Segmental noun/verb phonotactic differences are productive too
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Overview

• Not all statistical patterns in a speaker’s lexicon are acquired productively
• The English lexicon has statistical noun/verb phonotactic differences involving stress, fricative voicing, and vowel backness
  - A cross-linguistic survey of noun/verb phonotactic differences found mostly prosodic patterns (stress, tone...), not segmental ones—why? A learning bias?
• Results of this experiment:
  - English speakers apply all three patterns productively to nonce words, even the segmental ones
• These results contribute to a growing body of evidence that typological gaps do not necessarily correspond to unlearnable patterns

1. Background: Are there segmental noun/verb phonotactic differences?

(1) Nouns and verbs can have different phonotactics (Kelly 1992, Bobaljik 2008)
  (a) In Mono, tone is contrastive for nouns but predictable for verbs (Olson 2005)
  (b) In English, disyllabic nouns are more likely to be trochees, while disyllabic verbs are more likely to be iambs (Kelly & Bock 1988)
  • While some apparent noun/verb differences reduce to free/bound differences, this is not a general explanation (Smith 2011)

(2) A typological survey of categorical noun/verb phonotactic differences (Smith 2011) finds that segmental asymmetries are rare
  (a) Attested: stress, pitch accent, tone, and word size/prosodic shape
  (b) Strikingly absent: segmental characteristics such as voicing or nasality

<table>
<thead>
<tr>
<th>Stress</th>
<th>Spanish, Hebrew, Lenakel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pitch accent</td>
<td>Japanese, Proto-Korean, Sibe, Ancient Greek</td>
</tr>
<tr>
<td>Tone</td>
<td>Mono, Proto-Bantu, Ewe, Lamang</td>
</tr>
<tr>
<td>Word size/prosodic shape</td>
<td>Hebrew, Mbabaram, Chuukese, Chukchee, Koryak, Arabic, Itelmen</td>
</tr>
<tr>
<td>Diachronic segment deletion(?)</td>
<td>Paamese, Mohawk</td>
</tr>
</tbody>
</table>

• details and references in Smith (2011)
(3) There are also gradient noun/verb differences, and some of these are segmental
• Examples from English of gradient N/V differences:
  (a) **Stress**: Disyllabic N more likely to be *trochee* (Chomsky & Halle 1968)

<table>
<thead>
<tr>
<th>Disyllables used only as...</th>
<th>N</th>
<th>Initial stress</th>
<th>Final stress</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nouns</td>
<td>3002</td>
<td>94%</td>
<td>6%</td>
</tr>
<tr>
<td>Verbs</td>
<td>1021</td>
<td>31%</td>
<td>69%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>All disyllabic items that are...</th>
<th>N</th>
<th>Initial stress</th>
<th>Final stress</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nouns</td>
<td>4218</td>
<td>89%</td>
<td>11%</td>
</tr>
<tr>
<td>Verbs</td>
<td>1676</td>
<td>46%</td>
<td>54%</td>
</tr>
</tbody>
</table>

(b) **Fricative voicing**: N more likely to end in *voiceless fricative* (Albright 2008; Jespersen 1942)
  • Related to the existence of N/V pairs such as *hou[s]eN, hou[z]ev*

(c) **Vowel backness**: N more likely than V to have back vowel in main-stress syllable (Sereno & Jongman 1990; Berg 2000)
  • CELEX data (Berg 2000): out of the 1000 most frequent N and V, how many are monomorphemic and have a front or back main-stress vowel?

<table>
<thead>
<tr>
<th></th>
<th>front vowel</th>
<th>back vowel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nouns</td>
<td>206 (45.7%)</td>
<td>245 (54.3%)</td>
</tr>
<tr>
<td>Verbs</td>
<td>249 (53.4%)</td>
<td>245 (54.3%)</td>
</tr>
</tbody>
</table>

(4) Previous nonce-word experiments testing for **productivity** of noun/verb differences in English found:
(a) **Stress** differences were productive (Kelly & Bock 1988; Guion et al. 2003)
  • Oral production of nonce words presented in N or V frames, plus (Guion et al.) forced-choice stress preference judgments for nonce words in N or V frames

(b) No effect for **segmental** patterns (Albright 2008)
  • Wordlikeness judgments for nonce words presented in N or V frames

(5) But there is evidence for the psychological reality of N/V segmental differences in actual words of English
  • Sereno & Jongman (1990): Reaction times are faster (for N/V labeling and for a lexical-decision task) when N had back vowels, V had front
  • Effect was found for high-frequency words only
(6) Recent experimental evidence for productivity of N/V differences still inconclusive
(a) Only/mostly prosodic patterns?
- **Artificial-language experiment** (Smith 2014): participants exposed to languages with N or V restricted for vowel inventory (segmental) or stress (prosodic)
- **Prosodic** pattern was indeed learned more accurately than **segmental** pattern
  - But, 5 vs. 3 vowels // 1 vs. 2 stress patterns—just a complexity difference?
(b) Even segmental patterns?
- **Emergent effects experiments** with nonce blends (Moreton et al., submitted) probed for category-specific faithfulness (N vs. V, proper N vs. common N)
- Category-specific resistance to **segmental** deletion was found—and effect was stronger than for **stress** faithfulness
  - This may be evidence that the grammar can indeed represent a category-specific difference in segmental phonology (if deletion is segmental)

(7) Focus of this study:
- Are segmental differences **productive**? How do they compare to stress?
(a) Use a potentially more sensitive methodology to test for productivity of segmental noun/verb differences: **fricative voicing**, **vowel backness**
(b) Test for productivity of the **stress** difference too, as a control

2. Experiment

(8) Task: Intended to emphasize noun/verb differences
(a) Hear nonce-word minimal pairs (auditory presentation only)
(b) Label each pair as “NOUN...VERB” or “VERB...NOUN”
- Two-alternative forced-choice design
- Practice items (3 pairs of real English words): served as diagnostic pretest

(9) Participants: 80 English-speaking adults, recruited through Mechanical Turk

(10) Stimuli: 36 nonce-word pairs | 3 conditions
(a) 12 pairs differed in **stress** ([ˈpel.tæk~pel.ˈtækt]); all disyllabic
  - Control condition—identical to stimuli used in previous nonce-word experiments that found a productivity effect for stress on English speakers’ noun/verb judgments (Kelly 1988; Guion et al. 2003)
(b) 12 pairs differed in the voicing of a final **fricative** ([plɛf~plɛv])
(c) 12 pairs differed in the backness of the stressed **vowel** ([pə.ˈdʒud~pə.ˈdʒid])
  - Fricative and vowel pairs included monosyllables, trochees, and iambs
(d) Presentation order within pairs counterbalanced; pairs randomly sequenced
Experiment: Instructions

Welcome

This survey is part of an experiment about how speakers of English decide whether an unfamiliar word is a noun or a verb.

First, we will ask you to practice identifying real English words as nouns or verbs. You must get all three practice questions correct to continue with the survey. The practice questions are not hard if you are comfortable with real nouns and verbs in English.

Then, we will ask you to listen to "new" words of English (which we have created for this survey) and decide which are nouns and which are verbs. There will be 36 pairs of words to judge, and it will take you about 6 minutes to listen to them all.

Next

Experiment: One trial

Which word is which?

Listen to these two words as many times as you like. Then decide which is the noun and which is the verb.

What do you think you are hearing?

- VERB ... NOUN
- NOUN ... VERB

Next
3. Results and analysis

(13) Results analyzed in two ways

(a) By response: How many responses overall conformed to the lexical pattern?
(b) By participant: How many participants had >50% conforming responses?

• Reason for including both approaches: To get a sense of whether there are distinct categories of participants with different response patterns

3.1 Results: All items

(14) Results by response—all items

• The coefficient estimates and standard errors from the logistic-regression model (see (15)) were used to derive 95% confidence intervals for each coefficient; logits were then converted to proportions

(15) Are the effects of each phonological pattern different from chance?\(^1\)

|                  | #conforming | #non-conforming | Estimate | Std. Error | \(z\) value | \(Pr(>|z|)\) |
|------------------|-------------|-----------------|----------|------------|-------------|-------------|
| Stress           | 632 (65.8%) | 328 (34.2%)     | 0.6839   | 0.1255     | 5.449       | \(p<0.0001\) *** |
| Fricatives       | 586 (61.0%) | 374 (39.0%)     | 0.4774   | 0.1248     | 3.824       | \(p=0.0001\) *** |
| Vowels           | 562 (58.5%) | 398 (41.5%)     | 0.3647   | 0.1243     | 2.934       | \(p=0.0033\) ** |

\(^1\)Logistic regression analysis; see Appendix B for details

(16) Is the magnitude of the effect of either fricative voicing or vowel backness different from that of stress?\(^2\)

|                  | #conforming | #non-conforming | Estimate | Std. Error | \(z\) value | \(Pr(>|z|)\)  |
|------------------|-------------|-----------------|----------|------------|-------------|--------------|
| (Stress)         | 632 (65.8%) | 328 (34.2%)     |          |            |             |              |
| Fricatives       | 586 (61.0%) | 374 (39.0%)     | -0.2066  | 0.1686     | -1.225      | \(p=0.2205\) n.s. |
| Vowels           | 562 (58.5%) | 398 (41.5%)     | -0.3192  | 0.1683     | -1.897      | \(p=0.0578\) . |

\(^2\)Logistic regression analysis; see Appendix B for details

(17) Summary: Analysis by response, all items

(a) All three phonological patterns had an effect significantly greater than chance

• More responses mapped the pattern to a noun/verb pair as predicted than would be expected due to chance

(b) The stress pattern and the fricative voicing pattern had the strongest effect

• Magnitude of effect not significantly different
(c) The vowel backness pattern was perhaps not quite as strong
- Magnitude of effect marginally significantly different from that of stress

(18) Results by participant (80 participants total)—all items
- How many participants had more than 6 out of 12 (>50%) conforming responses?
- Color key for graphs: □ <6 | □ =6 | △ >6 conforming responses

![Histograms of performance by participant for stress, fricatives, and vowels.](image)

Exact binomial test, one-tailed (compare >6 participants with <6; chance=50%)
- Stress: 58/(80–11) (84%) \( p < 0.00001 \)
- Fricatives: 51/(80–12) (75%) \( p = 0.00002 \)
- Vowels: 51/(80–9) (72%) \( p = 0.00015 \)

(19) Summary: Analysis by participant, all items
(a) All three phonological patterns had an effect significantly greater than chance
   - More participants mapped the pattern to a noun/verb pair as predicted than would be expected due to chance
(b) Numerically, the effects were stress > fricative voicing > vowel backness

3.2 Results: Non-morphologically supported items only

(20) Possible reasons why the effect of vowel backness might be comparatively small
(a) Weak lexical evidence for the N/V difference? (see (3)(c))
(b) Lack of evidence from morphologically related N/V pairs?

(21) In general: Can we confirm the effects in §3.1 are phonological, not morphological?
(a) Stress pairs exist: \( p\text{erm}it_N, \text{perr}mit_V \)
(b) Fricative voicing pairs exist: \( hou[s]e_N, hou[z]e_V \)
(c) Some vowel backness pairs exist: \( f[u:]d_N, f[i:]d_V \)
   - Could participants be assigning N/V based on knowledge of these relationships?
Morphologically supported pattern = has lexical N/V (near-)minimal pairs

(a) Morphologically supported patterns = stress, fricative voicing, [uː]~[iː]
(b) Non-morphologically supported patterns = [ʊʊ]~[ɛɪ], [æ]~[ɑ]
  • 8 of the 12 vowel backness items

Results by response across all participants—non-morphological

• 95% confidence intervals as in (14)

Are the results of the non-morphological items different from chance?³

|          | #conforming | #non-conforming | Estimate | Std. Error | z value | Pr(>|z|) |
|----------|-------------|-----------------|----------|------------|---------|----------|
| Non-morph| 367 (57.3%) | 273 (42.7%)     | 0.3379   | 0.1849     | 1.827   | 0.0677   |

³Logistic regression analysis; see Appendix B for details

Summary: Analysis by response, non-morphological items only
(a) Numerically, more responses mapped the pattern to a noun/verb pair as predicted than the reverse
(b) However, this effect is only marginally statistically significant
  • Data set is also considerably smaller (640 vs. 2880 observations, or 1:4.5)

Results by participant (80 participants)—non-morphological items only
• How many participants had at least 5 out of 8 (>50%) conforming responses?
• Color key for graph: □ <4 | □ =4 | ■ >4 conforming responses

Summary: Analysis by participant, non-morphological items only
(a) More participants matched the pattern to a noun/verb pair as predicted than would be expected due to chance
(b) Effect is not as strong as in the full data set, however
- Still evidence for **phonological** effect of vowel backness on N/V assignment
- But patterns that are **morphologically** supported appear to be more productive

4. Implications

**(28)** Full data set

(a) All three patterns (stress, fricative voicing, vowel backness) had an effect significantly greater than chance
- Significant both by overall responses and by individual participant
(b) The stress (control) pairs replicated findings (Kelly 1988; Guion et al. 2003) that trochaic nonce-words (vs. iambics) are more likely to be labeled as nouns
(c) Effect also found for [–voice] final fricatives (vs. [+voice]), and for [+back] stressed vowels (vs. [–back])
- Vowel backness effect marginally statistically weaker than stress effect

**(29)** Non-morphologically supported items (subset of the vowel-backness items) still showed effects, but not as strongly

(a) Analysis by participant was statistically significant
(b) Analysis by responses was marginally statistically significant
- This difference between the two types of analysis seems to show that **more participants than expected by chance** show a **relatively weak effect** of **vowel backness** in non-morphological items (see (26))

**(30)** The status of a pattern as **morphologically supported** seems to be **more influential** than the status of a pattern as **prosodic vs. segmental**
- The nature of the task (stimuli were minimal pairs) may have encouraged participants to think about potential morphological relationships

**(31)** Implications for category-sensitive phonological differences

(a) The typological asymmetry favoring prosodic patterns probably does not directly reflect a learning bias
(b) We need to look elsewhere:
- Difference in pattern complexity?
- Difference in the kinds of evidence learners can see in the input?

**(32)** Implications for sources of phonological typology
- Adds to the growing body of examples of gaps in typology that do not correspond to unlearnable patterns
Acknowledgments

- Thanks to Elliott Moreton, Katya Pertsova, Michael Becker, Sarah Finley, Adam Albright, and audiences at LAGB 2014 and the UNC-CH Phonology/Phonetics Research Group for comments and discussion on this and related material
- Thanks to Chris Wiesen of the Odum Institute for Research in Social Science, UNC-CH, for statistical consultation
- Thank you!

Appendix A: Experiment stimuli

<table>
<thead>
<tr>
<th>Fricative voicing</th>
<th>Vowel backness</th>
<th>Stress</th>
</tr>
</thead>
<tbody>
<tr>
<td>N-like</td>
<td>N-like</td>
<td>Form</td>
</tr>
<tr>
<td>slآثار f</td>
<td>glv:ι</td>
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<td>pυ:ι.'фαυδ</td>
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</table>

<table>
<thead>
<tr>
<th>V-like</th>
<th>V-like</th>
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</tbody>
</table>

Appendix B: Details of the logistic-regression analyses

(33) Results by response, all items (see (15))

|                  | #conforming | #non-conforming | Estimate | Std. Error | z value | Pr(>|z|)   |
|------------------|-------------|-----------------|----------|------------|---------|------------|
| Stress           | 632 (65.8%) | 328 (34.2%)     | 0.6839   | 0.1255     | 5.449   | p<0.0001 *** |
| Fricatives       | 586 (61.0%) | 374 (39.0%)     | 0.4774   | 0.1248     | 3.824   | p=0.0001 *** |
| Vowels           | 562 (58.5%) | 398 (41.5%)     | 0.3647   | 0.1243     | 2.934   | p=0.0033 **  |

Generalized linear mixed model fit by the Laplace approximation

This analysis models the probability of conforming responses, in terms of:
- Phonological pattern | stress, fricatives, or vowels
- Items and participants are included as random effects

9
Comparison of fricative items and vowel items with stress items (see (16))

| (# conforming | # non-conforming | Estimate | Std. Error | z value | Pr(>|z|) |
|---------------|------------------|----------|------------|---------|----------|
| (Stress) 632 (65.8%) | 328 (34.2%) |           |            |         |          |
| Fricatives 586 (61.0%) | 374 (39.0%) | -0.2066 | 0.1686 | -1.225 | p=0.2205 n.s. |
| Vowels 562 (58.5%) | 398 (41.5%) | -0.3192 | 0.1683 | -1.897 | p=0.0578 . |

Generalized linear mixed model fit by the Laplace approximation
This analysis models difference from stress in prob. of conforming responses, in terms of:
- Phonological pattern | stress vs. fricatives, stress vs. vowels
- Items and participants are included as random effects

For (33)–(34):

<table>
<thead>
<tr>
<th>AIC</th>
<th>BIC</th>
<th>logLik</th>
<th>deviance</th>
</tr>
</thead>
<tbody>
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<td>3777.4</td>
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</tr>
</tbody>
</table>

Number of observations: 2880, participants, 80; items, 36

(35) Results by response, non-morphological items (see (24))

| (# conforming | # non-conforming | Estimate | Std. Error | z value | Pr(>|z|) |
|---------------|------------------|----------|------------|---------|----------|
| Non-morph 367 (57.3%) | 273 (42.7%) | 0.3379 | 0.1849 | 1.827 | p=0.0677 . |

Generalized linear mixed model fit by the Laplace approximation
This analysis models the probability of conforming responses for non-morphological items
- Items and participants are included as random effects

<table>
<thead>
<tr>
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<th>BIC</th>
<th>logLik</th>
<th>deviance</th>
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<tbody>
<tr>
<td>854.2</td>
<td>867.6</td>
<td>-424.1</td>
<td>848.2</td>
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</tbody>
</table>

Number of observations: 640, participants, 80; items, 8

References


