French schwa in Harmonic Grammar

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UCLA

Joe Pater
UMass Amherst

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Linguistic Symposium on Romance Languages
Stonybrook (SUNY)
• Ongoing collaboration with Joe Pater
Today

- Experimental data on the phonological conditioning of two optional processes in French
  - Schwa epenthesis
  - Schwa deletion
- Both processes can be accounted for with weighted constraints, and both demonstrate ganging effects
- Takeaway: weighted constraints provide a natural fit for the data, capture both *cumulative* and *independent* effects of constraints
Plan

• The idealized (categorical) epenthesis pattern
  • Analysis in HG
  • Alternatives
• Experiment: variation in epenthesis and deletion
• A MaxEnt-HG model of variable epenthesis and deletion
Schwa background

• Definition: front rounded mid vowel that alternates with zero

• Phonetically [ø], [œ], or somewhere between
Background

• Dell (1973/1985) describes three levels of optionality

  • Forbidden schwa    Jacques l€achète
  • Optional schwa    Marie l(e) vend
  • Obligatory schwa    Jacques le vend

• I’ll follow his notation, and mostly use his examples (all IPA transcriptions are by me)
Schwa epenthesis

- Described as obligatory (Léon 1966); occurs iff:
  - The epenthesis site is after a complex cluster
  - The site is followed by exactly one syllable

- Data for Verb+Noun compounds

<table>
<thead>
<tr>
<th>Word</th>
<th>IPA</th>
<th>Context of e</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. garde-fou</td>
<td>garde+fu</td>
<td>VCC_σ</td>
<td>railing</td>
</tr>
<tr>
<td>b. porte-clefs</td>
<td>porte+kle</td>
<td>VCC_σ</td>
<td>keychain</td>
</tr>
</tbody>
</table>
Schwa epenthesis

• No schwa if epenthesis site is followed by 2+ syllables

<table>
<thead>
<tr>
<th>Word</th>
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<th>Context of ə</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>c. portɛ-manteau</td>
<td>poʁt+mãtɔ</td>
<td>VCC_σσ</td>
<td>coat rack</td>
</tr>
<tr>
<td>d. gardɛ-manger</td>
<td>gaʁd+mãʒe</td>
<td>VCC_σσ</td>
<td>cold kitchen</td>
</tr>
</tbody>
</table>
Schwa epenthesis

- No schwa if epenthesis site isn’t preceded by a cluster

<table>
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<th>Context of $\ddot{a}$</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>e. cass$\dddot{e}$-noix</td>
<td>kas+nwa</td>
<td>VC$_\sigma$</td>
<td>nutcracker</td>
</tr>
<tr>
<td>f. piqu$\dddot{e}$-nique</td>
<td>pik+nik</td>
<td>VC$_\sigma$</td>
<td>picnic</td>
</tr>
<tr>
<td>g. coup$\dddot{e}$-papier</td>
<td>kup+papje</td>
<td>VC$_\sigma\sigma$</td>
<td>paper cutter</td>
</tr>
<tr>
<td>h. pass$\dddot{e}$-partout</td>
<td>pas+paʁtu</td>
<td>VC$_\sigma\sigma$</td>
<td>master key</td>
</tr>
</tbody>
</table>
Why analyze as epentheses?

- Not just in compounds. Occurs at every morpheme boundary (if CC_σ), even if there’s no orthographic ‘e’

(i) une veste rouge
    une veste rouge et blanc
    \[ yn \ v^\varepsilon st^\theta \ \varepsilon u^\zeta \] (Dell: 224)
    \[ yn \ v^\varepsilon st^\theta \ v^\zeta \ e \ bl^\alpha \] (Dell: 224)

(j) exact\varepsilon+ment
    massiv\varepsilon+ment
    \[ \varepsilon g^zakt^\varepsilon^\theta+m^\alpha \] (Dell: 228)
    \[ masiv+m^\alpha \] (Dell: 228)

(k) un short vert
    \[ \varepsilon \ v^\varepsilon r^\varepsilon t \] (Dell: 237)

- Completely predictable \(\rightarrow\) epentheses (not deletion)
One more requirement

• Epenthesis is forbidden before a vowel

(l) notre ø âmes  /nɔtʁ am/
     our souls            [nɔtʁ am]    *[nɔtʁɛ am]

• Cannot create a schwa-V sequence (which is avoided throughout French, excepting h-aspiré)
An HG analysis of schwa epenthesis

• Lends itself to analysis with weighted constraints in Maximum Entropy Harmonic Grammar (MaxEnt: Goldwater & Johnson 2003)

• HG is like OT — with constraints and candidate sets — but constraints are weighted instead of ranked

• Results in **ganging**: one strong constraint can be overtaken by two weaker constraints together

• MaxEnt is a probabilistic variant of HG: outputs a probability distribution
Constraints

• Two independent requirements:
  • Requirement 1: Schwa must be in the penult
  • Requirement 2: Schwa must be after a cluster
• Translated into two constraints:
  • \texttt{Penult = Schwa}
  • \texttt{*Cluster}
Constraints

• **Cluster**: Assign one violation for every coda cluster.

  • Well-documented effects across French, most famously Grammont’s (1894) *La Loi de Trois Consonnes* (An early constraint: *CCC*)

  • Abstracting away from the effects of sonority, which have been noticed as early as Grammont

    • (The cluster in *livre* [livʁ] is more marked than *pest* [pɛst]*)
Constraints

• **Penult = Schwa**: Assign one violation if the penultimate syllable of the Phonological Phrase is a non-schwa vowel

• Restated: pre-tonic syllable should contain the least sonorous vowel

  • Common across stress systems (de Lacy 2006)

  • Stress is phrase-final in French, and schwa ([ø]~[œ]) is the closest thing in French to a mid central vowel
### Calculating Harmony

<table>
<thead>
<tr>
<th>/gaʁd+fu/</th>
<th>*Cluster w=20</th>
<th>Penult=ə w=10</th>
<th>Dep w=25</th>
<th>Harmony</th>
</tr>
</thead>
<tbody>
<tr>
<td>gaʁ.ə fu</td>
<td>0</td>
<td>0</td>
<td>−1</td>
<td>−25</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(0<em>20)+(0</em>10)+(-1*25)</td>
</tr>
<tr>
<td>gaʁd.fu</td>
<td>−1</td>
<td>−1</td>
<td>0</td>
<td>−30</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(-1<em>20)+(-1</em>10)+(0*25)</td>
</tr>
</tbody>
</table>
Exponentiating

<table>
<thead>
<tr>
<th>/gaːd+fu/</th>
<th>*CLUSTER w=20</th>
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<th>DEP w=25</th>
<th>Harmony</th>
<th>$e^{\text{Harmony}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>gaːd.ə̃.fu</td>
<td>0</td>
<td>0</td>
<td>−1</td>
<td>−25</td>
<td>$1.39 \times 10^{-11}$</td>
</tr>
<tr>
<td>gaːd.fu</td>
<td>−1</td>
<td>−1</td>
<td>0</td>
<td>−30</td>
<td>$9.35 \times 10^{-14}$</td>
</tr>
</tbody>
</table>

Natural exponential function
## Probabilities

<table>
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<tr>
<th>/gæd+fu/</th>
<th>*Cluster w=20</th>
<th>Penult=ə w=10</th>
<th>Dep w=25</th>
<th>Harmony</th>
<th>e^{Harmony}</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>gæd.ə.fu</td>
<td>0</td>
<td>0</td>
<td>-1</td>
<td>-25</td>
<td>1.39 e^{-11}</td>
<td>0.99</td>
</tr>
<tr>
<td>gæd.fu</td>
<td>-1</td>
<td>-1</td>
<td>0</td>
<td>-30</td>
<td>9.35 e^{-14}</td>
<td>&lt;0.01</td>
</tr>
</tbody>
</table>

Normalize: divide each candidate’s $e^H$ by sum of all candidates’ in set
Both constraints violated: epenthesis

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<thead>
<tr>
<th></th>
<th>*CLUSTER w=20</th>
<th>PENULT=ə w=10</th>
<th>Dep w=25</th>
<th>Harmony</th>
<th>eHarmony</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>ga demás</td>
<td>0</td>
<td>0</td>
<td>-1</td>
<td>-25</td>
<td>1.39 e^{-11}</td>
<td>0.99</td>
</tr>
<tr>
<td>ga demás</td>
<td>-1</td>
<td>-1</td>
<td>0</td>
<td>-30</td>
<td>9.35 e^{-14}</td>
<td>&lt;0.01</td>
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Ganging: two weaker constraints (*CLUSTER and PENULT=ə) overcoming stronger constraint (DEP)
Just **PENULT=*/ə/: no epentheses

<table>
<thead>
<tr>
<th>/kas+nwa/</th>
<th><em>C</em>LUSTER w=20</th>
<th><strong>P</strong>ENULT=ə w=10</th>
<th><strong>D</strong>EP w=25</th>
<th>Harmony</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>ka.sә.nwa</td>
<td>0</td>
<td>0</td>
<td>−1</td>
<td>−25</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>kas.nwa</td>
<td>0</td>
<td>−1</td>
<td>0</td>
<td>−10</td>
<td>0.99</td>
</tr>
</tbody>
</table>
Just *CLUSTER: no epenthesis

<table>
<thead>
<tr>
<th>/gæd+malad/</th>
<th>*CLUSTER w=20</th>
<th>PENULT=ə w=10</th>
<th>DEP w=25</th>
<th>Harmony</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>gæd.ə.ma.lad</td>
<td>0</td>
<td>−1</td>
<td>−1</td>
<td>−35</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>gæd.ma.lad</td>
<td>−1</td>
<td>−1</td>
<td>0</td>
<td>−30</td>
<td>0.99</td>
</tr>
</tbody>
</table>
Summary of the MaxEnt analysis

• Two independent markedness constraints
  - \( *\text{CLUSTER} \)
  - \( \text{Penult} = \emptyset \)
• Weighted to produce a ganging effect: epenthesis only applies if it avoids violations of both constraints
Alternative accounts

• To compare: other accounts of French epenthesis capture the pattern without ganging or cumulativity.

• Charette 1991: (in GP) Epenthesis occurs after clusters, and epenthetic schwa is only licensed in the penultimate syllable.

• Coté 2007: (in OT) Cluster-driven epenthesis only occurs within PWds. Garde-fou is parsed as one PWd, garde-malade is parsed as two.
Why MaxEnt?

• All three accounts can handle the basic pattern
  • MaxEnt with two constraints and a ganging effect
  • Licensing in Charette (1991)
  • Prosodic analysis in Côté (2007)
Why MaxEnt?

• The MaxEnt analysis captures the pattern through the cumulative interaction of two independent constraints

• If we find independent evidence for *CLUSTER and PENULT=Schwa in French, the MaxEnt account is on the right track

• If we need *CLUSTER and PENULT=Schwa independently, why not take advantage of their cumulative interaction?
Why MaxEnt?
Empirical arguments

- **The rest of today**: both *CLUSTER* and *PENULT=SCHWA* play a role in variable epenthesis and deletion
  - Independently of each other
  - Outside of the context VCC_σ

- We need **both** of the constraints to capture the full set of data
Variable epenthesis and deletion
Variation and epenthesis

- Côté (2007) describes epenthesis as variable

(m) la secte part \[\text{la sɛktə pa̯k}\] \text{CCe} σ
la sect(e) partait \[\text{la sɛkt(ə) pa̯kɛ}\] \text{CC(e) σσ}
l’Aztèque part \[\text{l aztɛk pa̯k}\] \text{Cφ σ}

- Epenthesis most likely after clusters and followed by one syllable

- Generally occurs after clusters, regardless of position

- No independent effect of position
Clusters and deletion

• Schwa deletion is optional after a single consonant, but only if it doesn’t create a coda cluster.

  • _tu le retrouves_ (Dell: 248)
    
    \[\text{/ty l}_\text{e ət}_\text{ʁ}_\text{uv/} \quad [\text{ty l}_\text{e ət}_\text{ʁ}_\text{uv}] \quad [\text{ty l}_\text{e b}_\text{t}_\text{ʁ}_\text{uv}] \quad [\text{ty l}_\text{e ət}_\text{ʁ}_\text{uv}] \quad *[\text{ty l b}_\text{t}_\text{ʁ}_\text{uv}]\]

• Doesn’t matter where the resulting cluster is.

  • _la queue de ce renard_ (Dell: 248)
    
    \[\text{/la k}_\text{o d}_\text{e s}_\text{e ən}_\text{ʁ}_\text{aʁ/} \quad *[\text{la k}_\text{o d}_\text{e s}_\text{e ən}_\text{ʁ}_\text{aʁ}]\]
Cluster and position

• Some coda clusters are possible outcomes of deletion, and these clusters show an effect of prosodic position (Dell: 231, citing Morin 1974)

  • la terre se vend /la tɛʁ sə vã/

  • la terre s(e) vend bien /la tɛʁ s(ə) vã bjѣ/
Position alone

• There’s an effect of position outside of coda clusters, although this effect is much more subtle

venez in Dell: 227:

/vəne isi/  /vəne/
venez ici  venez

<- Less schwa  More schwa ->
Summary of previous literature

• In both epenthesiss and deletion:
  • Schwa is most likely to be pronounced in CC_σ
  • Schwa is generally more likely after clusters
• In deletion: schwa is more likely in C_σ than C_σσ (but the effect is weak)
• In epenthesiss: C_σ and C_σσ are equal
Next

- Although there are hints of independent effects of both constraints in descriptions, we don’t know the actual probabilities of schwa

- An experiment to estimate the rates of deletion and epenthesis
Experiment
Experiment

- Web-based, through IbexFarm
- Two alternative forced choice, with confidence rating
Design

- 2 x 2 x 2 factorial design
  - Cluster ( C_ or CC_ )
  - Position ( _σ or _σσ )
  - Epentheses / Deletion
Design: epenthesi

- **Noun + Adjective**
  - **Noun**: C-final or CC-final, all final Cs obstruents
  - **Adjective**: σ or σσ, all obstruent-initial

<table>
<thead>
<tr>
<th>C_</th>
<th>CC_</th>
</tr>
</thead>
<tbody>
<tr>
<td>_σ</td>
<td>une bott(e) jaune [yn bɔt _ ʒɔn]</td>
</tr>
<tr>
<td>_σσ</td>
<td>une bott(e) chinoise [yn bɔt _ ʃinwaz]</td>
</tr>
</tbody>
</table>
Design: deletion

- **Name** + te + **Verb** (e.g. Maurice te cite)

- **Name**: C-final or V-final, all final Cs obstruents

- **Verb**: σ (present) or σσ (imperfect), all obstruent-initial

---

<table>
<thead>
<tr>
<th>C_</th>
<th>CC_</th>
</tr>
</thead>
<tbody>
<tr>
<td>_σ</td>
<td>Eva t(e) choque [evat _ʃok]</td>
</tr>
<tr>
<td>_σσ</td>
<td>Eva t(e) choquait [evat _ʃokɛ]</td>
</tr>
</tbody>
</table>
Design

• 78 judgments per participant
  • 24 deletion (6 per condition, no name or verb repeated)
  • 24 epenthesis (6 per condition, no adj. or noun repeated)
• 30 fillers
  • Different tenses (future, past) and contexts (V_, _V, _σσσ)
  • 20 fillers for deletion (e.g. Anna s(e) est levée)
  • 10 fillers for epenthesis (e.g. un iguan(e) solitaire)
Predictions

• **Cumulativity**: schwa is most likely when it avoids violations of both constraints

• **Independence**: schwa is more likely when it avoids a violation of a single constraint

• Predicted probabilities of schwa:
  \[ C_{\sigma\sigma} < CC_{\sigma\sigma}, C_{\sigma} < CC_{\sigma} \]
  \[ \text{Neither} < *\text{CLUSTER, PENULT}=\emptyset < \text{Both} \]
Participants

- Recruited online through word of mouth
- 51 respondents (ongoing)
- Preliminary results for 33 native French speakers who aren’t from Canada
Results

• A lot of experimental noise — schwa is conditioned by geography, social factors, register

• Reaction time cutoffs
  
  • min RT = 100 ms, max RT = 9.3 hrs

  • Only considered responses between 3000s-7500s
Rate of schwa from experiment: deletion

<table>
<thead>
<tr>
<th>Condition</th>
<th>Pr(schwa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C_σσ</td>
<td>0.42</td>
</tr>
<tr>
<td>C_σ</td>
<td>0.59</td>
</tr>
<tr>
<td>CC_σσ</td>
<td>0.87</td>
</tr>
<tr>
<td>CC_σ</td>
<td>0.90</td>
</tr>
<tr>
<td><em>V or V</em></td>
<td>0.03</td>
</tr>
</tbody>
</table>
Effect of position in deletion

\[ \text{Pr(schwa)} \]

<table>
<thead>
<tr>
<th>Position</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>C_σσ</td>
<td>0.00</td>
</tr>
<tr>
<td>C_σ</td>
<td>0.25</td>
</tr>
<tr>
<td>CC_σσ</td>
<td>0.50</td>
</tr>
<tr>
<td>CC_σ</td>
<td>0.75</td>
</tr>
<tr>
<td><em>V or V</em></td>
<td>1.00</td>
</tr>
</tbody>
</table>

\[ \text{n.s.} \quad \text{(*)} = p<0.05 \text{ in chi-square test} \]

* = p<0.05 in chi-square test
Effect of cluster in deletion

* = $p < 0.05$ in chi-square test
Rate of schwa from experiment: epenthesi
Effect of position

\[ \text{Pr(schwa)} = \begin{array}{c|c|c|c|c}
\text{Pr} & 0.00 & 0.25 & 0.50 & 0.75 & 1.00 \\
\text{C}_{\sigma\sigma} & 0.07 & 0.07 & 0.17 & 0.17 & 0.14 \\
\text{C}_{\sigma} & 0.56 & 0.75 & & & \\
\text{CC}_{\sigma\sigma} & & & & & \text{n.s.} \\
\text{CC}_{\sigma} & & & & & \\
\text{_V or V_} & & & 0.07 & & \\
\end{array} \]

* = \( p<0.05 \) in chi-square test
Effect of cluster

* = p<0.05 in chi-square test

Pr(schwa)

C_σσ

C_σ

CC_σσ

CC_σ

_V or V_

0.14

0.17

0.56

0.75

0.07

*
Epentheses and deletion

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</table>

**Figure:**
- Blue bars represent deletion probabilities.
- Green bars represent epentheses probabilities.
Mixed effects logistic regression

• Fixed effects:
  Epenthesis/deletion
  Cluster
  Position
  Cluster x Position

• Random effects: intercepts for Subject & Item, random slopes for Subject for all fixed effects
Findings

• sig. effect for Cluster
  \text{Pr(schwa): CC}_ - > C_ -

• sig effect of Position
  \text{Pr(schwa): } _\sigma > _\sigma\sigma

• sig effect of Deletion/Epenthesis:
  \text{Pr(schwa): deletion > epenthesi}s

• Effect of Cluster is greater than the effect of Position

• Interaction of Cluster x Position is not significant
Data from Racine (2008)

• 12 speakers from Nantes

• Frequency judgments for single words with schwa
  • 1 = infrequent schwa, 7 = very frequent schwa

• Judgments for nearly 2,000 words with orthographic ‘e’
Ratings for deletion

Words in which schwa isn’t at a morpheme boundary

“Internal” schwas, e.g. devenir
Ratings for epenthesis

Words in which schwa is at a morpheme boundary

e.g. brusque
tment

Rating for word with schwa

<table>
<thead>
<tr>
<th></th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>C_σσ</td>
<td>1.7</td>
</tr>
<tr>
<td>C_σ</td>
<td>2.1</td>
</tr>
<tr>
<td>CC_σσ</td>
<td>5.27</td>
</tr>
<tr>
<td>CC_σ</td>
<td>6.27</td>
</tr>
</tbody>
</table>
A model of variable epenthesis and deletion
Epenthesi and deletion

- Epenthesi and deletion obey similar tendencies with respect to schwa
  
  - Not often modeled together

- A single weighted constraint grammar can model both epenthesi and deletion
  
  - The model captures all target generalizations
  
  - and generates probabilities close to experiment probabilities (within 5 percentage points)
Qualitative goals of the model

- \( \text{Pr(schwa)} \)
  \[ C_{\sigma\sigma} < C_\sigma < CC_{\sigma\sigma} < CC_\sigma \]

- **Cumulativity and independence:**
  Schwa is most likely when two conditions are met
  Schwa is least likely when zero conditions are met
  Both requirements have an effect (across all contexts)

- Cluster plays a bigger role than position

- \( \text{Pr(schwa)} \)
  Epenthesis < Deletion
Fitting the actual values

- \*CLUSTER
- PENULT = θ
- \*SCHWA Need some constraint to drive deletion
- MAX Constraint against deletion
- DEP Constraint against epenthesis
Target probabilities

Taken directly from experiment

<table>
<thead>
<tr>
<th></th>
<th>_σσ</th>
<th>_σ</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CC</strong></td>
<td>0.86</td>
<td>0.90</td>
</tr>
<tr>
<td><strong>C</strong></td>
<td>0.42</td>
<td>0.59</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>_σσ</th>
<th>_σ</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CC</strong></td>
<td>0.56</td>
<td>0.75</td>
</tr>
<tr>
<td><strong>C</strong></td>
<td>0.13</td>
<td>0.17</td>
</tr>
</tbody>
</table>
Target probabilities

Taken directly from experiment

<table>
<thead>
<tr>
<th></th>
<th>Deletion: $p(\text{schwa})$</th>
<th>Epenthesis: $p(\text{schwa})$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CC</strong></td>
<td>_σσ  0.86</td>
<td>_σσ  0.56</td>
</tr>
<tr>
<td></td>
<td>_σ  0.90</td>
<td>_σ  0.75</td>
</tr>
<tr>
<td><strong>C</strong></td>
<td>0.42</td>
<td>0.13</td>
</tr>
<tr>
<td></td>
<td>0.59</td>
<td>0.17</td>
</tr>
</tbody>
</table>

60
Learning

• Constraint weights found using MaxEnt grammar tool
  • http://www.linguistics.ucla.edu/people/hayes/MaxentGrammarTool/

• Learner is supplied target probabilities, inputs, outputs, and constraint violations

• Objective: maximize likelihood: find a set of weights that matches the target probabilities as closely as possible
## Model probabilities

(Target probabilities)

<table>
<thead>
<tr>
<th>Constraint Weight</th>
<th>Weight</th>
<th>Penult=∅ 0.69</th>
</tr>
</thead>
<tbody>
<tr>
<td>*CLUSTER</td>
<td>2.16</td>
<td></td>
</tr>
<tr>
<td>*SCHWA</td>
<td>0.27</td>
<td></td>
</tr>
<tr>
<td>MAX</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>DEP</td>
<td>1.66</td>
<td></td>
</tr>
</tbody>
</table>

**Deletion: Pr(schwa)**

<table>
<thead>
<tr>
<th></th>
<th>_σσ</th>
<th>_σ</th>
</tr>
</thead>
<tbody>
<tr>
<td>CC_</td>
<td>0.87(0.86)</td>
<td>0.93(0.90)</td>
</tr>
<tr>
<td>C_-</td>
<td>0.43(0.42)</td>
<td>0.60(0.59)</td>
</tr>
</tbody>
</table>

**Epenthesis: Pr(schwa)**

<table>
<thead>
<tr>
<th></th>
<th>_σσ</th>
<th>_σ</th>
</tr>
</thead>
<tbody>
<tr>
<td>CC_</td>
<td>0.55(0.56)</td>
<td>0.71(0.75)</td>
</tr>
<tr>
<td>C_-</td>
<td>0.13(0.13)</td>
<td>0.22(0.17)</td>
</tr>
</tbody>
</table>
Constraints have weaker effects at the margins

• In the data and model, PENULT=ə has a weaker effect when the rate of schwa is closer to 0% and 100%, and a stronger effect when closer to 50%

• This falls out of the math of the MaxEnt model, without interaction terms or special constraints (see McPherson & Hayes 2015 for an application of this)

<table>
<thead>
<tr>
<th>Deletion (model)</th>
<th></th>
<th></th>
<th>Diff</th>
</tr>
</thead>
<tbody>
<tr>
<td>_σσ</td>
<td>0.87</td>
<td>0.93</td>
<td>0.06</td>
</tr>
<tr>
<td>CC_</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>_σ</td>
<td>0.43</td>
<td>0.60</td>
<td>0.27</td>
</tr>
<tr>
<td>C_</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Epenthesisis (model)</th>
<th></th>
<th></th>
<th>Diff</th>
</tr>
</thead>
<tbody>
<tr>
<td>_σσ</td>
<td>0.55</td>
<td>0.71</td>
<td>0.16</td>
</tr>
<tr>
<td>CC_</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>_σ</td>
<td>0.13</td>
<td>0.22</td>
<td>0.09</td>
</tr>
<tr>
<td>C_</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Modeling summary

• Model captures cumulativity in both epenthesis and deletion

• Both processes are conditioned by *CLUSTER and *\text{PENULT}=\emptyset, most likely when both constraints are applicable

• Both constraints have independent effects

• The fact that the constraints have weaker effects at margins falls out of MaxEnt
Conclusion

• Two types of analysis for epenthesis in VCC_σ
  • MaxEnt: Two constraints and ganging effects
  • Others: Constraints specific to VCC_σ
• For the categorical data, these approaches are equal
• For the variable data, MaxEnt captures the fact that both constraints have independent effects
  • Condition both epenthesis and deletion, outside of context VCC_σ
General conclusion

• Weighted constraints allow us to capture patterns with fewer constraints

• Thanks to ganging effects

• In this case, matching probabilities for 8 inputs with a simple 4 constraint grammar

• Weighted constraints provide a straightforward model of variation, with machine-learnable parameters
Thank you

http://www.linguistics.ucla.edu/people/bsmith/
Acknowledgments

• Thanks to many French speakers and learners for help with stimuli and recruitment, especially:

  • Magda Oiry          Isabelle Lin
    Yu Tanaka            Kie Zuraw

• Thanks to Isabelle Racine for sharing French data


• Grammont, Maurice (1894). La loi des trois consonnes. Mémoires de la société de linguistique de Paris 8, 53-90.

Thank you

http://www.linguistics.ucla.edu/people/bsmith/