

Wug-testing Uyghur Vowel Harmony

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Overview

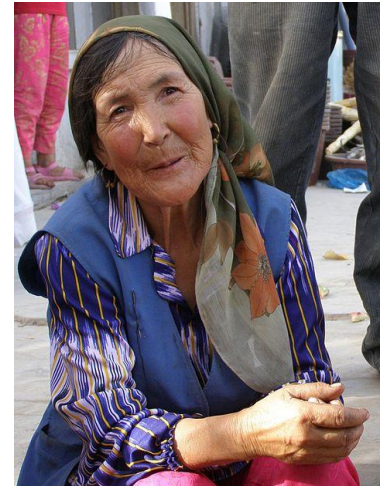
In this presentation we will:

- Present new empirical data from wug tests on the basic pattern of Uyghur backness harmony
- Present an updated phonological analysis of this pattern with a particular attention to:
 - Gradient phonological outcomes
 - Conflicting vowel and consonant triggers
 - Distance effects

The Uyghur Language

Uyghur is a Southeastern Turkic language

- Spoken by roughly 10 million people, primarily in China, Uzbekistan, Kazakhstan, Kyrgyzstan
- Exhibits vowel backness and rounding harmony



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https://commons.wikimedia.org/wiki/File:Uyghur_woman_Xinjiang.jpg

Uyghur backness harmony

Standard descriptions of Uyghur backness harmony requires suffix forms to agree with backness with vowels and certain consonants in the stem (e.g., Lindblad 1990; Hahn 1991; Engsaeth et al. 2010).

- We use the locative suffix /-DA/ as a prototypical example
- Backness agreement is reflected in the vowel: /a/ or /æ/
- Voicing changes in the initial segment are not relevant: /t/ or /d/

Relevant segments

	Front		Back	
	Unrounded	Round	Unrounded	Round
High	i	y		u
Mid	e	ø		o
Low	æ		a	

	Front	Back
Voiceless	k	q
Voiced	g	ɣ

- The front vowels /i/ and /e/ are **transparent** to harmony
- **Velars** pattern as **front**
- **Uvulars** pattern as **back**

Vowel Harmony

Most suffixes must match the backness of the final harmonizing vowel in the stem

	Front	Back
1	køz-dæ “on/in an eye”	at-ta “on/in a horse”
2	syt-tæ “on/in milk”	orun-da “on/in a place”
3	xæmit-tæ “on/in Xemit”	tarix-ta “on/in history”
4	halæt-tæ “on/in a situation”	æwlad-da “on/in a generation”

Consonant Harmony

In the absence of a harmonizing vowel, dorsal consonants serve as triggers for harmony

Front	kijɪ-dæ “on/in a person”
	gezi-tæ “on/in a newspaper”
Back	qiz-da “on/in a girl”
	qirɨz-da “on/in the Kyrgyz”

Conflicting triggers

In cases of backness conflict between vowels and consonants in the same word, a more distant vowel overrides a less distal consonant

Front	mæfɔ-tæ “on/in an exercise”
Back	rak-ta “on/in a shrimp”

Transparent Vowels

Stems with no harmonizers are arbitrarily specified for backness

- Statistical preference for back suffixes

Front	biz-d \ae “on/in us”
	siz-d \ae “on/in you”
Back	it-ta “on/in a dog”
	pil-da “on/in an elephant”

Prior Phonological Analyses (non-exhaustive)

- Lindblad (1990) and Hahn (1991) discuss (covert?) contrasts between /i/ and /i:/ to account for spreading and transparent words.
- Vaux (2000), Halle et al. (2000), and Hall and Ozburn (2018) focus on accounting for vowel harmony in cases of derived transparency.

Why revisit Uyghur backness harmony?

- Previous studies rely primarily on written data. There is no detailed empirical description of the basic harmony process.
 - Though see McCollum (2018) for a phonetic description of gradient backness spreading
- The ‘fallback’ pattern in Uyghur harmony is typologically unusual
- Uyghur backness harmony poses difficulties for formal language models of phonotactics (Mayer and Major 2018).

The present study

We use wug testing to provide an empirical phonological description of the basic pattern of Uyghur backness harmony, with particular attention to:

- Differences in the strength of front/back vowels and front/back dorsals
- Distance effects on trigger strength
- Inter-speaker variation

We also have corpus and elicited data from real words (not presented here).

Creating wug words

We used a custom Python script to generate a large set of wug words matching the following 15 word templates in 5 categories:

- **Non-harmonizers:** CNC, CNCNC, CNCNCNC
- **Front vowels:** CFC, CFCNC, CFCNCNC
- **Back vowels:** CBC, CBCNC, CBCNCNC
- **Front vowels with back dorsal:** CFQ, CFCNQ, CFCNCNQ
- **Back vowels with front dorsal:** CBK, CBCNK, CBCNCNK

C: transparent consonant; **N:** transparent vowel;

F: front vowel; **B:** back vowel; **K:** front dorsal; **Q:** back dorsal

Creating wug words

A native Uyghur speaker selected **four words per template**:

- Based on phonological plausibility and balance of vowel qualities
- Consonants were not carefully controlled
- Resulted in a total of **60 wug words**

A few examples:

- **CVC**: [nir], [des], [viv], [ref]
- **CFQ**: [dʒøʙ], [møʙ], [ryq], [pæq]
- **CBK**: [tug], [mok], [zak], [nuk]

Frame sentences

We embedded wug words in one of **three frame paragraphs**:

- Elicit both **unsuffixed** and **locative suffixed** forms
- Provides a relatively naturalistic context

Frames:

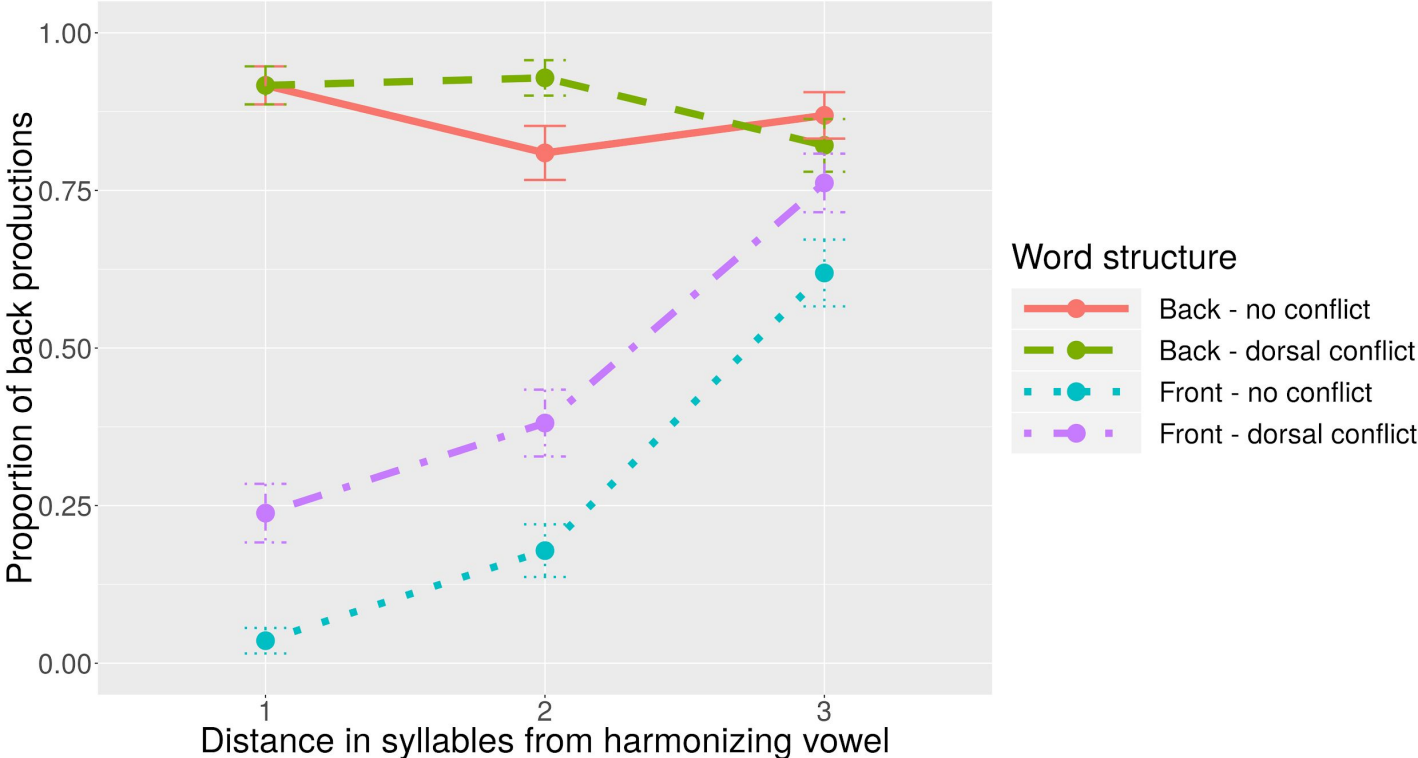
- “They say _____ was an old city. Nowadays, people don’t live in _____.”
- “In the library, _____ is a book that we wrote. In my opinion, there are many great stories in _____.”
- “Last year they bought a massive _____. They cook food in _____.”

Participants

We elicited from **23 native speakers** of Uyghur living in Kazakhstan (ages 19-62; mean 40).

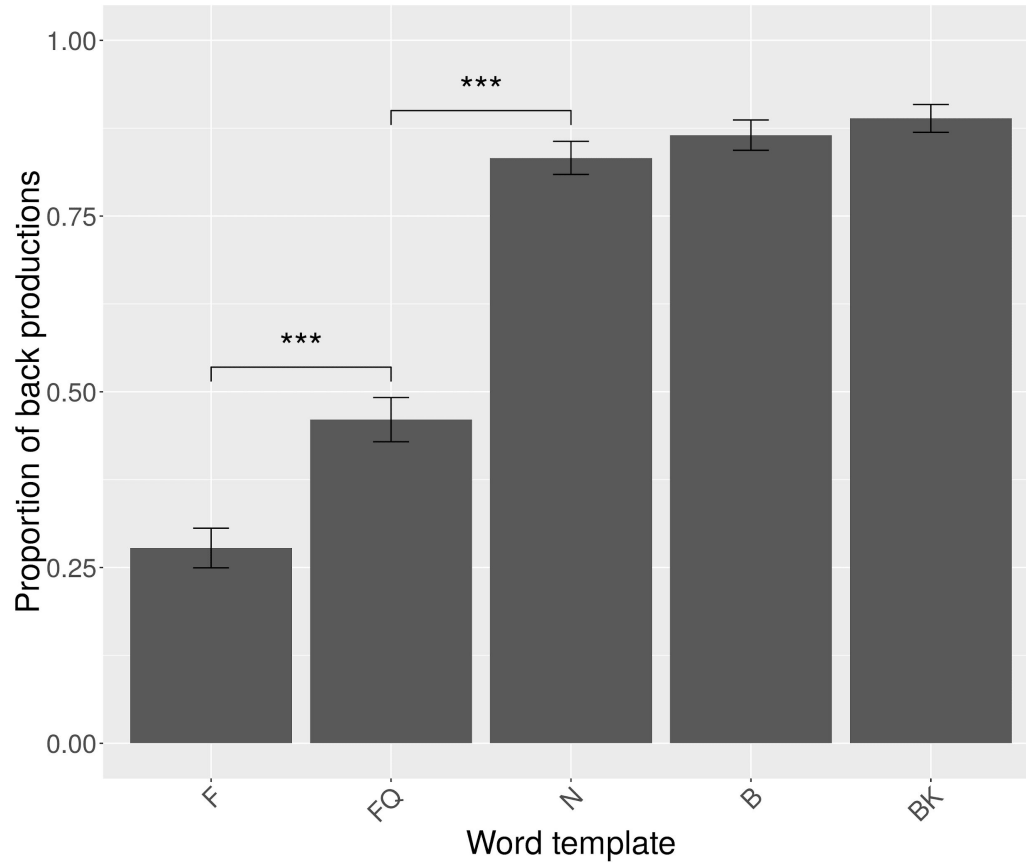
- Stimuli were presented in one of two random orders
- 1/3rd of words elicited in each frame paragraph
- Participants were recorded reading stimuli
- Choice of /-Dæ/ vs. /-Da/ form of locative was coded

Interactions between distance and conflict



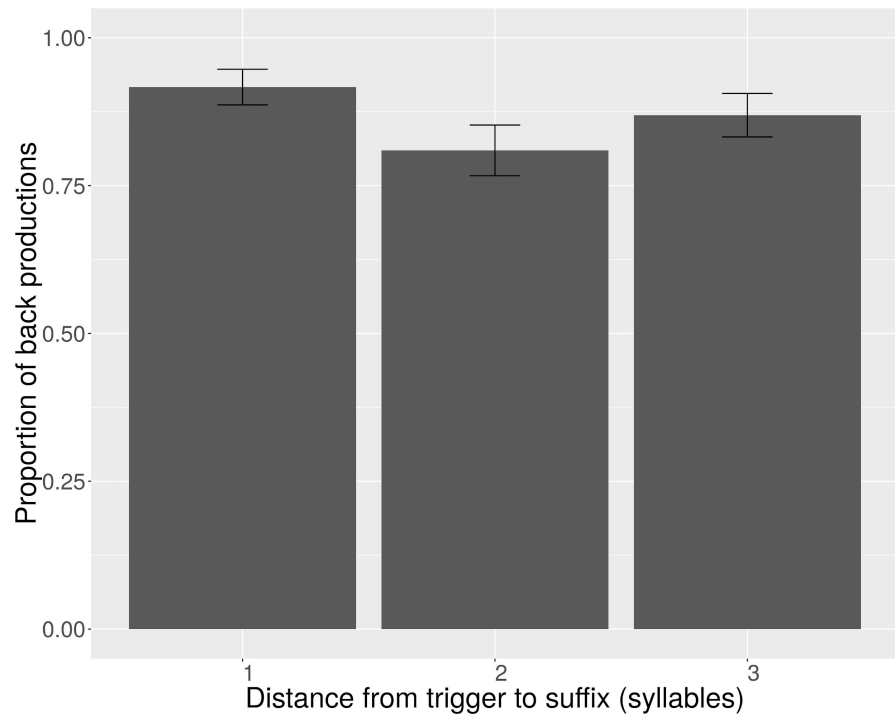
(Error bars are +/- one standard deviation)

By template (ignoring distance)

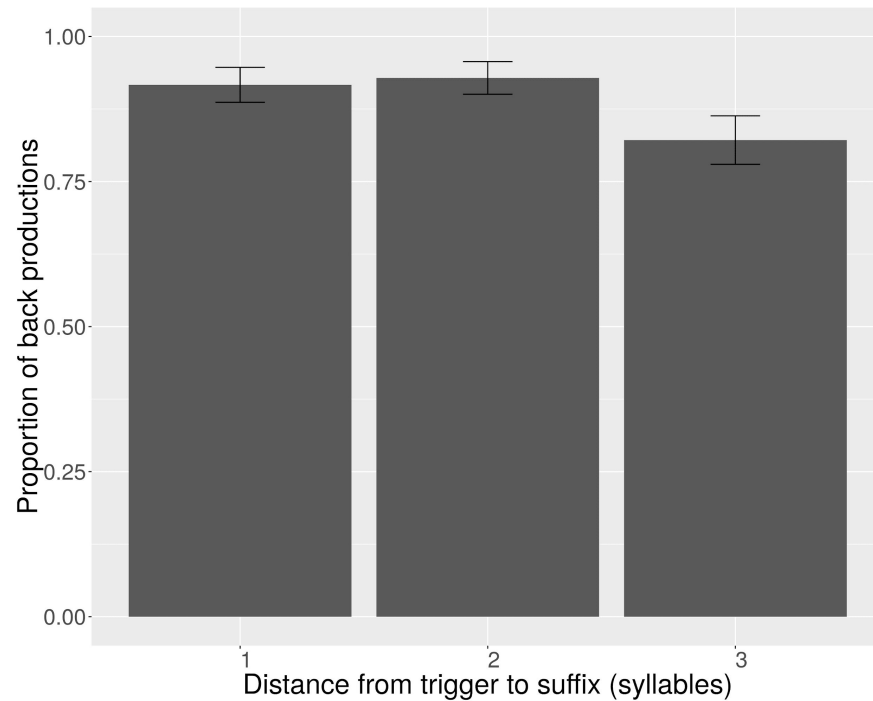


Distance by template: back vowels

B stems

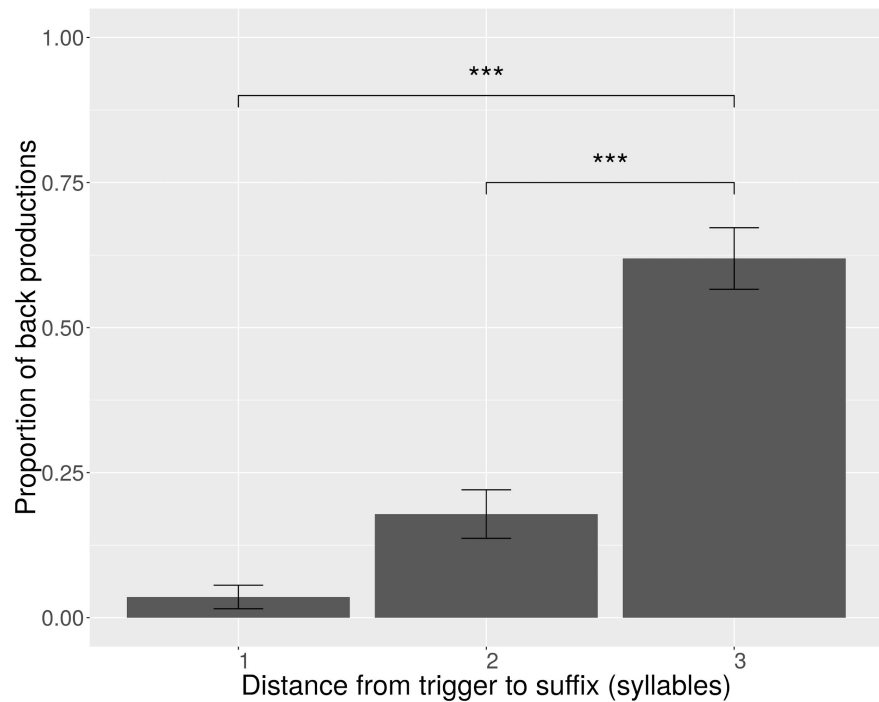


BK stems

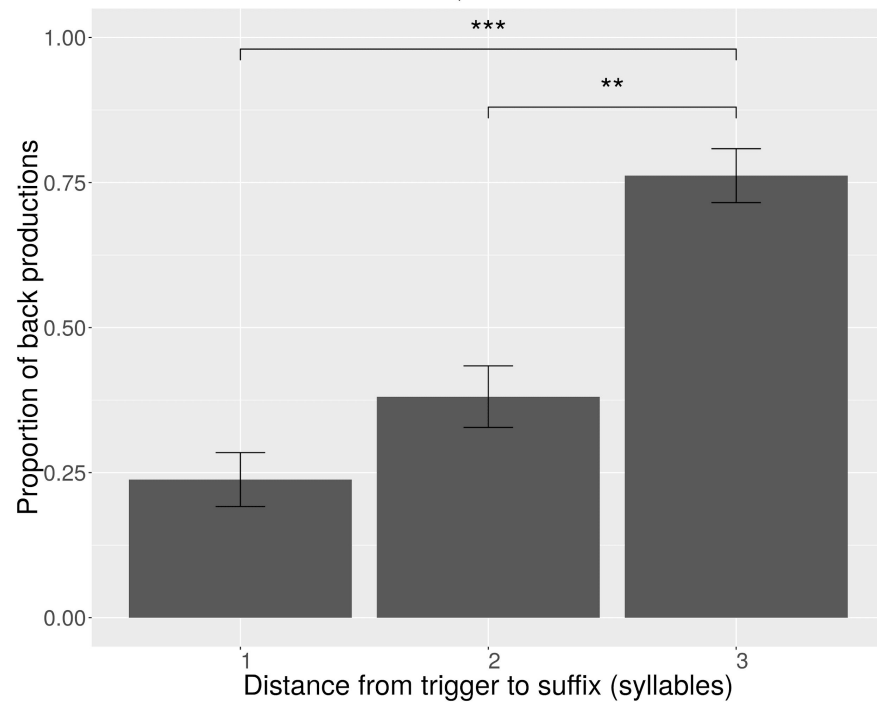


Distance by template: front vowels

F stems



FQ stems



Takeaway points

- **Neutral stems** skew heavily towards **back suffixes**
- **Trigger distance** effects only significant for **front vowel triggers**
- **Conflicting trigger** effects only significant for **front vowel triggers**

Phonological modelling

We model the data using **Maximum Entropy Harmonic Grammar** (MaxEnt; Smolensky 1986; Goldwater and Johnson 2003)

- Assigns (learnable) **weights** to constraints
- Produces a **probability distribution over candidate forms**
- Well-suited to capturing **phonological gradience**
- Probabilities can be used to calculate **likelihood of observed data**

MaxEnt models

- The *harmony* of a form \mathbf{x} is the sum of the products of the weights of each constraint (w_i) and the number of times \mathbf{x} violates that constraint ($f_i(\mathbf{x})$)

$$H(x) = \sum_i w_i f_i(x)$$

- The *eHarmony* (Wilson 2014) is e raised to the power of the negative harmony

$$H_e(x) = \exp\left(-\sum_i w_i f_i(x)\right)$$

MaxEnt models

- The probability of a candidate is its eHarmony divided by the sum of the eHarmonies of all other candidates for the same input.

$$P(x) = \frac{\exp\left(-\sum_i w_i f_i(x)\right)}{\sum \exp\left(-\sum_i w_i f_i(x)\right)}$$

This is basically just logistic regression!

Constraints

We assume the following constraints, momentarily ignoring distance effects:

- *S_F: Don't have front suffixes
- V_{AGREE}B_{ACK}: Don't have a front suffix following a back harmonizing vowel
- V_{AGREE}F_{FRONT}: Don't have a back suffix following a front harmonizing vowel
- C_{AGREE}B_{ACK}: Don't have a front suffix following a back harmonizing dorsal

Sample tableau

Input	Cand.	*S _F <i>w=1.56</i>	V _{AGREE} FRONT <i>w=2.51</i>	C _{AGREE} BACK <i>w=0.8</i>	Harmony	eHarmony	Probability
mæf _q -DA	mæf _q -ta		1		1 * 2.51 = 2.51	exp(-2.51) = 0.081	0.081 / (0.081 + 0.094) = 0.46
	mæf _q -tæ	1		1	1 * 1.56 + 1 * 0.8 = 2.36	exp(-2.36) = 0.094	0.14 / (0.37 + 0.14) = 0.54

Why these constraints?

* S_F captures the statistical tendency towards back suffixes in neutral forms

$V_{AGREEFRONT}$, $V_{AGREEBACK}$, and $C_{AGREEBACK}$ capture the influence of harmonizing segments on suffix choice

- Model comparison using Akaike Information Criterion (AIC) indicates that separate constraints for front and back sounds is important

What about $C_{AGREEFRONT}$?

- Does not improve likelihood of data under model!

A note on spreading

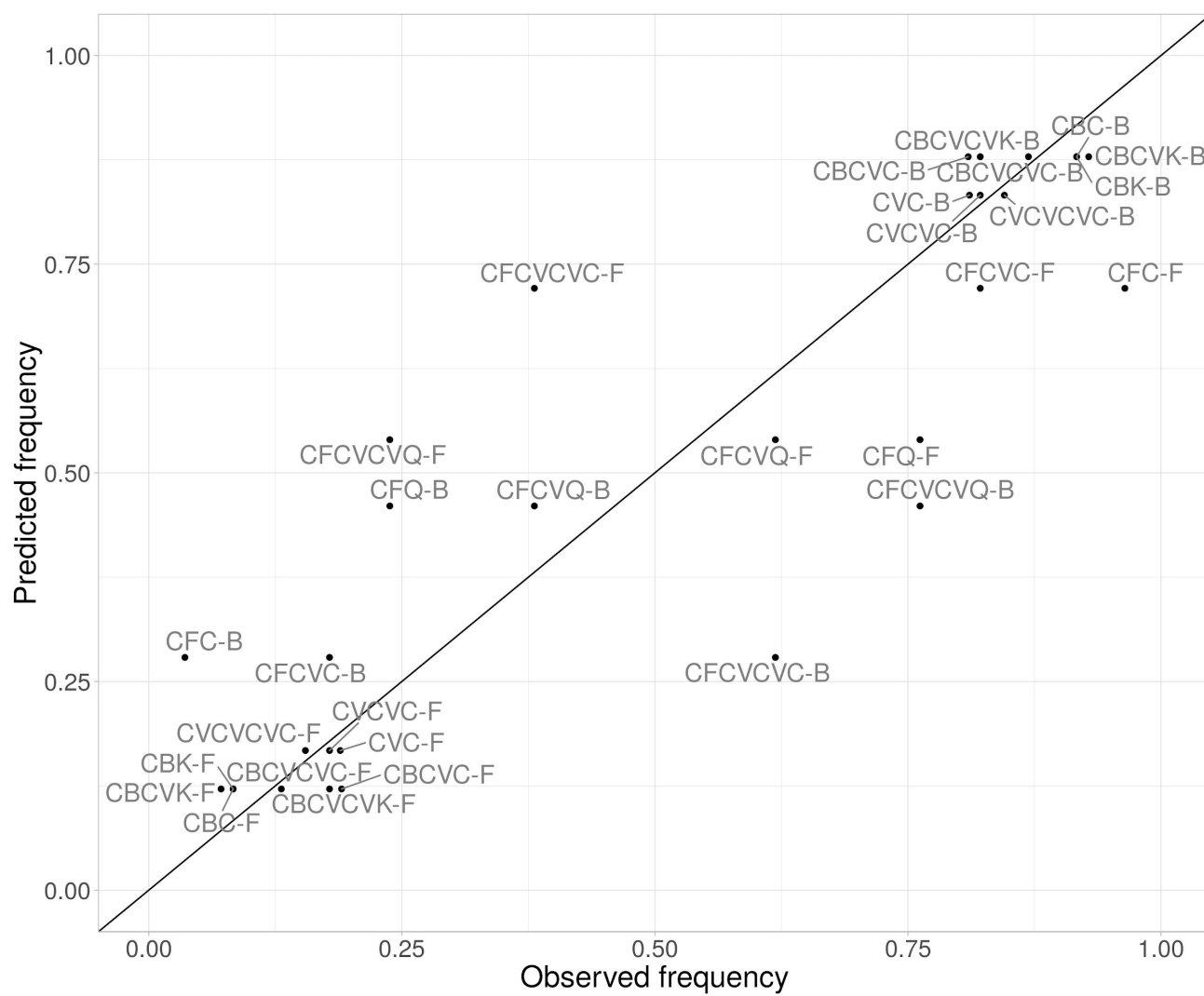
There is some phonetic evidence that Uyghur backness harmony is local, spreading through transparent vowels.

- See, e.g., Mayer & Major (2018); McCollum (2018)

The analysis presented here remains agnostic to the details of spreading.

- Easily modifiable to be compatible with local or non-local analyses

Basic model fit



Basic model

Learned weights:

- $*S_F$: 1.56
- $C_{AGREEBACK}$: 0.8
- $V_{AGREEBACK}$: 0.4
- $V_{AGREEFRONT}$: 2.51

Log-likelihood of data = **-270**

Fits **front** forms poorly because of **distance-based decay!**

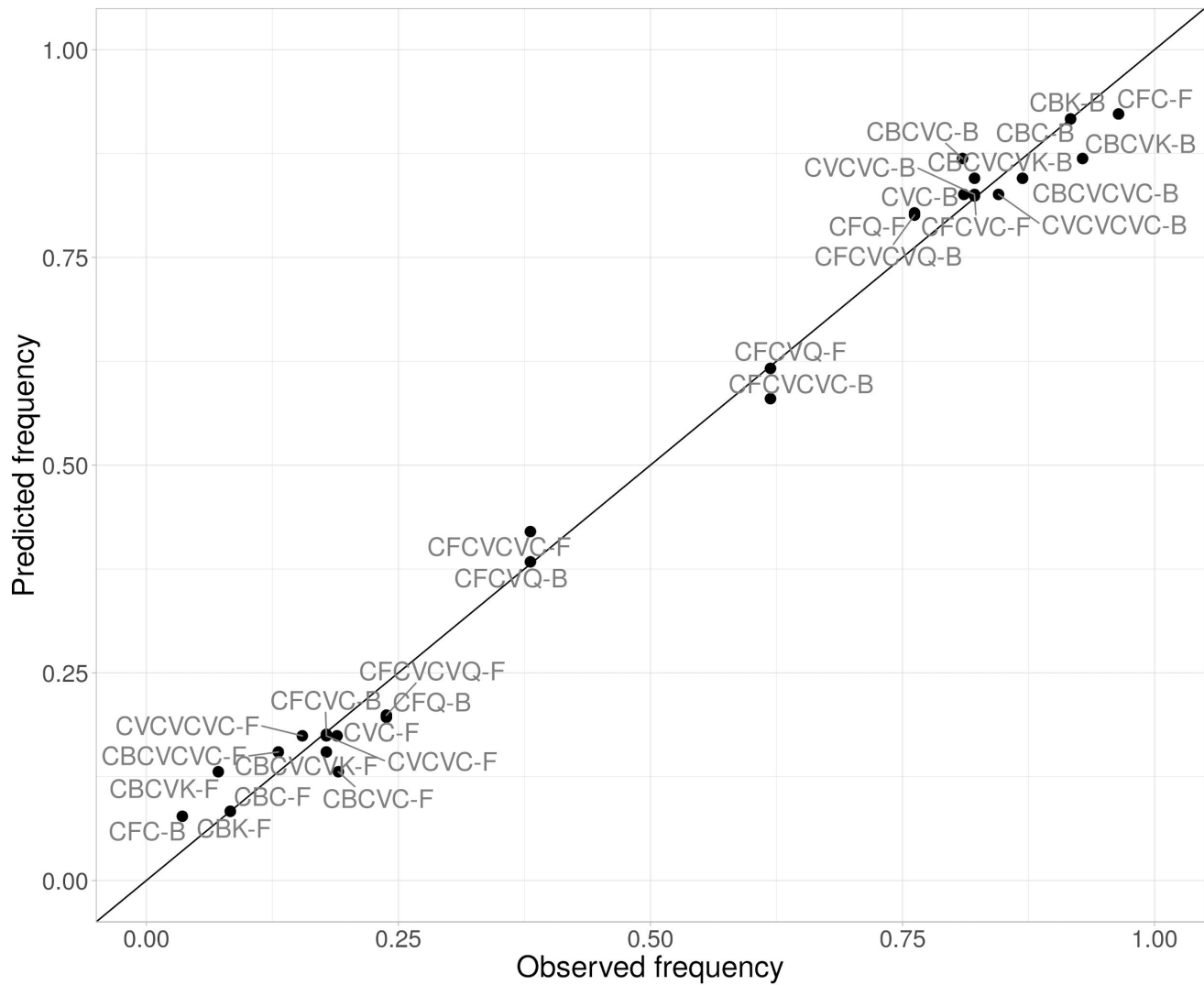
Modelling distance-based decay

One simple approach is to use distance-specific constraints (e.g., Hansson 2001; Martin 2005; Hayes & Londe 2006):

- **VAGREEBACK-1SYL**
- **VAGREEBACK-2SYL**
- **VAGREEBACK-3SYL**
- ...

Similarly for **VAGREEFRONT**

Model with distance-specific constraints



Model with distance-specific constraints

Constraint weights

- ***S_F**: 1.56
- **C_{AGREEBACK}**: 1.07
- **V_{AGREEBACK} (1,2,3)**: (0.84, 0.37, 0.14)
- **V_{AGREEFRONT} (1,2,3)**: (4.04, 3.1, 1.24)

Log-likelihood of data \approx **-241**

- Significantly better fit than model without distance-based decay

Alternative accounts of distance-based decay

Kimper (2011) and Zymet (2014) argue against distance-specific constraints because they permit **unattested phonological patterns**, e.g.,

- “Anti-decay,” where harmony increases with distance
- Greatest application at intermediate distances

Instead, they propose single constraints whose number of violations x (or credits for Kimper) are scaled by some decay function.

A model with distance-based decay

We use the decay function from Zymet (2014):

$$d(x) = \frac{1}{x^k}$$

Where $k \geq 0$ and may vary across languages.

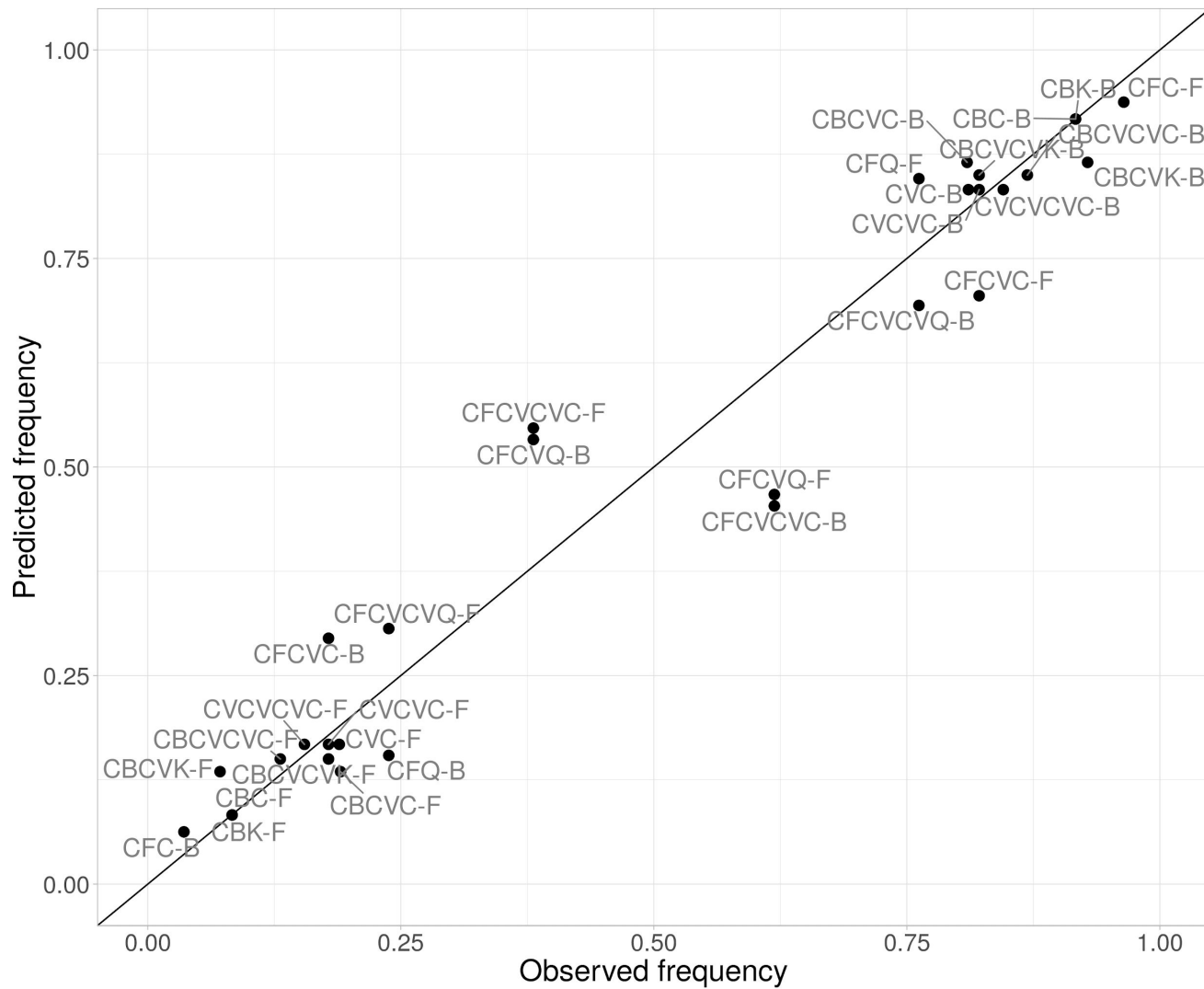
We assume separate values of k for front and back vowels based on weights in previous model.

- These are learned simultaneously with constraint weights

Sample tableau with distance-based decay

Input	Cand.	*S _F <i>w</i> =1.6	VAGREE FRONT <i>w</i> =4.31 <i>k</i> =1.65	CAGREE BACK <i>w</i> =0.5	Harmony
tæbliɰ-DA	tæbliɰ-ta		d(2) = 0.32		0.32 * 4.31 = 1.38
	tæbliɰ-tæ	1		1	1 * 1.6 + 1 * 0.5 = 2.1

Model with distance-based decay



Results for distance-based decay

Weights

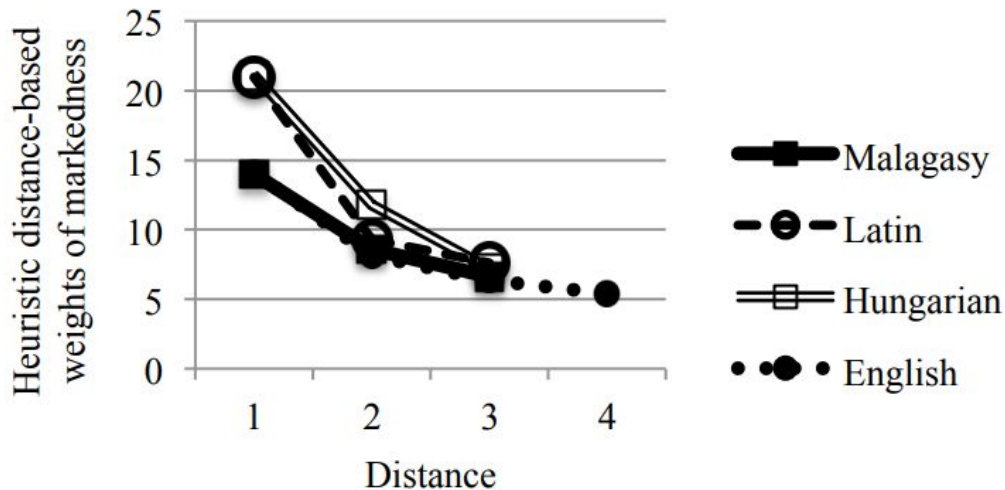
- *S_F: 1.6
- C_{AGREEBACK}: 0.5
- V_{AGREEBACK}: 0.8
- V_{AGREEFRONT}: 4.31
- *k* (back): 0.8
- *k* (front): 1.65

Log-likelihood of data \approx **-247**

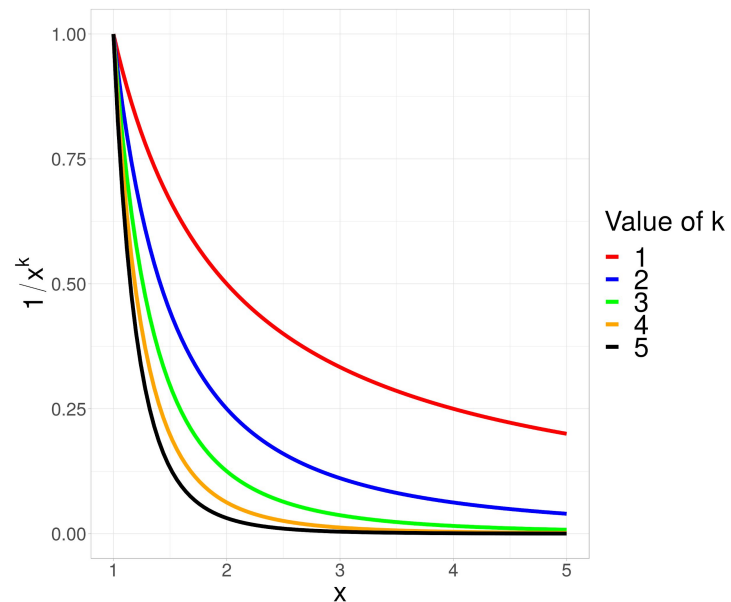
- **Significantly worse** than constraint families model

Choosing the decay function

Zymet (2014) motivates the choice of decay function by looking at learned weights for distance-specific constraints across languages.



From Zymet (2014)



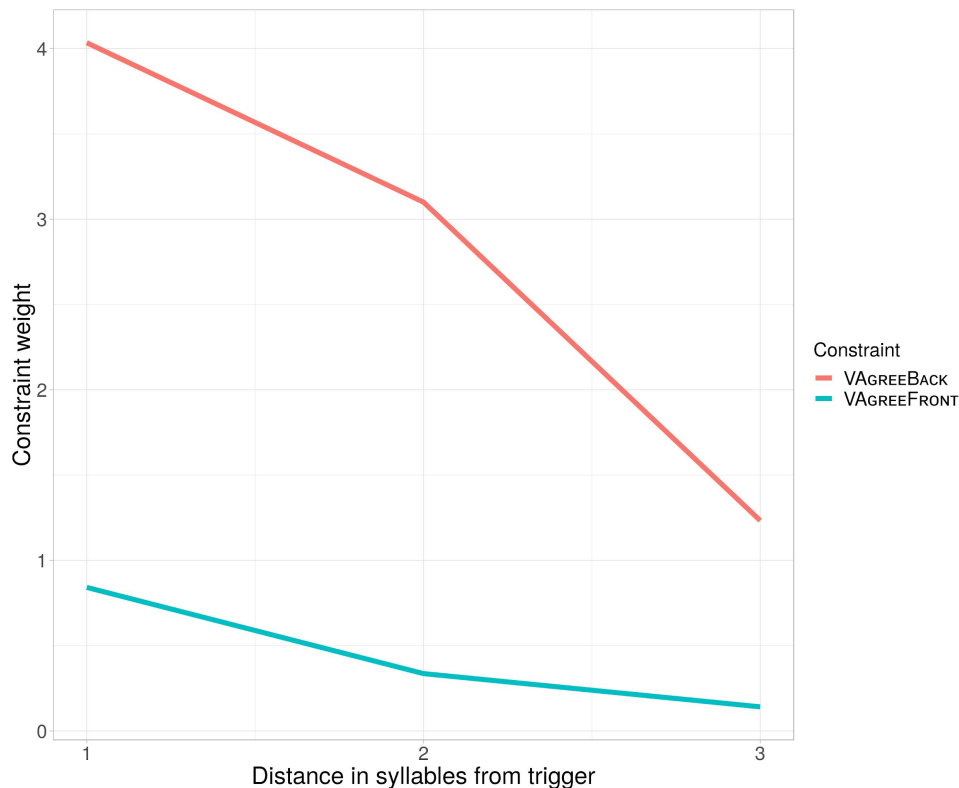
Choosing the decay function

The weights in Zymet (2014) are characterized by a rapid initial drop-off as distance increases, followed by slower decay.

The weights for **VAGREEFRONT** in Uyghur do not look like this!

- Slower initial drop-off

Motivates a more general decay function!



Conclusions

Uyghur backness harmony is more complex than previously described

- Highly gradient
- Some degree of inter-speaker variability
- Asymmetries between front and back trigger strengths

Implications for phonological models of distance-based decay

- Functions proposed by Kimper (2011) and Zymet (2014) do not fit Uyghur well
- Separate decay functions appear necessary for different features

Future work

Vowel harmony is frequently a proving ground for phonological theory

- It's important that we have a good empirical understanding!

We have additional data to analyze:

- “Giraffe tests” from the same speakers (wug testing real words)
- Corpus data

We plan to investigate whether harmony in these domains differs from wug tests.

We also plan to examine phonetic correlates of backness in these words.

Acknowledgements

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Appendices

Statistics

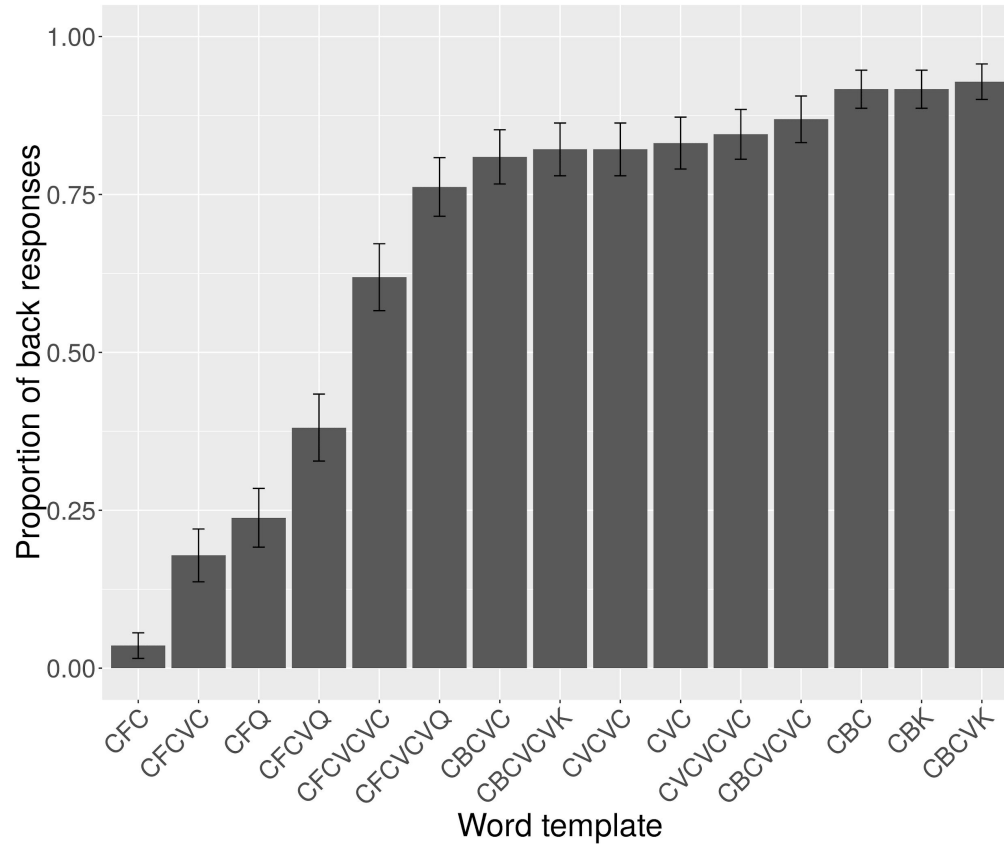
We used linear-mixed effects models (*lme4* in R) to perform statistical tests:

- **Dependent variable:** Suffix choice
- **Independent variables:**
 - Word template ignoring transparent segments
 - **B, F, BK, FQ, N**
 - Distance in segments from trigger vowel to suffix
 - Not applicable for **N** stems
- **Random effects:** Subject

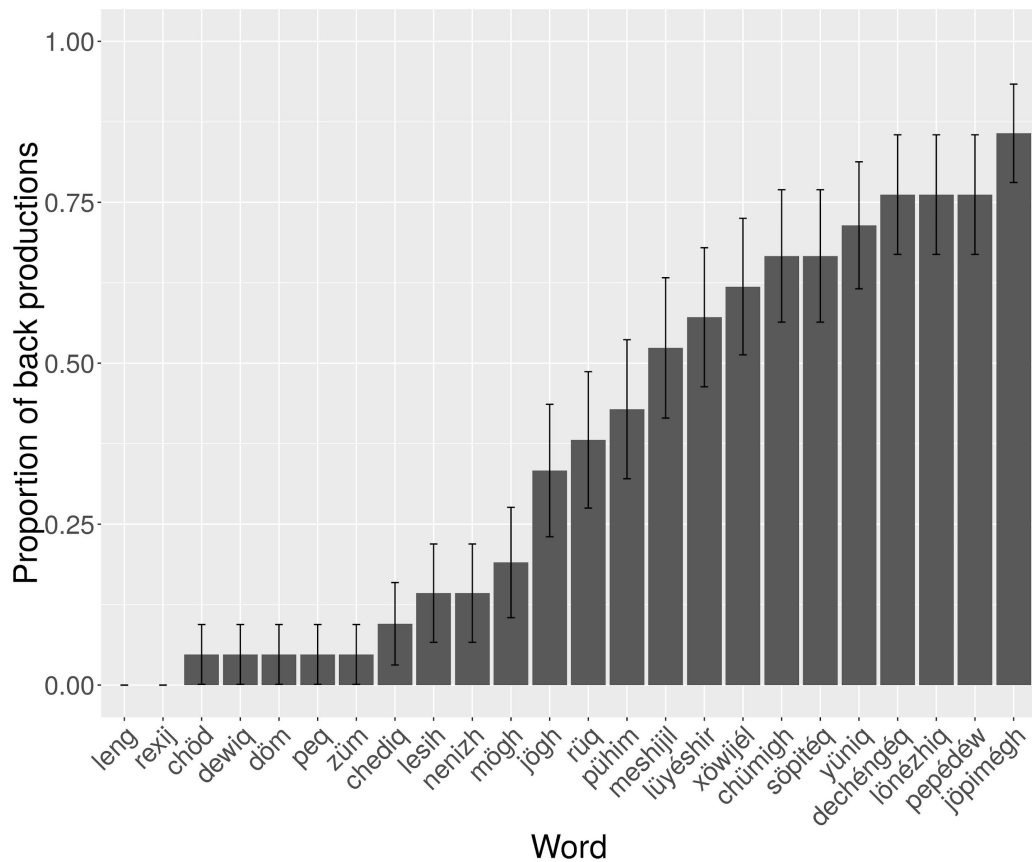
Post-hoc pairwise comparisons done using the *emmeans* package

p-values calculated using *lmerTest* package

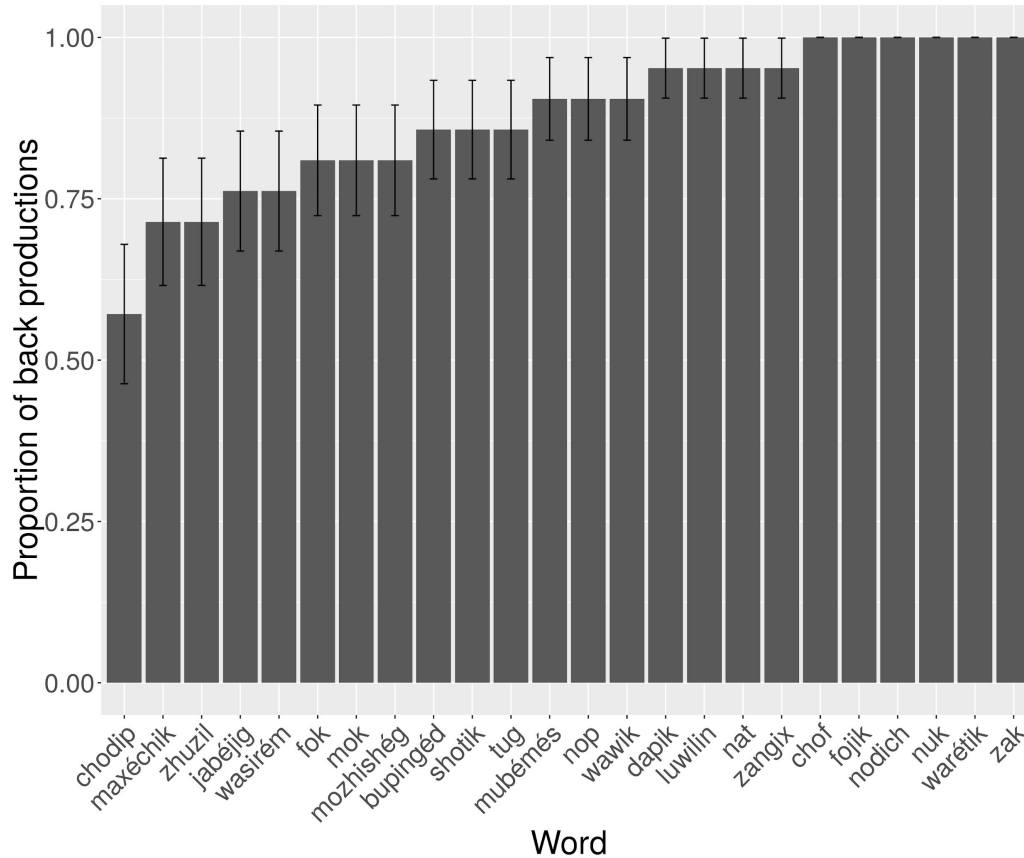
Wugs by detailed template



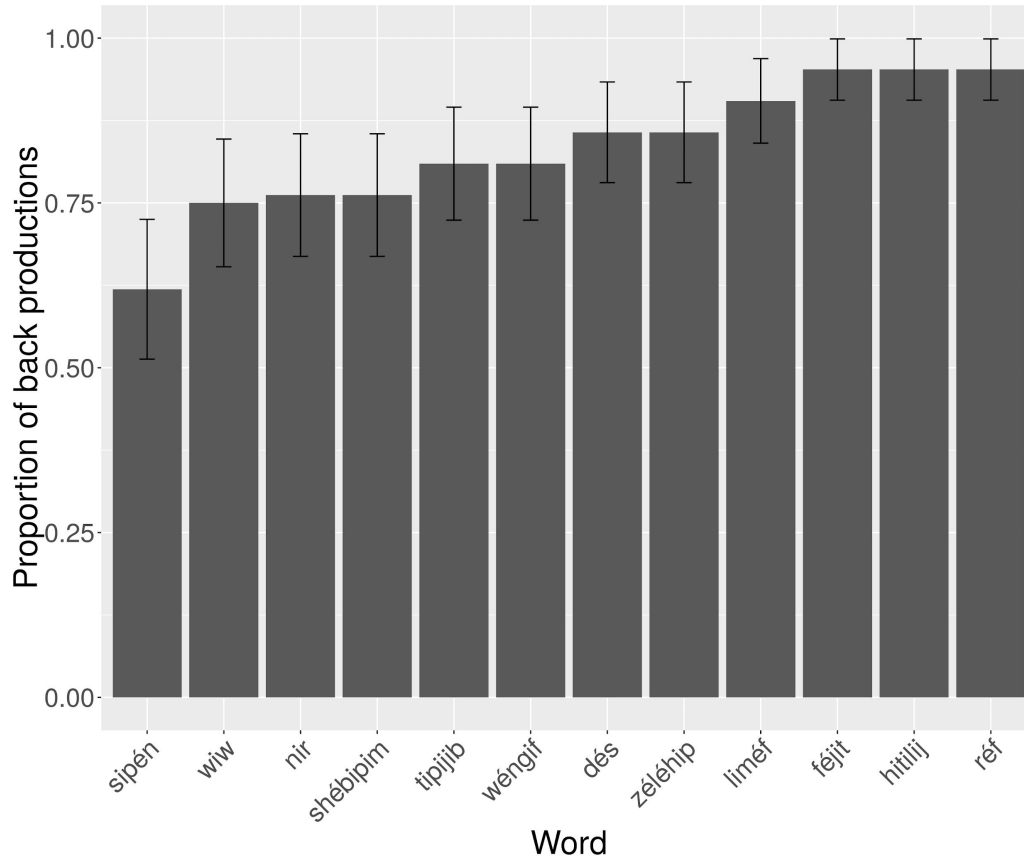
Wugs by word (front triggers)



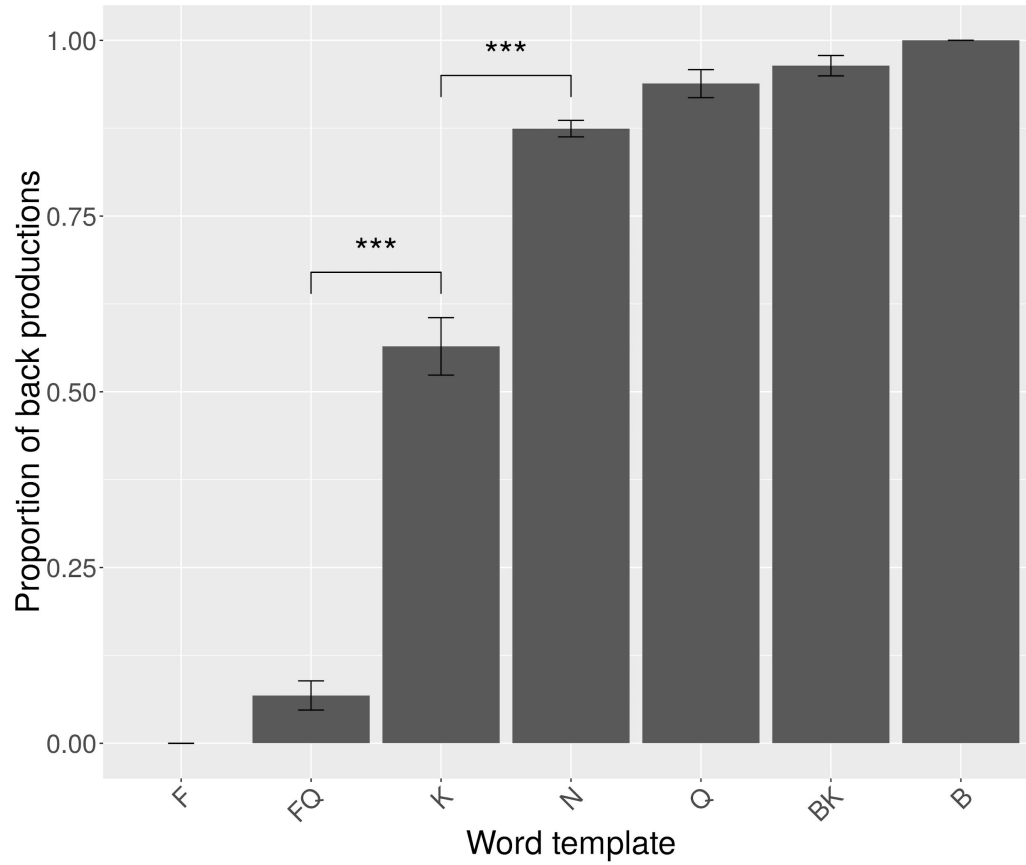
Wugs by word (back triggers)



Wugs by word (no trigger)



Real words by template



A note on constraint weights

These are the weights from the best model:

- $*S_F$: 1.56
- $C_{AGREEBACK}$: 1.07
- $V_{AGREEBACK} (1,2,3)$: (0.84, 0.37, 0.14)
- $V_{AGREEFRONT} (1,2,3)$: (4.04, 3.1, 1.24)

We need $*S_F$ to make transparent forms behave properly.

But this allows low weights for $V_{AGREEBACK}$, which seems counterintuitive...

Backness decay in McCollum (2018)

McCollum (2018) shows that phonetic backness does not persist through long words.

This may align with lower constraint weights for backness agreement.

If everyone expects words to be back, you don't have to work as hard to prove it!

