Corpus data vs. experiments in English phonotactics

Michael Hammond

U. of Arizona
Outline

Syllable onsets in different domains
Syllable onsets and grammar
Syllable onsets and frequency
Syllable onsets and acquisition
Syllable onsets and judgments
A model
Conclusions
Collaborators

- Jeff Berry
- Jordan Brewer
- Lynnika Butler
- Jason Ginsburg
- Ben Tucker
What does phonology say about syllable onsets?
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- **Onset substring** Big onsets are more marked than smaller onsets.
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- **Sonority sequencing** Onsets with more than one consonant increase in sonority. If a language has an onset $\ldots C_1 \ldots C_2 \ldots$, then $C_1$ is less sonorous than $C_2$. 
Are these true in English?
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What does it mean to be *true*?
Are these true in English?

What does it mean to be true?

Grammar
Are these true in English?

What does it mean to be true?

► Grammar
► Frequency
Are these true in English?

What does it mean to be true?

- Grammar
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- Grammar
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- Judgments
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Are these all in sync with each other?
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What does it mean to be true?

- Grammar
- Frequency
- Acquisition
- Judgments

Are these all in sync with each other? If not, what story do we tell?
## English consonants

<table>
<thead>
<tr>
<th>Consonants</th>
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<tbody>
<tr>
<td>p  t  k</td>
<td>b  d  g</td>
<td>f  θ  s  š</td>
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<tr>
<td>v  ď  z  ž</td>
<td></td>
<td>c  ý</td>
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<tr>
<td>m  n  ŋ</td>
<td>l</td>
<td>r</td>
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<tr>
<td>w  y  h</td>
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</tr>
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</table>

All of these can be syllable onsets except the ones marked in red (Hammond, 1999); [ŋ] cannot occur at all and [ž] is marginal.
The diphthong [yu]
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- Pig Latin
  - \textit{Strom} [stram] \quad \rightarrow \quad [am-stre]
  - \textit{Gwen} [gwɛn] \quad \rightarrow \quad [ɛn-gwe]
  - \textit{Beula} [byulə] \quad \rightarrow \quad [yulə-be]
Complex onsets
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\[
\{\text{stop, voiceless fricative}\} + \{l, r, w\}
\]

e.g. play [ple], fry [fray], queen [kwin], etc.
Complex onsets

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\left\{ \begin{array}{c}
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\text{voiceless fricative}
\end{array} \right\} + \left\{ \begin{array}{c}
l \\
r \\
w
\end{array} \right\}
\]

e.g. \textit{play} [ple], \textit{fry} [fray], \textit{queen} [kwin], etc.

\[
\left\{ \begin{array}{c}
\text{nasal}
\end{array} \right\}
\]

\[
\left\{ \begin{array}{c}
[s] + \\
\text{voiceless stop} \\
(\text{voiceless fricative})
\end{array} \right\}
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e.g. \textit{snow} [sno], \textit{spot} [spat], \textit{sphere} [sfir], etc.
Complex onsets

- {stop} + {\text{voiceless fricative}}
  - e.g. play [ple], fry [fray], queen [kwin], etc.

- [s] + {\text{voiceless stop (voiceless fricative)}}
  - e.g. snow [sno], spot [spat], sphere [sfir], etc.

- [s] + {\text{voiceless stop (voiceless fricative)}} + {\text{nasal}}
  - e.g. splash [splæʃ], spree [spri], squash [skwɔʃ], etc.
Grammatical generalizations
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Remember: neither generalization is a biconditional.

- Onset substring
- Sonority sequencing
Grammatical generalizations

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- **Onset substring True**: if $C_1^+ C_2^+$ is an onset, then $C_1^+$ and $C_2^+$ are both onsets. (Clements & Keyser, 1983)

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For example, in [kw] in *queen*, [k] and [w] are independently onsets, e.g. in *keel* [kil] and *we* [wi], and [k] is less sonorous than [w].
Markedness
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These are really claims about markedness, which makes stronger claims in the domains of frequency, acquisition, and gradient judgments. More marked elements should be:
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- less frequent;
- acquired earlier;
- judged more well-formed.
Predictions about onsets
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- Cluster size
- Sonority
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- **Cluster size**
  - Larger clusters are less frequent;

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- **Sonority**
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But there shouldn’t be any clusters that violate the Sonority generalization.
How frequent are these clusters in the Brown corpus?
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- **Size of clusters**

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\((X^2 : p < 2.2e - 16)\)
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\(X^2 : p < 2.2e - 16\)

- This latter comparison may not be apropos, since [s]-clusters are exceptional.
What happens in acquisition?
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- Levelt, Schiller & Levelt (1999-2000): smaller clusters are acquired before larger clusters.
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- Levelt, Schiller & Levelt (1999-2000): smaller clusters are acquired before larger clusters.
- Meta-analysis of Smit et al. (1993) shows no effect of rising/falling sonority on cluster acquisition. (Again, this comparison may not be apropos, because [s]-clusters are an exception.)
- But: D. Ohala (1996) shows that complex clusters are simplified to their least sonorous members.
Up to here
Corpus frequency and acquisition show clear effects of cluster size.
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It’s not clear whether or how sonority shows itself in these domains.
Judgments
Generative grammar says that grammaticality judgments are a direct reflection of competence.
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Are they?
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Are they?

Experimental judgment tasks are a way of examining judgments more closely.
Generative grammar says that grammaticality judgments are a direct reflection of competence.

Are they?

Experimental judgment tasks are a way of examining judgments more closely.

Gradient judgments allow us to look even more closely.
Neighborhood density
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- Nonsense words are judged as well-formed if they sound like lots of actual words (Ohala & Ohala, 1986).
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- Neighborhood density: how many actual words are “one segment away” from the form in question?
- For example, *blick* [blɪk] has these neighbors:

  - click [klɪk]
  - lick [lɪk]
  - brick [brɪk]
  - bleak [blæk]
  - blink [blɪŋk]
  - flick [flɪk]
  - slick [slɪk]
  - block [blæk]
  - bliss [blɪs]
Phonotactic probability
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  - $wf(\text{blIk}) \approx p(\text{bl}) \times p(\text{ik})$
Phonotactic probability

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  - \( \text{wf} (\text{blık}) \approx p(\text{bl}) \times p(\text{ık}) \)
  - \( \text{wf} (\text{bli̇k}) \approx p(\text{b}) \times p(\text{l|b}) \times p(\text{i|ı}) \times p(\text{k|ı}) \)
Phonotactic probability

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  - $wf(\text{blIk}) \approx p(\text{bl}) \times p(\text{Ik})$
  - $wf(\text{blIk}) \approx p(\text{b}) \times p(\text{l|b}) \times p(\text{i|l}) \times p(\text{k|i})$

- This effect is independent of neighborhood density (Bailey & Hahn, 2001).
Phonotactic probability

- Nonsense words are judged as well-formed if their parts are frequent (Coleman & Pierrehumbert, 1997).
  - $wf(b\text{\i}k) \approx p(b) \times p(\text{i}k)$
  - $wf(b\text{\i}k) \approx p(b) \times p(l|b) \times p(l|l) \times p(k|l)$
- This effect is independent of neighborhood density (Bailey & Hahn, 2001).
- Both effects also show up in yes-no tasks (Frisch et al., 2000).
Phonotactic probability

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  - $wf(blık) \approx p(bl) \times p(ık)$
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- Both effects also show up in yes-no tasks (Frisch et al., 2000).

- Both effects show up with auditory or visual presentation (Bailey & Hahn, 2001).
Previous results
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- If we want to look at the effects of markedness of onsets, we have to factor out the effects of neighborhood density and phonotactic probability.
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- If we want to look at the effects of markedness of onsets, we have to factor out the effects of neighborhood density and phonotactic probability.
- One way to do that is to carefully select materials so these are all balanced and controlled.
If we want to look at the effects of markedness of onsets, we have to factor out the effects of neighborhood density and phonotactic probability.

One way to do that is to carefully select materials so these are all balanced and controlled.

Match items for neighborhood density and phonotactic probability.
Previous results presented here

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<tr>
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<th>CCC</th>
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Items matched as closely as possible for neighborhood density and phonotactic probability.
Uh-oh!

But the effect appears to go in the **wrong** direction.
Many problems
Many problems

- Significant by subjects \([F(2, 19) = 4.31, p < .01]\), but not by items \([F(2, 18) = 1.27, \text{n.s.}]\).
Many problems

- **Significant by subjects** \( F(2, 19) = 4.31, p < .01 \), but not by items \( F(2, 18) = 1.27, \text{n.s.} \).

- If we add in neighbors and phonotactic probability, then:
  - there is an effect of neighbors, also in the wrong direction. By subjects: \( F(2, 19) = 7.95; p < .000 \); By items: \( F(2, 18) = 4.87; p < .03 \)
  - plus several significant interactions of phonotactic probability and neighbors with onset size.
The upshot
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- **A problem**: Did we somehow reverse the scale? Is there some unknown factor that overwhelms the factors we’re interested in?
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- **A significant problem**: We can’t control neighborhood density or phonotactic probability adequately for this investigation.
The upshot

- **A problem**: Did we somehow reverse the scale? Is there some unknown factor that overwhelms the factors we’re interested in?
- **A significant problem**: We can’t control neighborhood density or phonotactic probability adequately for this investigation.
- **Teaser**: There seems to be a typological effect of onset complexity in there somewhere.
New experiment
New experiment

- How else might we control for the effects of phonotactic probability?
New experiment

How else might we control for the effects of phonotactic probability? Choose materials that are *impossible* words of English.

<table>
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<td>thnlem</td>
<td>thnreef</td>
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<td>tnrafe</td>
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<td>zmrube</td>
<td>znafe</td>
<td>znape</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Items have **no** neighbors and have **zero** phonotactic probability.
New experiment

- How else might we control for the effects of phonotactic probability? Choose materials that are **impossible** words of English.

  - Items have **no** neighbors and have **zero** phonotactic probability.
  - Factors are size and **sonority cline** of onset.
Results from new experiment

Experiment #4 means

Response mean

- Rising 2
- Falling 2
- Rising 3
- Falling 3
Statistics
Judgments

Statistics

- Items with onsets that are bigger are judged as more ill-formed.

  [by subjects: $F(1, 20) = 122.116, p < .000$; by items: $F(1, 64) = 37.889, p < .000$]
Items with onsets that are bigger are judged as more ill-formed.
[by subjects: $F(1, 20) = 122.116$, $p < .000$; by items: $F(1, 64) = 37.889$, $p < .000$]

Items with onsets that violate the sonority hierarchy are judged as more ill-formed.
[by subjects: $F(1, 20) = 75.807$, $p < .000$; by items: $F(1, 64) = 23.521$, $p < .000$]
Statistics

- Items with onsets that are bigger are judged as more ill-formed.
  
  \[ F(1, 20) = 122.116, p < .000; \text{ by items: } F(1, 64) = 37.889, p < .000 \]

- Items with onsets that violate the sonority hierarchy are judged as more ill-formed.
  
  \[ F(1, 20) = 75.807, p < .000; \text{ by items: } F(1, 64) = 23.521, p < .000 \]

- **But the factors interact.**
  
  \[ F(1, 64) = 14.886, p < .000 \]
Up to here
Syllabic markedness plays a role in judgment tasks.
Syllabic markedness plays a role in judgment tasks.

Do other markedness relations play a role?
Segmental markedness
Segmental markedness

How to calculate segmental markedness: count the number of times each segment occurs in UPSID. Thanks to Natasha Warner!
Segmental markedness

- How to calculate segmental markedness: count the number of times each segment occurs in UPSID. Thanks to Natasha Warner!

- We replicated Bailey & Hahn’s visual presentation experiment and found an independent effect of segmental markedness: items containing typologically more marked sounds are judged as less well-formed in the Bailey & Hahn visual presentation replication. [By subjects: phonotactic probability $F(1, 17) = 197.33, p < .000$; neighborhood density $F(1, 17) = 46.32, p < .000$; markedness $F(1, 17) = 21.96, p < .000$] and [By items: phonotactic probability $F(1, 254) = 43.98, p < .000$; neighborhood density $F(1, 254) = 10.33, p < 0.001$; markedness $F(1, 254) = 4.89, p < 0.02$]
The effect of markedness

![Graph showing the effect of markedness on response. The graph plots markedness on the y-axis against response on the x-axis. The data points suggest a trend where higher markedness is associated with lower response values.]
Desiderata

What properties must a correct model of judgments have?
Desiderata

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- a role for phonotactic probability;
Desiderata

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- a role for phonotactic probability;
- a role for neighborhood density;
Desiderata

What properties must a correct model of judgments have?

- a role for phonotactic probability;
- a role for neighborhood density;
- a role for markedness;
Toward a model
Toward a model

- Several (cognitive) machines operating in parallel.
Toward a model

- Several (cognitive) machines operating in parallel.
- Each machine produces a numerical result.
Toward a model

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- What machines?
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- What machines?
  - **Weighted Finite automaton** (WFSA) for language-specific frequency distributions and for typological patterns. (Initial weights reflect typological predispositions.)
Toward a model

- Several (cognitive) machines operating in parallel.
- Each machine produces a numerical result.
- Outputs of machines combined by linear regression.
- What machines?
  - Weighted Finite automaton (WFSA) for language-specific frequency distributions and for typological patterns. (Initial weights reflect typological predispositions.)
  - Something else for lexical items.
Initial weights for onset size
Reweighting by experience

<table>
<thead>
<tr>
<th>onset</th>
<th>before</th>
<th>after</th>
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<tbody>
<tr>
<td>fV</td>
<td>.009</td>
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<td>.007</td>
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<tr>
<td>fnrV</td>
<td>.005</td>
<td>.005</td>
</tr>
</tbody>
</table>

Weights here are illustrative.
Neighborhood density
Neighborhood density

A Model

Michael Hammond  (U. of Arizona)
Why are there different effects?
Why are there different effects?

- Corpora and acquisition don’t show obvious effects of sonority cline;
Why are there different effects?

- Corpora and acquisition don’t show obvious effects of sonority cline;
- Corpora involve real words;
Why are there different effects?

- Corpora and acquisition don’t show obvious effects of sonority cline;
- Corpora involve *real* words;
- Naturalistic observations of children involve *real* words;
Why are there different effects?

- Corpora and acquisition don’t show obvious effects of sonority cline;
- Corpora involve real words;
- Naturalistic observations of children involve real words;
- Experiments on adults can involve impossible words.
Conclusions
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- It can be especially informative to look at impossible words, rather than just possible words.
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- It can be especially informative to look at impossible words, rather than just possible words.
- Segmental and syllabic markedness play a role in gradient judgments.
- These factors may not play a role in corpus studies or observations of natural acquisition for methodological reasons.
- Typology and neighborhood density can be incorporated into judgments by using WFSAs and setting initial weights accordingly.