Speakers apply morphological dependencies in the inflection of novel forms

Guy Tabachnick

New York University

University of Connecticut LingLunch,
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Introduction

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- irregulars: English plural *oxen*, *sheep*, *syllabi*
- inflection classes: Russian nouns in class I–IV

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Arbitrary inflection of lexical items must be somehow *grammatically marked*

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Gradient patterns and productivity

Productive extension of gradient lexical patterns

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  - Gouskova et al. (2015): Russian masculine nouns ending in consonant clusters form diminutives with -ik, not -ok or tʃʲik
- Correlations between inflected forms can be handled using the same grammatical tools

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  - Grammar induces identity, e.g. through shared structure, underspecification, impoverishment
  - Ex: Russian agreement doesn't show gender distinctions in the plural → rule deletes gender features in the context of PL

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  - Grammar induces identity, e.g. through shared structure, underspecification, impoverishment
  - Ex: Russian agreement doesn't show gender distinctions in the plural → rule deletes gender features in the context of PL
- Inflection class: lexical items "whose members each select for the same set of inflectional realizations" (Aronoff, 1994: 64)
  - Often assumed as discrete units of analysis, e.g. Russian "class I" (Corbett and Fraser, 1993; Müller, 2004; Caha, 2021)
  - These "macroclasses" often hide overlaps and complexities in inflectional patterns (Cameron-Faulkner and Carstairs-McCarthy, 2000; Finkel and Stump, 2007; Ackerman et al., 2009; Ackerman and Malouf, 2013; Bonami and Beniamine, 2016; Parker and Sims, 2020)

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- Not a new insight (see Wurzel, 1989), but rarely discussed in generative work (rare exception: Halle and Marantz (2008))
- Well-established in lexicon (e.g. Ackerman et al., 2009; Ackerman and Malouf, 2013), but rarely if ever tested experimentally (rare exception: Bybee and Moder (1983))
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These patterns can be learned as *phonotactics*

Outline

Morphological arbitrariness

- Arbitrary inflection of exceptional lexical items must be *grammatically marked*
- One common approach: *morphological features* (e.g. Lieber, 1980; Corbett and Baerman, 2006) that are attached as *diacritics* to lexical entries

Morphological arbitrariness

- Arbitrary inflection of exceptional lexical items must be *grammatically marked*
- One common approach: *morphological features* (e.g. Lieber, 1980; Corbett and Baerman, 2006) that are attached as *diacritics* to lexical entries
- Common subtype: *inflection class features*, which group together lexical items "whose members each select for the same set of inflectional realizations" (Aronoff, 1994: 64)

Inflection class features: the case of Russian

Russian feminine nouns: class II and III (Corbett and Baerman, 2006)

class	II	III
example	'newspaper'	'bone'
nominative	gazet-a	$kost^{j}$
dative	gazet-e	$kost^{j}$-i
instrumental	gazet-oj	$kost^{j}$-ju

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Feature-based analysis of Russian

The features II and III are each referenced in *multiple* (DM-style) *vocabulary insertion rules* (see Halle and Marantz, 1993; Müller, 2004; Embick and Marantz, 2008)

(1) *Vocabulary insertion rules for Russian cases*

a. NOM ↔ a / II ___
b. DAT ↔ e / II ___
c. INS ↔ oj / II ___
d. NOM ↔ Ø / III ___
e. DAT ↔ i / III ___
f. INS ↔ ju / III ___

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f. INS $\leftrightarrow$ ju / III ___

(2) *Lexical entries for Russian nouns*

a. II: /gazet_{II}/ 'newspaper', /tʃert_{II}/ 'characteristic', /$\text{dol}^{\text{j}}_{\text{II}}$/ 'portion', …

b. III: /$\text{kost}^{\text{j}}_{\text{III}}$/ 'bone', /$\text{tetrad}^{\text{j}}_{\text{III}}$/ 'notebook', /$\text{ploɕːad}^{\text{j}}_{\text{III}}$/ 'square', …

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- Rule (7e) → III in noun’s lexical entry

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- III in noun’s lexical entry → rule (7f)

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- Rule (7f) → instrumental [ju]

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The structure of the grammar, with features used in multiple rules, facilitates inference of new forms!

Narrowly tailored features: the case of Hungarian

Russian feminine nouns: class II and III (Corbett and Baerman, 2006)

class / *example*	II / 'newspaper'	III / 'bone'
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Hungarian plural (-ok/-ɒk) and possessive (-ɒ/-jɒ): all four possible combinations (Rácz and Rebrus, 2012)

			"lowering stems"	
noun	dɒl	tʃont	vaːlː	hold
gloss	'song'	'bone'	'shoulder'	'moon'
plural	dɒl-ok	tʃont-ok	vaːlː-ɒk	hold-ɒk
possessive	dɒl-ɒ	tʃont-jɒ	vaːlː-ɒ	hold-jɒ

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Feature-based analysis of Hungarian

Features for the possessive ([±j]) and plural ([lower]) are each referenced in *one rule* (see Siptár and Törkenczy (2000) for an alternate analysis)

(5) *Vocabulary insertion rules for Hungarian plural and possessive*

a. PL ↔ ɒk / [lower] ___

b. PL ↔ ok

c. POSS ↔ jɒ / [+j] ___

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a. [lower]: /vaːlː$_{[\text{lower},-\text{j}]}$/ 'shoulder', /hold$_{[\text{lower},+\text{j}]}$/ 'moon', /ɟaːr$_{[\text{lower},-\text{j}]}$/ 'factory', /ɲaːr$_{[\text{lower},+\text{j}]}$/ 'poplar', …

b. [+j]: /tʃont$_{[+\text{j}]}$/ 'bone', /hold$_{[\text{lower},+\text{j}]}$/ 'moon', /paːr$_{[+\text{j}]}$/ 'pair', /ɲaːr$_{[\text{lower},+\text{j}]}$/ 'poplar', …

c. [−j]: /dɒl$_{[-\text{j}]}$/ 'song', /vaːlː$_{[\text{lower},-\text{j}]}$/ 'shoulder', /kaːr$_{[-\text{j}]}$/ 'damage', /ɟaːr$_{[\text{lower},-\text{j}]}$/ 'factory', …

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b. [+j]: /tʃont$_{[+j]}$/ 'bone', /hold$_{[lower,+j]}$/ 'moon', /paːr$_{[+j]}$/ 'pair', /ɲaːr$_{[lower,+j]}$/ 'poplar', …

c. [−j]: /dɒl$_{[-j]}$/ 'song', /vaːlː$_{[lower,-j]}$/ 'shoulder', /kaːr$_{[-j]}$/ 'damage', /ɟaːr$_{[lower,-j]}$/ 'factory', …

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- [lower] in noun's lexical entry ↛ …

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Unlike in Russian, the structure of the grammar, with each feature used in a single rule, **does not** facilitate inference of new forms.

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Task

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- plural: lufɒnɒk **(lowering stem)**

Participants see another frame sentence, select possessive from drop-down menu

- [lufɒnɒ / lufɒnjɒ]

Stats

- 90 participants
- 35–50 trials per participant
- ...of which 8–12 lowering stem trials
- 81 stimuli (57 target, 24 filler)
- 2,398 total target trials

Phonological frequency matching

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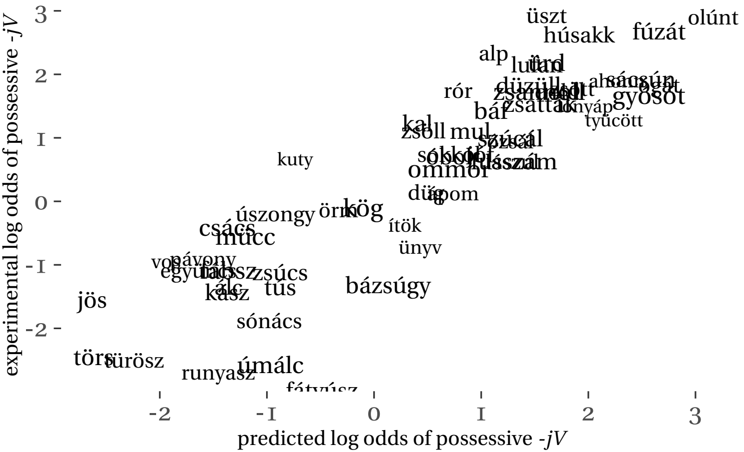
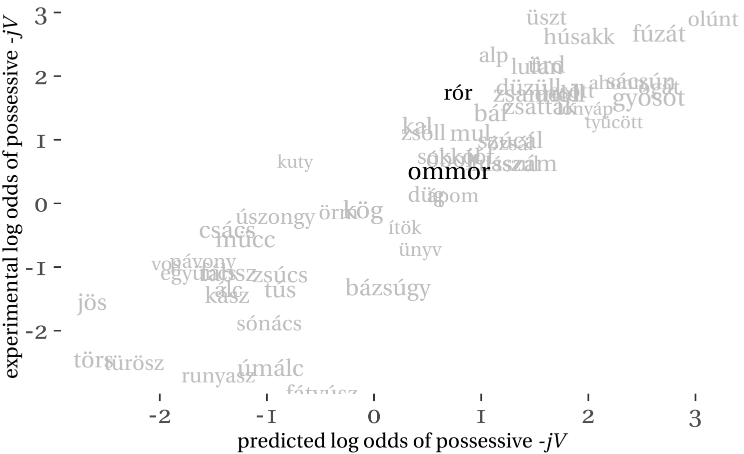


Baseline: the phonological model predicts experimental rate of possessives for *individual nonce words* quite well

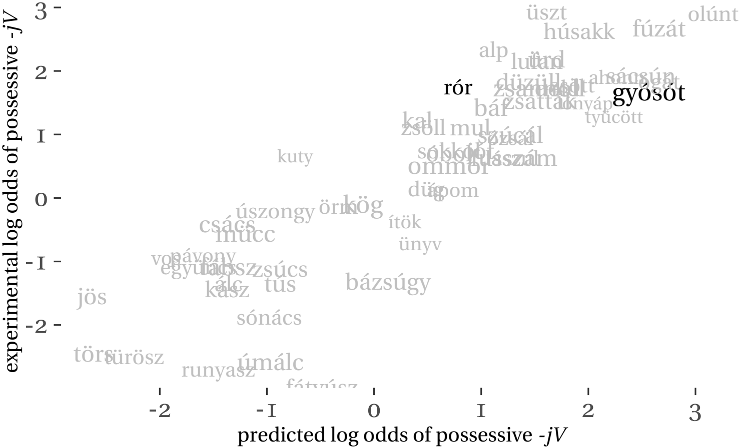
Results: phonological frequency matching



predicted: roːrjɒ = omːorjɒ

actual: roːrjɒ > omːorjɒ

Results: phonological frequency matching



predicted: roːrjɒ < ɟoːʃoːtjɒ

actual: roːrjɒ = ɟoːʃoːtjɒ

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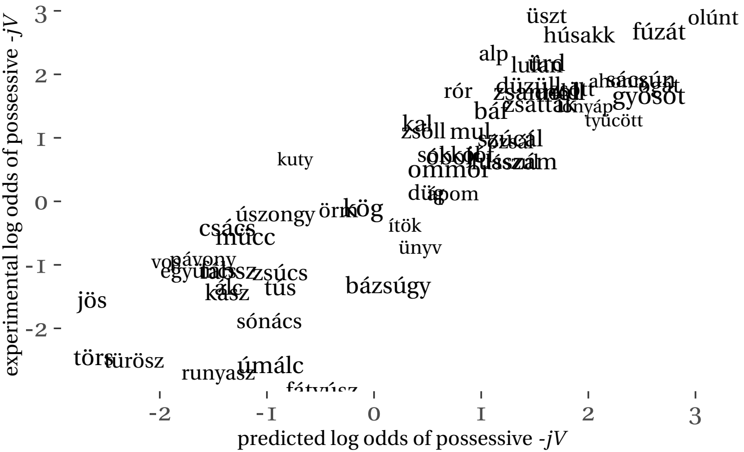

Baseline: the phonological model predicts experimental rate of possessives for *individual nonce words* quite well

Sensitivity to morphology

Baseline: phonological model trained on corpus of monomorphemic words from Papp (1969)

- Given *word*, predicts odds of -jɒ as coefficient *phon_odds*
- final C manner + final C place + harmony class + final V height + final V length + final coda complexity + word length

Then: predict experimental results from phonological model

- Given nonce word phonology and participant, predicts odds of -jɒ
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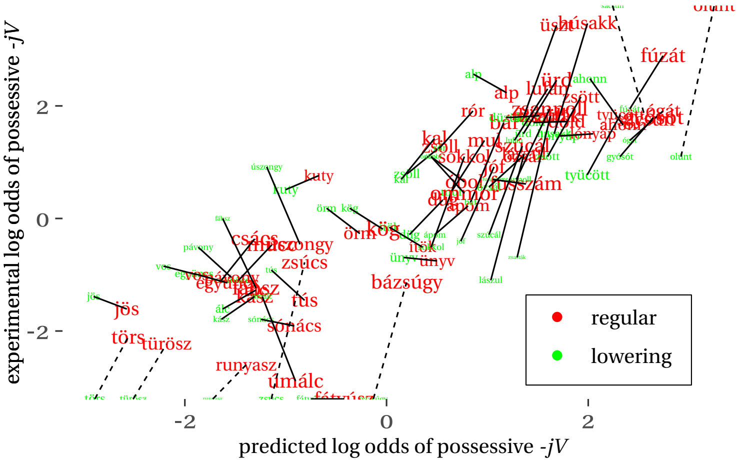
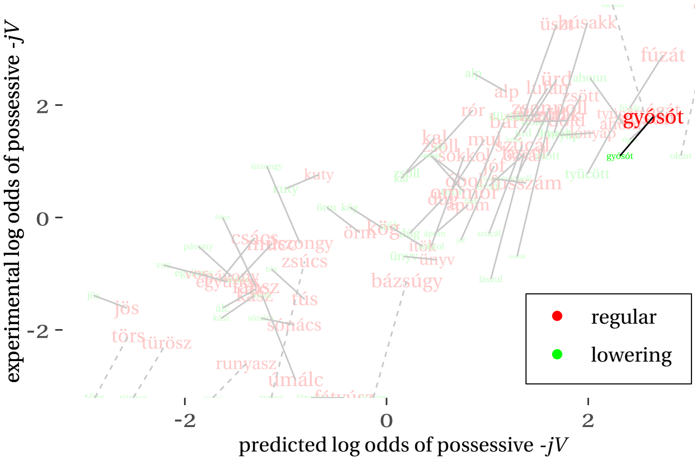


Target condition: most nonce words had a *lower* rate of -jɒ when presented as lowering stems

Results: sensitivity to morphology



predicted: ɟoːsoːtok, ɟoːsoːtjɒ > ɟoːsoːtɒk, ɟoːsoːtjɒ
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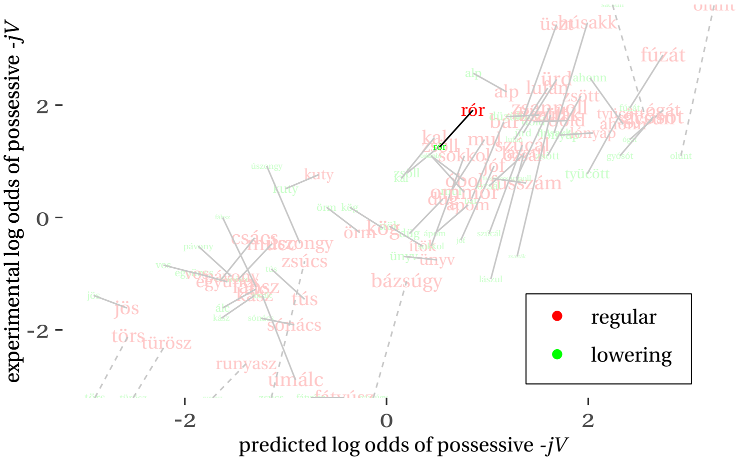

predicted: roːrok, roːrjɒ > roːrɒk, roːrjɒ
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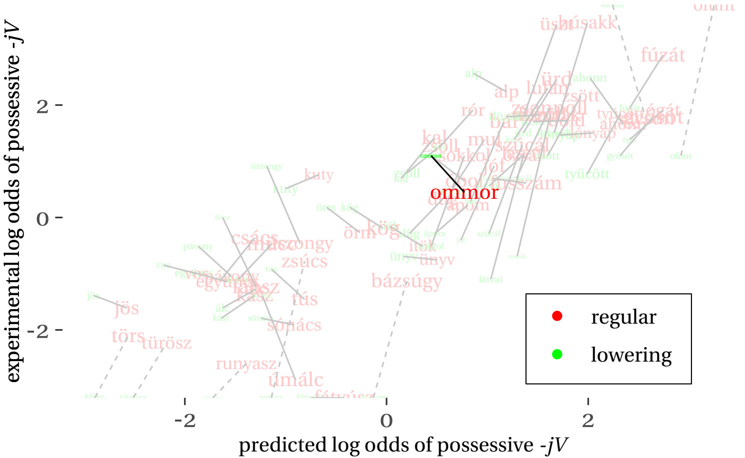

predicted: om:orok, om:orjɒ > om:orɒk, om:orjɒ
actual: om:orok, om:orjɒ < om:orɒk, om:orjɒ

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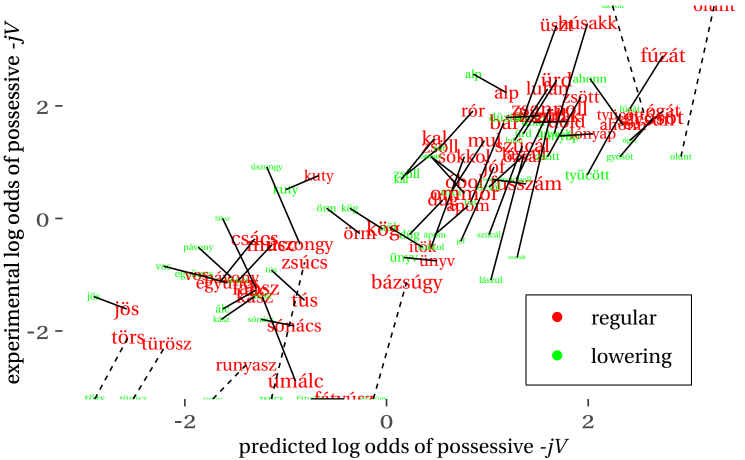

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- …Taking this into account, they also assigned -ɒ more to nonce words with plural -ɒk

Outline

1. Background: morphological features and inflection class
2. Experiment: Hungarian possessive and plural
3. Discussion

Interpretation of results

Rácz and Rebrus (2012) and others: -jɒ is the productive default for most words

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My results: speakers used -jɒ and -ɒ on the same words

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No obvious explanation for difference, but …

- clear that speakers have and can apply generalizations over the distribution of -jɒ and -ɒ in the lexicon
- these generalizations are both *phonological* and *morphological*

Generalizations and productivity

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  - Hungarian nouns ending in sibilants always take -ɒ ([−j])
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  - for [+j] words: *[+strident]# (weight: 5)
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  - Hungarian nouns with plural -ɒk ([lower]) usually take -ɒ ([−j])
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   - $P(/\text{ruɲɒs}_{\text{[lower,[+j]]}}/) = \frac{e^{H([+j])}}{e^{H([+j])}+e^{H([-j])}} = \frac{e^{-6}}{e^{-6}+e^{0}} = .002 = 0.2\%$
   - $P(/\text{fuːzaːt}_{\text{[lower,[+j]]}}/) = \frac{e^{H([+j])}}{e^{H([+j])}+e^{H([-j])}} = \frac{e^{-1}}{e^{-1}+e^{0}} = .269 = 26.9\%$

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- *morphological dependencies*: since morphological features like [+j] and [lower] are present in underlying forms, they can also define good and bad words for a different lexical class

Phonological and morphological effects are evaluated together, in a single analysis

We can handle morphological dependencies using independently necessary general phonological mechanisms

Do we need inflection class features at all?

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(5) *Vocabulary insertion rules for Hungarian plural and possessive*

a. PL ↔ ɒk / [lower] ___

b. PL ↔ ok

c. POSS ↔ jɒ / [+j] ___

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(1) *Vocabulary insertion rules for Russian cases*

a. NOM ↔ a / II ___

b. DAT ↔ e / II ___

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Ackerman et al. (2009); Baerman et al. (2017) and others: Russian and Hungarian differ in *degree* of cohesion, not kind
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(indeed, actual Russian inflection is messier than the oversimplified four-class analysis (Parker and Sims, 2020))

- We need separate generalizations to capture Hungarian morphological dependency between -ɒk and -ɒ
- Maybe Russian-style "inflection classes" are just very strong morphological generalizations

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Alternate Russian analysis

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Alternate Russian analysis

(1′) *Vocabulary insertion rules for Russian cases*

a.	NOM ↔ a	/ [N:a] ___		d.	NOM ↔ Ø	/ [N:Ø] ___
b.	DAT ↔ e	/ [D:e] ___		e.	DAT ↔ i	/ [D:i] ___
c.	INS ↔ oj	/ [I:oj] ___		f.	INS ↔ ju	/ [I:ju] ___

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Alternate Russian analysis

(1′) *Vocabulary insertion rules for Russian cases*

a.	NOM $\leftrightarrow$ a / [N:a] ___		d.	NOM $\leftrightarrow$ Ø / [N:Ø] ___	
b.	DAT $\leftrightarrow$ e / [D:e] ___		e.	DAT $\leftrightarrow$ i / [D:i] ___	
c.	INS $\leftrightarrow$ oj / [I:oj] ___		f.	INS $\leftrightarrow$ ju / [I:ju] ___	

(2′) *Lexical entries for Russian nouns*

a. II: /$\text{gazet}_{[\text{N:a,D:e,I:oj}]}$/ 'newspaper', /$\text{tʃert}_{[\text{N:a,D:e,I:oj}]}$/ 'characteristic', /$\text{dol}^{\text{j}}{}_{[\text{N:a,D:e,I:oj}]}$/ 'portion', …

b. III: /$\text{kost}^{\text{j}}{}_{[\text{N:Ø,D:i,I:ju}]}$/ 'bone', /$\text{tetrad}^{\text{j}}{}_{[\text{N:Ø,D:i,I:ju}]}$/ 'notebook', /$\text{ploɕːad}^{\text{j}}{}_{[\text{N:Ø,D:i,I:ju}]}$/ 'square', …

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(8) *Heavily weighted constraints for sublexicons*

a.	for [N:a] nouns: *[D:i]		c.	for [N:Ø] nouns: *[D:e]
b.	for [N:a] nouns: *[I:ju]		d.	for [N:Ø] nouns: *[I:oj]
	…			…

Summary

- Hungarian speakers productively apply correlations between inflected forms in the lexicon
- These cases are not well-suited for an “inflection class” analysis
- We need a way to account for gradient correlations between narrowly targeted inflectional features
- Gradient constraint-based phonotactic models can be easily extended to do this
- Inflection classes can be recast as *emergent* clusters of strong correlations between narrowly targeted features

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Full procedure

Sample trial (regular plural)

Full procedure

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Please select the word's plural form: [lufɒnøk / lufɒnɒk / lufɒnɛk / lufɒnok]

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That's correct! Now select the word in the appropriately inflected form according to you.

My [lufɒnɒm / lufɒnɛm / lufɒnøm / lufɒnom] couldn't sing well, however my husband's [lufɒnɛ / lufɒnjɛ / lufɒnɒ / lufɒnjɒ] sang brilliantly.

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Full procedure

Sample trial (lowering stem)

In 1997, the **lufɒn** entered into the competition for flowery **lufɒnɒk** for the first time.

Please select the word's plural form: [lufɒnøk / **lufɒnɒk** / lufɒnɛk / lufɒnok]

That's correct! Now select the word in the appropriately inflected form according to you.

My [**lufɒnɒm** / lufɒnɛm / lufɒnøm / lufɒnom] couldn't sing well, however my husband's [lufɒnɛ / lufɒnjɛ / **lufɒnɒ** / **lufɒnjɒ**] sang brilliantly.

Phonological model of lexicon

	β coef	*SE*	*Wald z*	*p*
Intercept	**3.02**	**.32**	**9.55**	**<.0001**
C Manner (default: plosive)				
fricative	**−1.44**	**.39**	**−3.73**	**.0002**
sibilant	**−10.69**	**.80**	**−13.36**	**<.0001**
nasal	**−1.95**	**.27**	**−7.16**	**<.0001**
approximant	**−4.08**	**.30**	**−13.47**	**<.0001**
C Place (default: alveolar)				
labial	**−2.02**	**.26**	**−7.94**	**<.0001**
palatal	**−8.88**	**1.10**	**−8.06**	**<.0001**
velar	**−3.26**	**.29**	**−10.96**	**<.0001**
Harmony (default: back)				
front	**−2.03**	**.18**	**−10.96**	**<.0001**
variable	**2.26**	**.97**	**2.33**	**.0197**
V Height (default: mid)				
high	**1.73**	**.22**	**7.89**	**<.0001**
low	.28	.19	1.50	.1342
V Length (default: short)				
long	**1.40**	**.17**	**7.98**	**<.0001**
Coda (default: singleton)				
geminate	**2.47**	**.40**	**6.25**	**<.0001**
cluster	.04	.21	0.18	.8602
Syllables (default: monosyllabic)				
polysyllabic	**1.15**	**.17**	**6.67**	**<.0001**

Phonological model of experimental results

Random effect	*variance*	*SD*		
Participant	.55	.74		

Fixed effects	β *coef*	*SE*	*Wald z*	*p*
Intercept	**.67**	**.10**	**7.03**	**$<$.0001**
Phon_odds	**.34**	**.01**	**22.76**	**$<$.0001**

Phonological and morphological model of experimental results

Random effect	*variance*	*SD*		
Participant	.54	.74		
Fixed effects	*β coef*	*SE*	*Wald z*	*p*
Intercept	**.74**	**.10**	**7.48**	**<.0001**
Phon_odds	**.34**	**.02**	**22.77**	**<.0001**
Plural (default: -ok)				
-ɒk	**−.33**	**.13**	**−2.62**	**.0086**

Experiment 2: Czech locative and genitive

Czech genitive (-u/-a) and locative (-u/-ɛ): all four possible combinations (for *masculine inanimate hard-stem* nouns)

noun	problɛːm	zaːpas	vɛtʃɛr	kostɛl
gloss	‘problem’	’match’	‘evening’	’church’
genitive	problɛːm-u	zaːpas-u	vɛtʃɛr-a	kostɛl-a
locative	problɛːm-u	zaːpas-ɛ	vɛtʃɛr-u	kostɛl-ɛ

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Historically: innovative -u has pushed out original -a and -ɛ in both cases

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- Today -u is much more common
- Morphological dependency: nouns that take genitive -a also tend to take locative -ɛ

Background: variation

Most nouns that take genitive -a or locative -ɛ do so *variably* (Bermel and Knittl, 2012; Guzmán Naranjo and Bonami, 2021)

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	in		*about*
bridge	v mosc-ɛ	>	o mosc-ɛ
	∨		∨
office	v uːɻaɟ-ɛ	>	o uːɻaɟ-ɛ

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office	v uːɹ̝aɟ-ɛ	>	o uːɹ̝aɟ-ɛ

For variable nouns, a higher rate of genitive -a corresponds to a higher rate of locative -ɛ

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Stimulus presented twice in frame sentence

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- prep + genitive: z cɪsu ([z] ‘out of’)

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Stats

- 88 participants
- 50 trials per participant
- …of which 12 shown with genitive -a
- 82 stimuli
- 4,397 total target trials

Phonological frequency matching

Baseline: phonological model trained on noun tokens from the Czech National Corpus (Křen et al., 2022)

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- Given nonce word phonology, syntactic context, and participant, predicts odds of -ɛ
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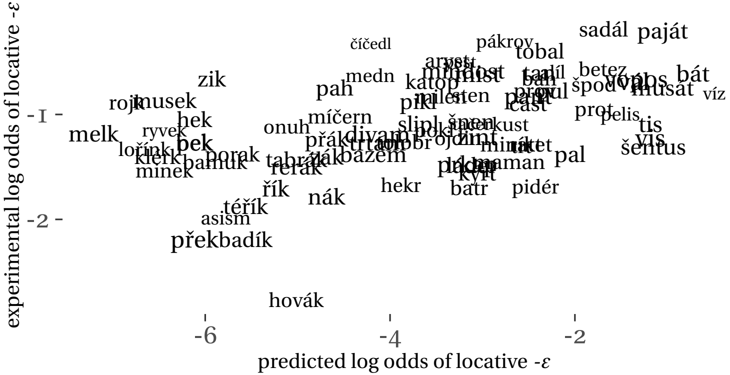
Results: phonological frequency matching



Baseline: the phonological model is slightly predictive of experimental rate of locatives for *individual nonce words*

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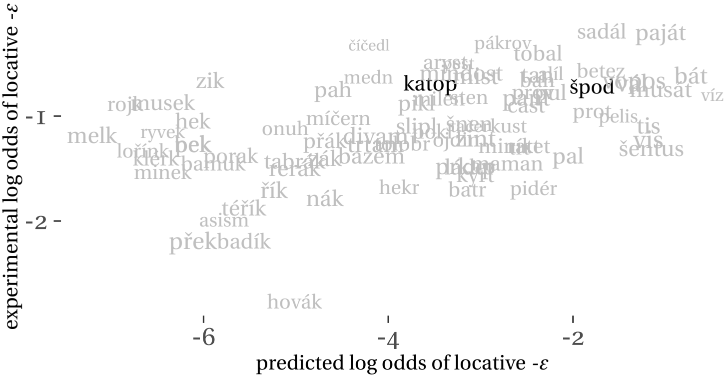
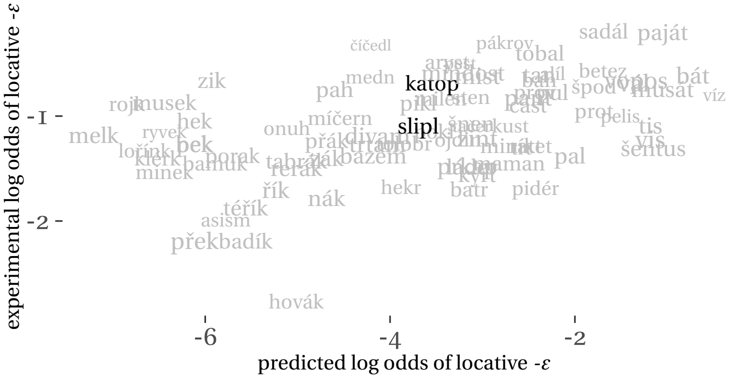


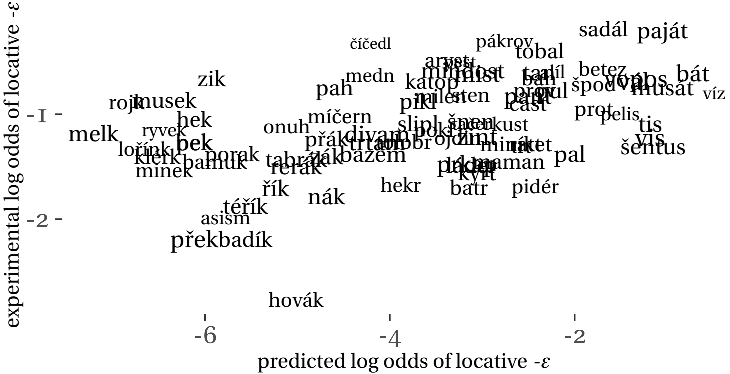
predicted: katopjɛ < ʃpoɟɛ

actual: katopjɛ = ʃpoɟɛ



predicted: katopjɛ = slɪplɛ
actual: katopjɛ > slɪplɛ

Results: phonological frequency matching



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Sensitivity to morphology

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Then: predict experimental results from phonological model **and genitive**

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- (1 | participant) + phon_odds + preposition

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- In part because the data are so skewed (94% of nouns take -u)

Then: predict experimental results from phonological model **and genitive**

- Given nonce word phonology, syntactic context, **genitive**, and participant, predicts odds of -ɛ
- (1 | participant) + phon_odds + preposition

Sensitivity to morphology

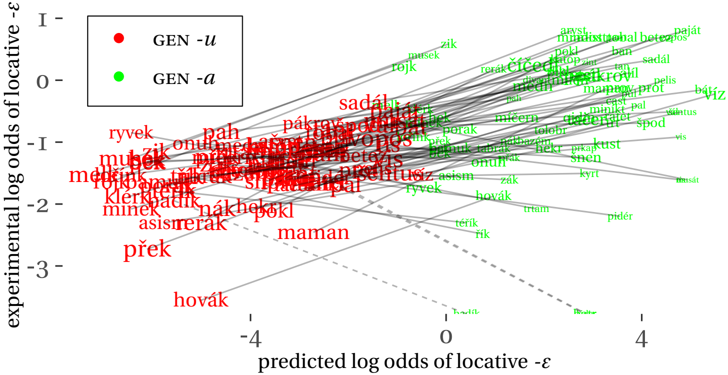
Baseline: phonological model trained on noun tokens from the Czech National Corpus (Křen et al., 2022)

- Nouns binned as categorical ($>$ 99% of tokens) locative -u vs. variable/categorical -ε
- Given *word*, predicts odds of -ε as coefficient *phon_odds*
- final C place + final C manner + final coda complexity + final V length + final V front + final V height + word length
- Phonology has a *much smaller effect* than in Hungarian ($R^2 = .09$)
- In part because the data are so skewed (94% of nouns take -u)

Then: predict experimental results from phonological model **and genitive**

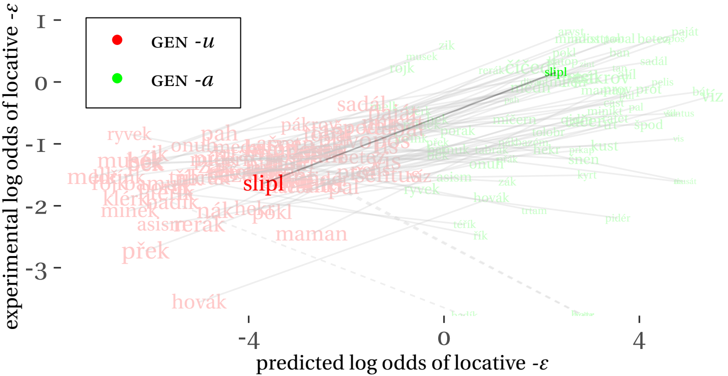
- Given nonce word phonology, syntactic context, **genitive**, and participant, predicts odds of -ε
- (1 | participant) + phon_odds + preposition **+ genitive**

Results: sensitivity to morphology



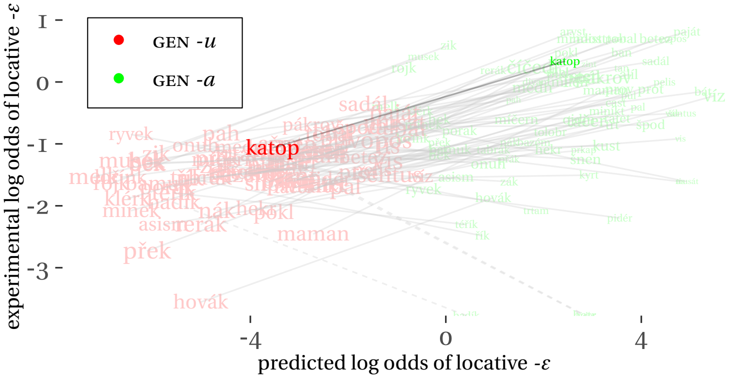
Target condition: most nonce words had a *much higher* rate of -ε when also assigned genitive as -a

Results: sensitivity to morphology



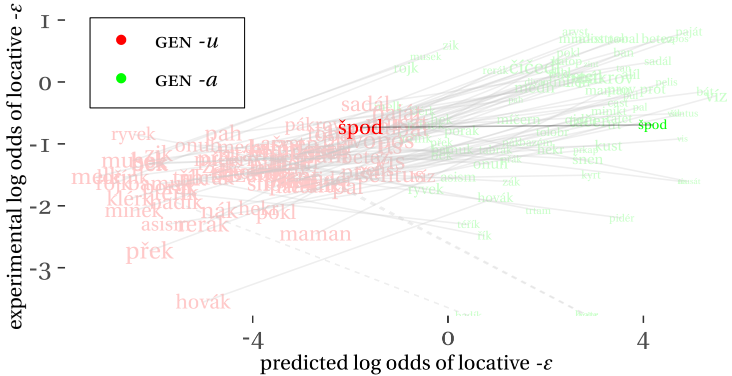
predicted: slɪplu, slɪplɛ < slɪpla, slɪplɛ
actual: slɪplu, slɪplɛ < slɪpla, slɪplɛ

Results: sensitivity to morphology



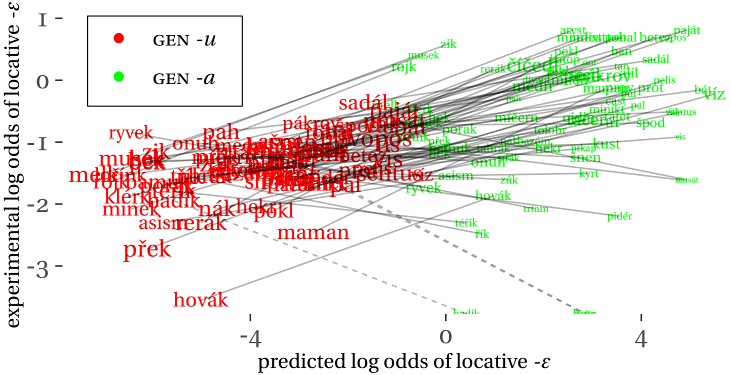
predicted: katopu, katopjɛ < katopa, katopjɛ
actual: katopu, katopjɛ < katopa, katopjɛ

Results: sensitivity to morphology



predicted: ʃpodu, ʃpoɟɛ < ʃpoda, ʃpoɟɛ
actual: ʃpodu, ʃpoɟɛ = ʃpoda, ʃpoɟɛ

Results: sensitivity to morphology



Target condition: most nonce words had a *much higher* rate of -ɛ when also assigned genitive as -a

Results: summary

- Participants (very loosely) matched the phonological distribution of -u and -ɛ in the lexicon

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- Participants (very loosely) matched the phonological distribution of -u and -ɛ in the lexicon
- Not shown: syntactic context (preposition) also closely mirrored the lexicon
- They assigned -ɛ much more to nonce words with genitive -a