The Psychological Reality of a Rime Size Constraint in Dutch

René Kager (Utrecht University)
Joe Pater (University of Massachusetts, Amherst)

Universiteit Utrecht

NWO Nederlandse Organisatie voor Wetenschappelijk Onderzoek

Department of Linguistics
University of Massachusetts Amherst

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.
  - Frisch & Zawaydeh (1997); Berent & Shimron (1997)
- 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
  - paːl ‘pole’ pɑlm ‘palm’ *paːlm
  - stoːm ‘steam’ stɔmp ‘dull’ *stoːmp
  - haːr ‘hair’ hɑrp ‘harp’ *haːrp
  - meːl ‘flour’ mɛlk ‘milk’ *meːlk

  Exceptions: /twaːlf/ ‘twelve’, /hiːlp/ ‘helped’, etc.

- However, the same VːCC sequences are also rare in disyllabic words.
  - zoːmər ‘summer’ dɔmpəl ‘immerse’ *doːmpəl
  - kaːpər ‘hijacker’ kɑrpər ‘carp’ *kaːrpər
  - teːlevizi ‘television’ tɛlkəns ‘each time’ *teːlkəns

  Exceptions: /tuːrmalɛin/ ‘tourmaline’, /buːrkaː/ ‘burqa’ etc.

A Note on Coronals

- *VːCC only holds before clusters that have non-coronals in second position
  - tautosyllabic beːlt ‘image’ paːrs ‘purple’
- Analysis of word-final coronals as extrasyllabic (Trommelen 1983; Kager & Zonneveld 1986)
- fails to predict pre-vocalic *VːCC$_{[cor]}$
  - heterosyllabic aːrdə ‘earth’ aːrzəl ‘hesitate’
- In sum, no evidence for syllable-dependency of *VːCC

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 *VːCC
- In any case, epenthesis is not driven by *VːCC]

Lexical Statistics (I)

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

Frequencies of VCC Portions (CELEX, monomorphemic words)

	V	Vː
$VCC_{[+cor]}$	1478	369
$VCC_{[-cor]}$	885	20

Lexical Statistics (II)

- Cases of *VːCC$_{[-cor]}$ are equally rare in word-final and pre-vocalic positions
  - Used the same monomorphemic word lexicon
  - 8,305 words; 905 VCC$_{[-cor]}$ strings
  - Counted word-final and pre-vocalic VCC$_{[-cor]}$ VːCC$_{[-cor]}$
  - $\chi^2 = 0.35$; $p = 0.55$
- Hence, lexical statistics do not predict any distinction in well-formedness between tauto-syllabic and hetero-syllabic cases of *VːCC

Frequencies of $VCC_{[-cor]}$ Portions (CELEX, monomorphemic words)

	V	Vː
$VCC_{[-cor]}$ #	272	3
$VCC_{[-cor]}$ V	565	11

Lexical Statistics (III)

- The under-representation of $V\!:\!CC_{[-cor]}$ 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 $CC_{[-cor]}$ $p_2 = 0.0384$
  - expected $V\!:\!CC_{[-cor]}$ $E = p_1 * p_2 * N = 149$
  - observed $V\!:\!CC_{[-cor]}$ $O = 20$
  - O/E ratio $O/E = 0.1344$

Lexical Statistics (IV)

- The under-representation of Vː$CC_{[-cor]}$ triphones cannot be predicted from diphones within rimes
- Sum of VCC rimes N = 962
- Calculated Observed/Expected ratio
  - probability of VːCC $p_1 = 0.1757$
  - probability of $VCC_{[-cor]}$ $p_2 = 0.2911$
  - expected Vː$CC_{[-cor]}$ $E = p_1 * p_2 * N = 49$
  - observed Vː$CC_{[-cor]}$ O = 3
  - O/E ratio O/E = 3/49 = 0.0612

Research Questions

- Have Dutch speakers internalized the long constraint *Vː 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, CVːC, CVCC, CVːCC
  - Clusters: $C_1 \in \{l\ r\ m\}$, $C_2 \in \{p\ f\ k\ x\ m\}$
- Disyllables: 4 sets of 30 non-words
  - CVCəC, CVːCəC, CVCCəC, CVːCCəC
  - 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

CVC	CVːC	CVCC	CVːCC
bɑm	baːm	bɑmk	baːmk
xɔl	xoːl	xɔlm	xoːlm
CVCəC	CVːCəC	CVCCəC	CVːCCəC
dɛmər	deːmər	dɛmxər	deːmxər
jɔlər	joːlər	jɔlbər	joːlbər

Statistical Controls in Stimulus Set

- We controlled between short/long classes, e.g. CVC versus CVːC, CVCC versus CVːCC
  - *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

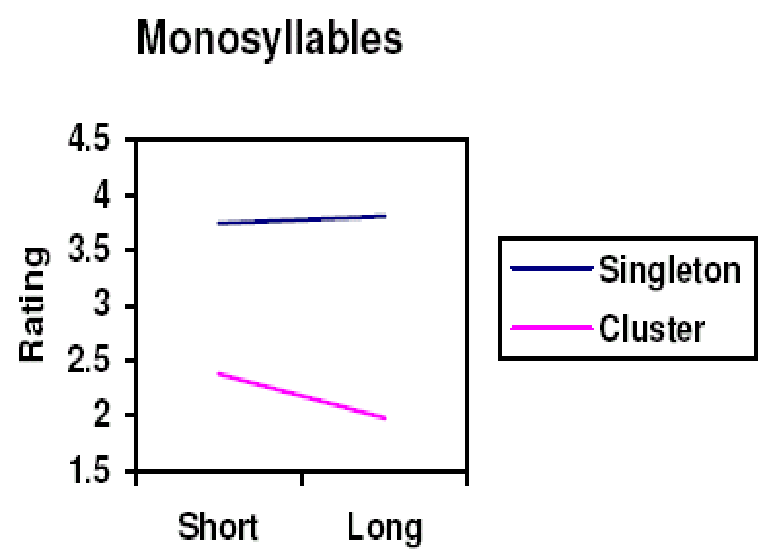
Experiment 1
Wordlikeness Rating

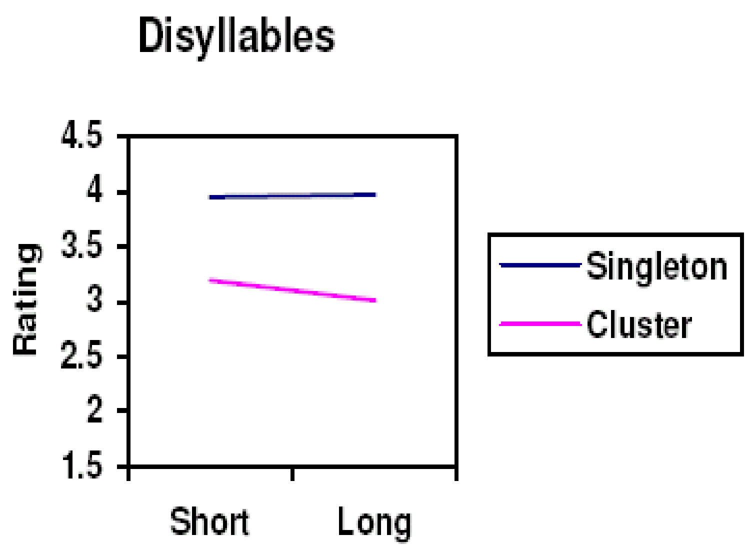
- Subjects: 20 native Dutch (linguistics students)
- Subjects asked to rate word-likeness of nonce words on 7-point scale
- 240 stimuli, 124 fillers played over headphones
- Stimulus order randomized between subjects
- Self-paced task

Results of Experiment 1

	Monosyllabic		Disyllabic	
	Singleton	Cluster	Singleton	Cluster
Short vowel	3.74	2.38	3.95	3.19
Long vowel	3.81	1.98	3.97	3.01
Δ Rating	+0.07	–0.40	+0.03	–0.18

Results of Experiment 1





Statistical Analysis

- Differential scores: differences in rating between short-long pairs

  CVC – CVːC CVCəC – CVːCəC

  CVCC –CVːCC CVCCəC – CVːCCəC

- 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

	Singleton	Cluster
Monosyllabic	Δ short - long for **monosyllables** with **singletons**, for each of 20 subjects	Δ short - long for **monosyllables** with **clusters**, for each of 20 subjects
Disyllabic	Δ short - long for **disyllables** with **singletons**, for each of 20 subjects	Δ short - long for **disyllables** with **clusters**, for each of 20 subjects

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 *VːCC 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 *VːCC constraint even more clearly

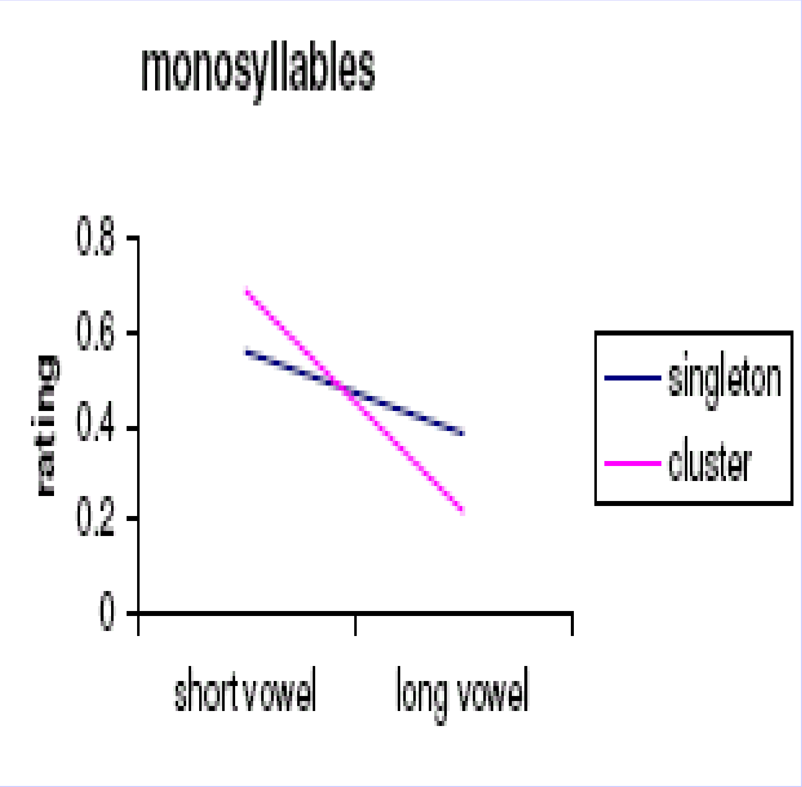
Experiment 2
Comparative Wordlikeness

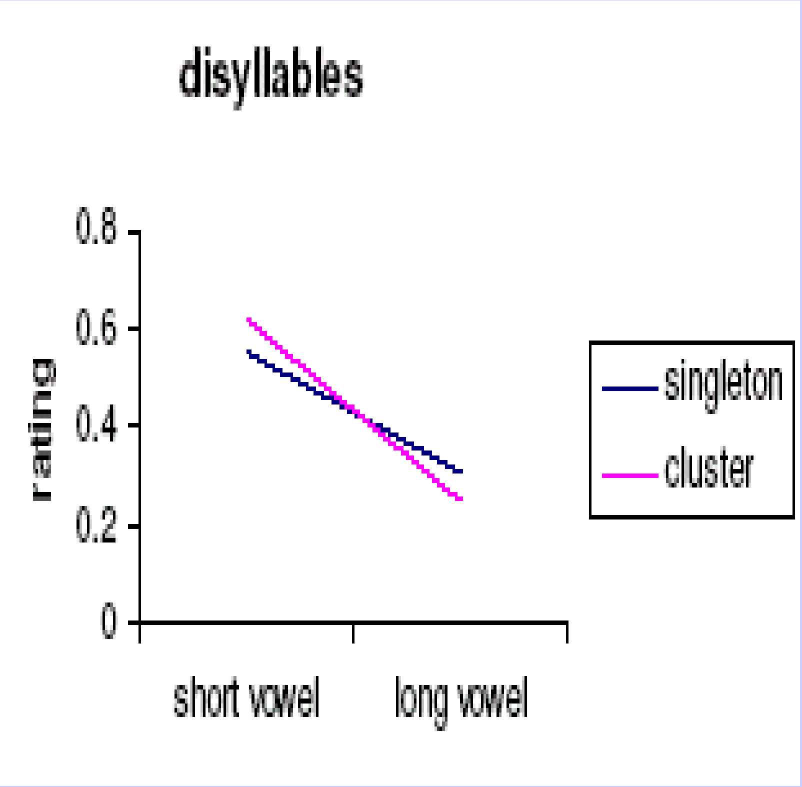
- Subjects: 34 native Dutch (linguistics students)
- Subjects asked to select the most word-like item of a stimulus pair
- 120 target pairs, 120 filler pairs, played over headphones
- Target pairs differed mainly on short-long vowel
- Stimulus order randomized between subjects
- Non-self-paced (interstimulus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

Results of Experiment 2

	Monosyllabic		Disyllabic	
	Singleton	Cluster	Singleton	Cluster
Short vowel	0.557	0.685	0.554	0.616
Long vowel	0.385	0.221	0.311	0.247
Δ Rating	-0.172	-0.464	-0.243	-0.369

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 *Vː 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