The Psychological Reality of a Rime Size Constraint in Dutch

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1. Are Phonotactics Phonology?

• Phonotactics: Restrictions on the sound shape of words, with or without alternations
• Null hypothesis: Words are memorized; no knowledge of patterns.
• BUT: Patterns generalize to nonce words. (e.g. Chomsky & Halle 1968)
• BUT: Is this knowledge phonological?
• Alternative hypothesis: Speakers know the statistics of segmental sequences.
What are ‘Segmental Statistics’?

- n-phone (di-phone, tri-phone) probabilities
  - e.g. probability [ba] = probability [a] / [b_]
- lexical neighborhood of a word: number of words produced by changing one phoneme
  - e.g. LN [kæt] = {[bæt], [kɪt], [kæp], [æt], [kæst] etc.}
- n-phones and lexical neighborhoods are independent predictors of word-likeness judgments
  (Vitevitch & Luce 1997; Bailey & Hahn 2001)
Phonology Versus Raw Segmental Statistics

• Phonological generalization defined
  – Featural generalization: ones that go beyond segmental statistics (e.g. generalization to unattested sequences – English plural of *Bach*)
  – Reference to supra-segmental structure: generalizations based on syllabic or other prosodic constituency
Experimental Designs

• Control for segmental statistics, test for phonological generalization
  – E.g. Frisch and Zawaydeh (2001) on Arabic OCP-Place,

• Regression analysis using segmental statistics and phonological generalizations as factors
  – E.g. Albright (2007) on English…
Restrictions on Non-Adjacent Segments

• Studies of restrictions between non-adjacent consonants provide evidence that a simple diphone probability account is inadequate.

• However, diphone statistics could be calculated over non-adjacent consonants separated by vowels (e.g. over autosegmental projections).
  – Newport & Aslin (2004); Hayes & Wilson (to appear)

• Cases that cannot be re-analyzed by projections?
2. Our Study

- A type of generalization that goes beyond diphone frequency: restrictions on longer sequences
- General schema: *ABB where AB & BB are OK
- Dutch rime(?) restriction
  - *VːCC] but VːC], CC] are both OK
    (Moulton 1962; Trommelen 1983; Kager 1989)
- Cannot be reduced to diphone frequency, even adding projections
Dependence on Syllable Structure?

• Examples suggesting a rime-sized restriction
  – pa:l ‘pole’  pælm ‘palm’  *pa:lm
  – stoːm ‘steam’  stɔmˈp ‘dull’  *stoːmp
  – haːr ‘hair’  hærp ‘harp’  *haːrp
  – meːl ‘flour’  mɛlk ‘milk’  *meːlk

• However, the same V:CC sequences are also rare in disyllabic words.
  – zoːmər ‘summer’  dɔmpəlˈimmerse’  *dɔːmpəl
  – kaːpər ‘hijacker’  kærpər ‘carp’  *kærpər
  – teːlevizi ‘television’  tɛlkəns ‘each time’  *teːlkəns
  Exceptions: /tuːrməlˈæin/ ‘tourmaline’, /buːrkaː/ ‘burqa’ etc.
A Note on Coronals

• *V:CC only holds before clusters that have non-coronals in second position
  – tautosyllabic  bəːlt ‘image’  pəːrs ‘purple’
• Analysis of word-final coronals as extrasyllabic
  (Trommelen 1983; Kager & Zonneveld 1986)
• fails to predict pre-vocalic *V:CC_{cor}
  – heterosyllabic  aːrdə ‘earth’  aːrzəl ‘hesitate’
• In sum, no evidence for syllable-dependency of *V:CC
A Note on Epenthesis

• Schwa epenthesis applies (optionally) to clusters Liquid + Noncoronal
  – frequent in tautosyllabic clusters  *half*  ‘half’
  – more rarely in heterosyllabic clusters  *zilver*  ‘silver’

• This shows the syllable-dependency of epenthesis, not of *V:CC*

• In any case, epenthesis is not driven by *V:CC*]
Lexical Statistics (I)

- Under-representation of $V:CC_{[-\text{cor}]}$
  - Created a monomorphemic word lexicon from CELEX (Baaijen, Piepenbrock & Gulikers 1995)
  - 8,305 words; 2,752 VCC strings
  - Counted $V$, $V:CC_{[+\text{cor}]}$, $CC_{[-\text{cor}]}$
  - $\chi^2 = 97.5$; $p = 0.000$
## Frequencies of VCC Portions (CELEX, monomorphemic words)

<table>
<thead>
<tr>
<th></th>
<th>V</th>
<th>V:</th>
</tr>
</thead>
<tbody>
<tr>
<td>VCC_{+cor}</td>
<td>1478</td>
<td>369</td>
</tr>
<tr>
<td>VCC_{-cor}</td>
<td>885</td>
<td>20</td>
</tr>
</tbody>
</table>
Lexical Statistics (II)

• Cases of $^{*}V:\text{CC}_{[-\text{cor}]}$ are equally rare in word-final and pre-vocalic positions
  – Used the same monomorphic word lexicon
  – 8,305 words; 905 $\text{VCC}_{[-\text{cor}]}$ strings
  – Counted word-final and pre-vocalic $\text{VCC}_{[-\text{cor}]}$ $^{*}V:\text{CC}_{[-\text{cor}]}$
    – $\chi^2 = 0.35$; $p = 0.55$

• Hence, lexical statistics do not predict any distinction in well-formedness between tauto-syllabic and hetero-syllabic cases of $^{*}V:\text{CC}$
Frequencies of $VCC_{[-\text{cor}]}$ Portions (CELEX, monomorphemic words)

<table>
<thead>
<tr>
<th></th>
<th>V</th>
<th>$V_i$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$VCC_{[-\text{cor}]}$ #</td>
<td>272</td>
<td>3</td>
</tr>
<tr>
<td>$VCC_{[-\text{cor}]}$ V</td>
<td>565</td>
<td>11</td>
</tr>
</tbody>
</table>
Lexical Statistics (III)

- The under-representation of $V:CC_{[-\text{cor}]}$ triphones cannot be predicted from diphones
- Collected all triphones $\ N = 23,915$
- Calculated Observed/Expected ratio
  - probability of $V:C$ $p_1 = 0.1619$
  - probability of $CC_{[-\text{cor}]}$ $p_2 = 0.0384$
  - expected $V:CC_{[-\text{cor}]}$ $E = p_1 \times p_2 \times N = 149$
  - observed $V:CC_{[-\text{cor}]}$ $O = 20$
  - O/E ratio $O/E = 0.1344$
Lexical Statistics (IV)

- The under-representation of V:CC\textsubscript{[-cor]} triphones cannot be predicted from diphones within rimes
- Sum of VCC rimes \( N = 962 \)
- Calculated Observed/Expected ratio
  - probability of V:CC \( p_1 = 0.1757 \)
  - probability of VCC\textsubscript{[-cor]} \( p_2 = 0.2911 \)
  - expected V:CC\textsubscript{[-cor]} \( E = p_1 \times p_2 \times N = 49 \)
  - observed V:CC\textsubscript{[-cor]} \( O = 3 \)
  - O/E ratio \( O/E = 3/49 = 0.0612 \)
Research Questions

• Have Dutch speakers internalized the long constraint *V:CC?
  – Are long vowels more strongly dispreferred before clusters than before singletons?

• Does syllable constituency affect their judgements?
  – Is the dispreference of long vowels before clusters stronger in monosyllables than in polysyllables?
Stimuli

• Monosyllables: 4 sets of 30 non-words
  – CVC, CV:C, CVCC, CV:CC
  – Clusters: $C_1 \in \{l \ r \ m\}$, $C_2 \in \{p \ f \ k \ x \ m\}$

• Disyllables: 4 sets of 30 non-words
  – Clusters: $C_1 \in \{l \ r \ m\}$, $C_2 \in \{p \ b \ f \ v \ m \ k \ x \ G\}$
  – Final $C \in \{l \ r\}$ non-identical to $C_1$
### Examples of Stimuli

<table>
<thead>
<tr>
<th>CVC</th>
<th>CV:C</th>
<th>CV:CC</th>
<th>CV:CCeC</th>
<th>CV:CCeC</th>
</tr>
</thead>
<tbody>
<tr>
<td>bam</td>
<td>ba:m</td>
<td>bamk</td>
<td>ba:mk</td>
<td></td>
</tr>
<tr>
<td>xol</td>
<td>xo:l</td>
<td>xolm</td>
<td>xo:lm</td>
<td></td>
</tr>
<tr>
<td>CVCeC</td>
<td>CV:CeC</td>
<td>CV:CeC</td>
<td>CV:CeC</td>
<td>CV:CeC</td>
</tr>
<tr>
<td>dɛmɛɾ</td>
<td>de:mer</td>
<td>dɛmxɛɾ</td>
<td>de:mxɛɾ</td>
<td></td>
</tr>
<tr>
<td>jolɛɾ</td>
<td>jo:ler</td>
<td>jolbaɾ</td>
<td>jo:lbær</td>
<td></td>
</tr>
</tbody>
</table>
Statistical Controls in Stimulus Set

- We controlled between short/long classes, e.g. CVC versus CV:C, CVCC versus CV:CC
  - n-phones (diphone and triphone TPs)
  - Lexical Neighborhood Density and Cohort Density
- Possible residual effects of segmental statistics were assessed in a regression model of the results
- Hence, segmental statistics were controlled in the stimulus set as well as tested in the results
Experiment 1
Wordlikeness Rating

- Subjects: 20 native Dutch (linguistics students)
- Subjects asked to rate word-likeness of nonce words on 7-point scale
- 240 stimuli, 124 fillers played over headphones
- Stimulus order randomized between subjects
- Self-paced task
## Results of Experiment 1

<table>
<thead>
<tr>
<th></th>
<th>Monosyllabic</th>
<th></th>
<th>Disyllabic</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Singleton</td>
<td>Cluster</td>
<td>Singleton</td>
<td>Cluster</td>
</tr>
<tr>
<td>Short vowel</td>
<td>3.74</td>
<td>2.38</td>
<td>3.95</td>
<td>3.19</td>
</tr>
<tr>
<td>Long vowel</td>
<td>3.81</td>
<td>1.98</td>
<td>3.97</td>
<td>3.01</td>
</tr>
<tr>
<td>Δ Rating</td>
<td>+0.07</td>
<td>–0.40</td>
<td>+0.03</td>
<td>–0.18</td>
</tr>
</tbody>
</table>
Results of Experiment 1

Monosyllables

Disyllables

Singleton
Cluster

Rating
4.5
4
3.5
3
2.5
2
1.5

Short  Long

Rating
4.5
4
3.5
3
2.5
2
1.5

Short  Long
Statistical Analysis

• Differential scores: differences in rating between short-long pairs
  
  CVC – CVːC  
  CVCC – CVːCC  
  CVCːC – CVːCːC  
  CVCCːC – CVːCCːC

• Two-factor ANOVA, with factors
  – Cluster: Δ short-long related to singleton-cluster
  – Syllable: Δ short-long related to syllable number

• Repeated measures on both factors

• Four differential scores for each subject

• 80 data points: 20 subjects * 4 differential scores
## Structure of the ANOVA

<table>
<thead>
<tr>
<th></th>
<th>Singleton</th>
<th>Cluster</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Monosyllabic</strong></td>
<td>(\Delta) short - long for <strong>monosyllables</strong> with <strong>singletons</strong>, for each of 20 subjects</td>
<td>(\Delta) short - long for <strong>monosyllables</strong> with <strong>clusters</strong>, for each of 20 subjects</td>
</tr>
<tr>
<td><strong>Disyllabic</strong></td>
<td>(\Delta) short - long for <strong>disyllables</strong> with <strong>singletons</strong>, for each of 20 subjects</td>
<td>(\Delta) short - long for <strong>disyllables</strong> with <strong>clusters</strong>, for each of 20 subjects</td>
</tr>
</tbody>
</table>
Testing Hypothesis 1

• H1: Long vowels are more strongly dispreferred before clusters than before singletons

• Prediction 1: There should be a main effect of the factor Cluster

• ANOVA
  – Main effect, Cluster $F_{(1,79)} = 9.87$  $p = 0.005$

• Interpretation: H1 is supported
Testing Hypothesis 2

• H2: Long vowels before clusters are more strongly dispreferred in monosyllables than in disyllables

• Prediction 2: There should be an interaction of the factors Cluster and Syllable

• ANOVA
  – Main effect, Cluster $F_{(1,79)} = 9.87$ $p = 0.005$
  – No effect, Syllable $F_{(1,79)} = 0.93$ $p = 0.347$
  – Interaction, C * S $F_{(1,79)} = 4.25$ $p = 0.053$

• Interpretation: H2 is (marginally) supported
Regression Analysis

• Checking the independence of the rime constraint of non-phonological factors (for monosyllables)

• Phonological factors
  – Effect of CLUSTER (t = 5.4; p = 0.000)
  – No effect of V-LENGTH
  – Interaction, CLUSTER * V-LENGTH (t = 1.9; p = 0.062)

• Non-phonological factors
  – diphone TPs (t = 4.0; p = 0.000)
  – Lexical Neighborhood Density (t = 1.5; p = 0.000)
Experiment 1: Discussion

• Hypothesis 1 is strongly supported, suggesting that the abstract constraint *V:CC is internalized
• Segmental statistics cannot explain this
• Hypothesis 2 is marginally supported, suggesting that the internalized constraint is sensitive to the syllable
• Segmental statistics cannot explain this
• No overall effect of vowel length: controlled for
• Clusters rated worse than singletons: this was not controlled for
Experiment 2
Comparative Wordlikeness

• Subjects asked to select the most word-like item of a pair of non-words

• Comparative wordlikeness has been found to bring out finer-grained differences in word-likeness as compared to absolute scaling (Experiment 1)
  Berent & Shimron (1997); Coetzee (2007)

• Expectation: a comparative wordlikeness study should bring out the syllable-dependency of the *V:CC constraint even more clearly
Experiment 2
Comparative Wordlikeness

- Subjects: 34 native Dutch (linguistics students)
- Subjects asked to select the most word-like item of a stimulus pair
- 120 target pairs, 120 filler pairs, played over headphones
- Target pairs differed mainly on short-long vowel
- Stimulus order randomized between subjects
- Non-self-paced (interstimulus interval 200 msec)
## Results of Experiment 2

<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Singleton</td>
<td>Cluster</td>
</tr>
<tr>
<td><strong>Short vowel</strong></td>
<td>0.557</td>
<td>0.685</td>
</tr>
<tr>
<td><strong>Long vowel</strong></td>
<td>0.385</td>
<td>0.221</td>
</tr>
<tr>
<td><strong>Δ Rating</strong></td>
<td>-0.172</td>
<td>-0.464</td>
</tr>
</tbody>
</table>
Results of Experiment 2
Hypotheses 1 & 2

• H1: Long vowels are more strongly dispreferred before clusters than before singletons
  – Prediction: There should be an interaction of cluster and length

• H2: Long vowels before clusters are more strongly dispreferred in monosyllables than in disyllables
  – Prediction: There should be a three-way interaction of cluster, length, and syllable count

• Logistic regression model used
Testing the Hypotheses

• Effects of phonological factors
  – LONG (p=0.000), CLUS (p=0.003)
  – LONG * CLUS (p=0.000), LONG * SYLL (p=0.000)
  – LONG * CLUS * SYLL (p=0.001)

• Predictions from both hypotheses were confirmed

• Phonological factors found to be independent of
  – segmental statistics (diphone TPs)
  – lexical factors (Lexical Neighborhood Density, Cohort Density)
Conclusions

• Evidence for an internalized constraint *V:CC
• Evidence that this constraint is rime-based
• Evidence that this constraint is abstract, i.e. cannot be reduced to lexical statistics
Why should learners internalize *VCC as syllable-dependent?

• Assumptions we would like to make:
  – Long distance segmental dependencies involve reference to suprasegmental structure
  – Constraints stated in terms of vowel length and consonant clusters naturally refer to the syllable

• Assumptions we do not make:
  – Phonotactic constraints are generally syllable-dependent