds contextual retention
- Contextual retention weighted by frequency
- Exemplar cloud updated by experience

\[ T_{G'} = \sum_{i=1}^{n} T_G F_{Gi} C_i \]
Exemplar Simulation

\[ T_{G'} = \sum_{i=1}^{n} T_{G} F_{Gi} C_i \]

- **t's in cloud:**
- **Prob of drawing t:**
- **Contextual Retention:**
  - A: \( (T_{G} \ast C_{A}) \)
  - B: \( (T_{G} \ast C_{B}) \)
  - C: \( (T_{G} \ast C_{C}) \)
- **Contextual frequency:**
  - \( (* F_{GA}) \)
  - \( (* F_{GB}) \)
  - \( (* F_{GC}) \)

\[ F_{GA} + F_{GB} + F_{GC} = 1 \]
Exemplar Simulation--Assumptions

1. Probability of \( t \) = Proportion of \(/t/\) exemplars in the cloud
2. Proportion of \( t \) exemplars begins at 100%
3. New proportion of \( T \) exemplars = Output of production

\[
T_{G'} = \sum_{i=1}^{n} T_G F_{G_i} C_i
\]
Exemplar Simulation--Data

- Contextual frequency can be determined from a corpus
- Contextual retention can be estimated
  - $\text{Retention}_A = (T_G \cdot C_A)$
  - If $T_G \approx 1$; $\text{Ret}_A \approx C_A$
  - Grammatical class with least deletion will have $T_G$ closest to 1
  - Contextual retention for past tense taken to be $C_i$

$$T_{G'} = \sum_{i=1}^{n} T_G F_{G_i} C_i$$
Exemplar Simulation -- Corpora

- Buckeye Corpus (Pitt et al 2007)
  - Total N = 12273

<table>
<thead>
<tr>
<th></th>
<th>Past Tense</th>
<th>Irregular</th>
<th>Mono</th>
</tr>
</thead>
<tbody>
<tr>
<td>1696</td>
<td>351</td>
<td>7172</td>
<td></td>
</tr>
</tbody>
</table>
TD: Exemplar Simulation

Buckeye Corpus

Retention Rate

Mono | Deriv | Past

Grammatical Class
TD: Exemplar Simulation

Buckeye Corpus

Retention Rate

0.0 0.2 0.4 0.6 0.8 1.0

m d p

Mono Deriv Past

Grammatical Class
TD: Exemplar Simulation
TD: Exemplar Simulation
TD: Exemplar Simulation

- Differences between grammatical classes are rather small
- Quantal jumps between iterations are an idealization
  - Actual retention rates appear to be quantally separated
  - Past tense near first iteration, irregular past near second iteration, monomorphemes near third
The Philadelphia Corpus

- Sociolinguistic interviews with 7 Philadelphians coded for TD features
- Total N = 1555

<table>
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<th>Past Tense</th>
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<th>Mono</th>
</tr>
</thead>
<tbody>
<tr>
<td>316</td>
<td>54</td>
<td>773</td>
</tr>
</tbody>
</table>
TD: Exemplar Simulation

![Graph of Philadelphia Corpus](image)
TD: Exemplar Simulation

Why this relationship between the simulation and actual rates?
TD: Exemplar Simulation

- By taking contextual retention to be retention for past tense
  - $T^0 = 1$
  - $T^1 \approx$ Retention for past tense
- Model is basically one of exponential decay
  - Retention = $(1-\text{Online Reduction})^{\text{Time}}$
- Rates of online reduction across grammatical classes are basically equivalent
- Reproduces exponential relationship
Exponential Change
Exponential Change

- Factors like frequency, phonological neighborhood density and lexical competitors will bias rate of decay.
- Language change is typically described as taking place over an s-shaped curve (Labov 2001).
Exponential Change

- No countervailing force against reduction
  - Contextual Retention not included in speaker knowledge
  - Perceived forms not checked against expectations
Conclusions

- Lexical distribution across phonetic contexts is insufficient to produce sufficient variability to explain grammatical effect.
- The quantal, exponential relationship between grammatical classes remains to be explained.
- To prevent rapid, complete reduction, deletion should be controlled by abstract phonological forms.


