Nonce words show that Russian yer alternations are governed by the grammar*

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Abstract

Even though vowel deletion in Russian is lexically restricted, the identity of alternating vowels is partially predictable: only mid vowels delete, but even mid vowels cannot delete in some contexts. We report on two nonce word studies asking Russian speakers to rate paradigms in which a vowel was deleted. The ratings strongly correlated with the quality of the vowel: deletion of mid vowels was rated higher than deletion of high and low vowels. We also found that deletion in certain syllabic contexts was rated as ungrammatical: deletion cannot affect words that have a complex coda, and it cannot create clusters with a medial sonorant. Finally, deletion in disyllables was rated higher than deletion in monosyllables, reflecting the trends in the lexicon. These results suggest that even for this lexically restricted alternation, speakers have formed a phonological generalization.

1 Introduction

Russian has a rule known as yer deletion.[1] As shown in (1), the last vowel of the stem deletes when a vowel-initial suffix is attached. Yer deletion is lexically restricted: in the same consonantal context,

*For helpful comments and suggestions, we would like to thank Adam Albright, Ryan Bennett, Junko Ito, Heather Mahan, Armin Mester, Jaye Padgett, Donca Steriade, Colin Wilson, and audiences at New York University, UMass Amherst, the University of California, Santa Cruz, NELS 42, and LSA 86. We would also like to thank Anna Aristova, Yevgenia Gouskova, Vera Gribanova, Stephanie Harves, Pavel Iosad, Sofya Kasyanenko, Inna Livitz, Maria Minchenko, Barbara Partee, Amanda Rysling, as well as the many native Russian speakers for volunteering their time for our study. Special thanks to Junko Ito and the anonymous reviewers for helpful feedback, which has greatly imrpoved the article. Please address correspondence to `maria.gouskova@nyu.edu` and `michael.becker@phonologist.org`.

[1]Yers, or jers, are named after the Old Church Slavonic letters Ь and Ъ, which were used to write the historical ancestors of modern alternating vowels. All Slavic languages have inherited vowel-zero alternations that can be traced to the proto-language, so the term is not specific to Russian (see Jetchev 1997 for Bulgarian, Zec 1988 et seq. for Serbo-Croatian, Kenstowicz and Rubach 1987 for Slovak, Bethin 1992, Rowicka 1999 and many others for Polish).

most words either have vowels that don't delete (see (2a,b)) or clusters that are never interrupted by a vowel (cf. (1a) and (2c)).[2]

(1) Some typical yer alternations from Russian

a.	ʃatʲór	ʃatr-ú	'tabernacle (nom/dat sg)'
b.	kavʲór	kavr-á	'carpet (nom/gen sg)'
c.	kalʲét͡s	kalʲt͡s-ó	'ring (gen pl/nom sg)'

(2) Lack of alternations in identical contexts

a.	matór	matór-u	'motor (nom/dat sg)'
b.	gravʲór	gravʲór-ə	'engraver (nom/gen sg)'
c.	métr	métr-u	'meter (nom/gen sg)'

Like many lexically restricted alternations, this one was once fully productive: the alternating vowels derive from the high lax vowels [ɪ] and [ʊ], which have merged with [e] and [o] (see Lightner 1965, Kiparsky 1979, Vlasto 1986). As a result of historical change, Russian mid vowels now come in two varieties: deleting and non-deleting. The main question we ask is whether speakers form generalizations over the quality and context of the alternating yer vowels and apply these generalizations productively to nonce words ("wugs", Berko 1958).

We show that Russian speakers know the generalizations that govern yer deletion, as demonstrated in ratings of nonce paradigms. We asked people to rate pairs of nonce words with deletion alternations that either followed the attested pattern (e.g., [tʲipʲés]∼[tʲips-á]) or one of several unattested patterns (e.g., deletion of non-mid vowels, as in [karút]∼[kart-á], deletion in words with word-final clusters, as in [sótr]∼[str-á], and deletion that creates sonority sequencing violations, as in [kasnét]∼[kasnt-á]). People prefer wugs that match attested patterns. We moreover discovered that people extend lexical trends to nonce words. For example, alternations are more likely to be rated as acceptable when the wugs are longer than one syllable; even though monosyllabic yer

[2] The following abbreviations are used in glosses: "nom" for "nominative", "dat" for "dative", "gen" for "genitive", "acc" for "accusative", "inst" for "instrumental", "sg" for "singular", "pl" for "plural", "adj" for "adjective", "pred" for "predicative", "dim" for "diminutive", "masc" for "masculine", "fem" for "feminine". All the data are transcribed in IPA and come from one of the authors, unless otherwise indicated. Stress is shown with an acute accent on the vowel that bears it. Yer alternations often cooccur with palatalization alternations; we transcribe but do not analyze them. See Iosad and Morén-Duolljá (2010) and Padgett (to appear) for recent discussions of palatalization in Russian.

words do exist in Russian, they are rare, and speakers don't find them as acceptable as yers in polysyllables. Nonce yer words are also unacceptable if they delete a non-mid vowel or contain a final consonant cluster—even if this cluster is not created by deletion. The results show that speakers apply phonological patterns from the lexicon to nonce words. This is remarkable, because yer deletion is not productively extended to neologisms or to loanwords in Russian. The experimental methodology probes Russian speakers' grammatical knowledge about various aspects of yer alternations, identifying those properties of yer words that are phonologically relevant.

There is growing evidence that speakers have detailed knowledge about phonological trends in their lexicon (Albright et al. 2001, Albright and Hayes 2002, 2003, 2006, Zuraw 2000, Ernestus and Baayen 2003, Pierrehumbert 2006, Becker 2009, Becker et al. 2011, Hayes and Londe 2006). The theoretical treatment of lexically restricted rules has been more controversial, however. Some proposals contrastively underspecify individual alternating segments in the UR (Lightner 1972, Kenstowicz and Rubach 1987, Inkelas et al. 1997), others develop subphonologies that apply only to subsets of morphemes (Jarosz 2008, Becker et al. 2011, Gouskova 2012), and still others list the alternating morphemes as suppletive allomorphs (Rubach and Booij 2001, Green 2007). We demonstrate that speakers have fairly detailed knowledge of the phonological properties of alternating morphemes, contrary to what one might expect given underspecification theories that stipulate the identities of the alternating segments. On the other hand, the speakers' knowledge is not so detailed as to project the properties of alternating morphemes directly from the lexicon by proportional analogy. Speakers do extract generalizations about the alternations rather than relying on gross similarity to other alternating words.

The rest of the paper is structured as follows. Section 2 reviews three competing theories of lexically restricted alternations. Section 2.1 presents our theoretical assumptions about how exceptional phonology is captured in the grammar and presents the generalizations about yer deletion in Russian that we test in our subsequent studies. Sections 2.2 and 2.3 present two alternative theories of lexically restricted phonological alternations and the predictions they make. Section 3 presents a quantitative study of the Russian lexicon. In Sections 4 and 5, we report on the two rating studies we conducted. The first study looks at the effects of vowel quality, morphological class, order of presentation, and syllable count. The second study tests some more specific hypotheses about the blocking effects of syllable structure constraints. Finally, Section 6 concludes.

2 Lexically restricted phonology at the level of the morpheme

Lexically specific rules such as yer deletion have been approached in a variety of ways in phonological theory. In this section, we review the morpheme-by-morpheme theory, segment-by-segment theory, and phonologically conditioned suppletive allomorphy theory of restricted alternations. Our primary concern here is whether and how these theories derive phonological generalizations about alternating morphemes. As we will argue, there are systematic gaps in yer alternations that are left unexplained in segment-by-segment and allomorphy theories.

2.1 Morpheme-level exceptionality and constraint cloning

Under the whole morpheme approach, each morpheme is specified in the lexicon for syntactic, semantic, and phonological idiosyncrasy (Lieber 1980 and others), but such marking does not extend below the morpheme level. We implement phonological idiosyncrasy as constraint indexation, or cloning, in Optimality Theory (Pater 2006, 2008, Becker 2009, Becker et al. 2011, among others): two clones are made of a constraint, with some morphemes indexed to one clone and other morphemes indexed to the other clone.

Our analysis aims to capture several generalizations about the quality and position of alternating vowels. First, Gouskova (2012) argues that these vowels must be mid: [e] and [o] can delete, whereas [i], [u], and [a] do not (see (3)). Russian has lexical stress and vowel reduction, so the deleting vowels can be either stressed [é, ó] or reduced in unstressed position to [i] and [ə] depending on whether the preceding consonant is palatalized (Crosswhite 1999, Padgett and Tabain 2005). Mid vowels never reduce to [u], and this vowel cannot alternate with zero (see (4)).

(3) Yer deletion in Russian: stressed mid vowels alternate with zero

a.	[ó]∼∅	bab$^{j}\underline{\text{ó}}$r	babr-á	‘beaver (nom/acc sg)’
b.	[é]∼∅	r^{j}im$^{j}\underline{\text{é}}$n^{j}	r^{j}imn^{j}-á	‘belt (nom/gen sg)’
c.	*[ú]∼∅	*bab$\underline{\text{ú}}$r	babr-á	*unattested*
d.	*[á]∼∅	*r^{j}im$\underline{\text{á}}$n^{j}	r^{j}imn^{j}-á	*unattested*

(4) Reduced unstressed allophones of [é] and [ó]—{ə, i}—alternate with zero, but [u] doesn't

a.	[ə]∼∅	kúkəl	kúkl-ə	'doll (gen pl/nom sg)'
b.	[i]∼∅	sósʲin	sasn-á	'pine (gen pl/nom sg)'
c.	*[u]∼∅	*kókul	kókl-ə	*unattested*

Second, there are phonotactic constraints on deletion. Mid vowels delete when the result is a medial two-consonant cluster (see (5)) or a CCC cluster with a medial obstruent (see (6)), but deletion does not create CRC clusters with a medial sonorant (see (7)) or word-final CC clusters (see (7)).

(5) Yer deletion creates medial CC clusters

a.	rubét͡s	rup-t͡s-á	'scar (nom/gen sg)'
b.	kəmsamólʲit͡s	kəmsamólʲ-t͡s-ə	'a member of the Komsomol (nom/gen sg)'

(6) Yer deletion creates medial CCC clusters that respect sonority sequencing

a.	kastʲór	kastr-á	'fire (nom/gen sg)'
b.	svʲist-ók	svʲist-k-á	'whistle (nom/gen sg)'
c.	dólʒ-ən	dalʒ-n-á	'must (masc/fem pred adj)'
d.	nʲjujórk-ʲit͡s	nʲjujórk-t͡s-ə	'New Yorker (nom/gen sg)'

(7) Vowel-zero alternations blocked in suffix if CRC or CC# cluster would result

	Nom. Sg.	Gen. Sg.		
a.	arl-ʲét͡s	arlʲ-it͡s-á	'rhodonite'	*arlt͡sá
b.	makr-ʲét͡s	makr-ʲit͡s-á	'midge'	*makrt͡sá
c.	umn-ʲét͡s	umn-ʲit͡s-á	'smart-ass'	*umnt͡sá
d.	*rúp-t͡s	rup-t͡s-á	cf. (5a)	
e.	*kəmsamól-ʲt͡s	kəmsamól-ʲt͡s-ə	cf. (5b)	

Although CRC and CC# clusters cannot be created by yer deletion, both types of clusters are permitted in Russian (see (8)). Thus, constraints against such clusters block vowel deletion but do not trigger vowel epenthesis or consonant deletion. There are a few exceptions to CRC blocking, too: note (8a), which contains the same suffix as the examples in (7).[3]

(8) Examples of medial CRC clusters

a.	ágn-t͡s-ə	'lamb of god (gen sg)'	cf. ágn^{j}-it͡s (nom sg)
b.	bódr-stv-əv-ən^{j}-ij-ə	'alertness'	
c.	a-smótr-ʃʃ^{j}-ik	'surveyor'	cf. asmótr 'survey'
d.	at-mʃʃ^{j}-én^{j}-ij-ə	'revenge (archaic)'	cf. mst^{j}-it^{j} 'to avenge' (st→ʃʃ^{j})
e.	kòntr-pr^{j}id-laʒ-én^{j}-ij-ə	'counterproposal'	
f.	rótm^{j}istr-ʃ-ə	'captain's wife, captainness'	

Third, the vowel that deletes is normally not in the first syllable. In all of the examples we have cited so far, it is the last vowel in the word that alternates, whether it belongs to the root or the suffix. Monosyllabic roots tend to resist deletion: there are a few much-cited examples such as [lop]∼[lb-á] 'forehead (nom/gen sg)' and [rot]∼[rt-á] 'mouth (nom/gen sg)', but we will show in our quantitative study of the lexicon that these famous yer monosyllables are quite atypical in Russian. Most of the words with deletion are longer than a syllable, and it is always the last vowel that deletes.

We analyze these generalizations as follows.[4] To capture the mid vowel generalization, we index alternating morphemes to the markedness constraint *Mid$_{yer}$ (Beckman 1997; see (9)). *Mid$_{yer}$ is ranked above Max-V, triggering the deletion of mid vowels in indexed morphemes such as [ʃat^{j}ór$_{yer}$] 'tabernacle (nom sg)' (see (10a)). Here, the subscript "yer" is shorthand for {[ʃat^{j}ór], [-et͡s]}, and all other yer morphemes. *Mid$_{yer}$ does not apply to morphemes such as [grav^{j}ór$_{reg}$] 'engraver (nom sg)'—for those, the ranking is Max-V ≫ *Mid$_{reg}$. Here, the subscript "reg" is shorthand for {[grav^{j}ór], [m^{j}étr]}, and all other non-alternating (regular) morphemes. The ranking Max-V ≫

[3] The first syllable of [kòntr-pr^{j}id-laʒ-én^{j}-ij-ə] has secondary stress because the prefix is exceptional; normally, non-compound phonological words in Russian have only one stress (Gouskova 2010).

[4] This analysis is largely parallel to Gouskova (2012), except that we use constraint cloning rather than Pater-style lexical indexation. The difference between Pater's (2006) lexical constraint indexation theory and the cloning theory of Becker et al. (2011) is minor. In Pater's theory, exceptions are indexed to a higher-ranked version of a constraint, and the lower-ranked version of the constraint applies generally, to all items. In the theory of Becker et al., all lexical items are indexed to some constraint: thus, both the higher and the lower ranked clones of a constraint come with a list of morphemes that they apply to.

*MID$_{reg}$ favors the retention of the mid vowel in these words.[5]

(9) Constraints for basic deletion

*MID$_{reg}$: 'Assign a violation mark for every vowel that is [−high] and [−low] and is affiliated with a morpheme labeled *reg*.'

*MID$_{yer}$: 'Assign a violation mark for every vowel that is [−high] and [−low] and is affiliated with a morpheme labeled *yer*."

MAX-V: 'Assign a violation mark for every vowel in the input that does not have a correspondent in the output.'

(10) Sketch of a morpheme-level account of Russian yer deletion

/ʃat^{j}or$_{yer}$-a/ 'tabernacle (gen sg)'	*MID$_{yer}$	MAX-V	*MID$_{reg}$
a. ʃatr-á ≻ ʃatór-ə	W	L	
/grav^{j}or$_{reg}$-a/ 'engraver (gen sg)'			
b. grav^{j}ór-ə ≻ gravr-á		W	L

We do not treat the deletion of reduced vowels in detail here. In brief, *MID is independently active in Russian in motivating reduction of unstressed vowels and has different effects in yer words vs. regular words (Gouskova 2012). In yer words, the default is to delete mid vowels, reducing them only where deletion is not possible. On the other hand, in regular words, the default is to reduce rather than delete.[6]

To analyze the phonotactic blocking of deletion, we posit the constraints *CC# and SSP (see 11), which dominate *MID$_{yer}$ as shown in (12).[7]

(11) Constraints that block yer deletion

[5] We use comparative tableaux (Prince 2000). Each row contains a winner ≻ loser comparison, and columns show whether the constraint prefers the winner (W), the loser (L), or neither (empty cell). In a working grammar, at least one W precedes every L in any given candidate comparison row.

[6] Non-mid vowels do alternate with zero elsewhere in Russian. For example, the verbal reflexive suffix [-s^{j}a] is realized as [-s^j] after vowels; discourse particles [ʒə] and [bɨ] can also appear as [ʃ] and [p] respectively. Verbal stems have alternations of stressed [i] and other vowels with zero, which have been analyzed as yer deletion (see Gouskova 2012 for arguments against such analyses). In nouns, however, only mid vowels alternate.

[7] We assume that morphemes without mid vowels, such as /mudr/ 'wise' in (12c), are not indexed to either clone of *MID, since they vacuously satisfy it. Nothing crucially depends on this, though—as Gouskova (2012) shows, the analysis works even if learners assume that these morphemes are indexed to *MID$_{reg}$.

*CC#: 'Assign a violation mark for a word-final consonant sequence.' (after Yearley 1995)

SSP: 'Assign a violation mark for any tautosyllabic sequence of consonants in which sonority decreases toward the nucleus.' (Selkirk 1984 and many others)

Max-Vσ1: 'Assign a violation mark for every vowel in the first syllable that does not have a correspondent in the output.' (Beckman 1998, Becker et al. 2011, to appear)

(12) Yer deletion cannot create a final cluster (CC#) or a medial Sonority Sequencing Principle (SSP) violation: *CC#, SSP ≫ *Mid$_{yer}$

/gon$_{reg}$-et͡s$_{yer}$/ 'messenger (nom sg)'	*CC#	SSP	*Mid$_{yer}$	Max-V	*Mid$_{reg}$
a. gan-^{j}ét͡s ≻ gón-t͡s	W		L	W	W
/gon$_{reg}$-et͡s$_{yer}$-a/ 'messenger (gen sg)'					
b. gan-t͡s-á ≻ gan-^{j}ét͡s-ə			W	L	
/mudr-et͡s$_{yer}$-a/ 'wise man (gen sg)'					
c. mudr-^{j}et͡s-á ≻ mudr-t͡s-á		W	L	W	

To analyze the resistance of first-syllable mid vowels to deletion, we posit that the positional faithfulness constraint Max-Vσ1 dominates *Mid for most yer words.[8] This constraint has several effects. First, it ensures that the first and not the second vowel is preserved in words with two mid vowels. Second, it protects both vowels from deleting simultaneously in disyllables. Third, it protects most monosyllables from losing their vowels. Thus, the diminutive form of the word /kov^{j}or/ 'carpet', [kóvr-^{j}ik], preserves the first vowel of the stem, which does not satisfy *Mid$_{yer}$ quite as well as deleting both vowels would. Most monosyllables in the language[9] are indexed to Max-Vσ1, but a handful of monosyllabic yer words do have deletion, such as [l^{j}ón] ∼ [l^{j}n-á] 'linen (nom/gen sg)'. Yer words are thus segregated by size: the clone of Max-Vσ1$_{m.yer}$ lists the few

[8] To implement this analysis explicitly, we would have to assume the Harmonic Serialism view of positional faithfulness constraints (Jesney to appear): since correct syllabification in the input is not guaranteed, faithfulness constraints cannot refer to the initial syllable of a root in the input; the constraints instead refer to the fully faithful candidate that is the first stage of a phonological derivation.

[9] Words such as [sot-ɨ] 'honeycomb' historically had yers (Vasmer 1958, Gouskova 2012) but have regularized over time. Monosyllabic words such as [l^{j}ot]∼[l^{j}d-a] 'ice (nom/gen sg)' seem to be headed in the direction of regularization: they variably keep their vowels in compounds and with derivational suffixes, for example (Gouskova 2010:438–9). Another track for regularization in Russian has been to lose the yer vowel altogether: thus, [mgl-á] 'mist', which historically had a yer between the first two consonants, has a paradigm gap in the genitive plural instead of the expected *[mgol] or *[mogl] (cf. the Polish cognate [mgw-a]∼[mg^{j}ew]). For more on paradigm gaps in Russian, see Halle (1973) et seq.

monosyllabic yer words, and the clone of MAX-V$\sigma 1_{p.yer,reg}$ lists most other yer words, which are polysyllabic.

(13) Initial syllables are protected from deletion

	/kov^{j}or$_{p.yer}$-ik/ ‘carpet (dim)’	MAX-V$\sigma 1_{p.yer,reg}$	*MID$_{m.yer,p.yer}$	MAX-V$\sigma 1_{m.yer}$	MAX-V
a.	kóvr-^{j}ik ≻ kv^{j}ór-^{j}ik	W			
b.	kóvr-^{j}ik ≻ kvr-^{j}ik	W	L		W
c.	kóvr-^{j}ik ≻ kov^{j}or-^{j}ik		W		L
	/l^{j}on$_{m.yer}$-a/ ‘linen (gen sg)’				
d.	l^{j}n-á ≻ l^{j}ón-ə		W	L	L

Gouskova (2012) has a different analysis of the positional generalization, arguing that the deletion of both vowels in words such as /kov^{j}or$_{yer}$-ik/ to *[kvr^{j}ik] is blocked by the prohibition on three-consonant clusters. This analysis explains why there are also no synchronic yer alternations in words such as [m^{j}est^j] ‘revenge’, which historically had yers in them. As we will show shortly, there is a better explanation for the behavior of [m^{j}est^j]: monosyllables tend to resist alternations, as do words with coda clusters.

Two things are worth noting about the analysis: the constraints we use are independently motivated cross-linguistically, and the analysis makes predictions about how alternations should be generalized. The set of constraints available for indexation is the same as the content of CON, which is assumed to be universal in the strongest version of OT (Prince and Smolensky 1993/2004). Our analysis derives the mid quality of alternating vowels from their markedness, and thus the mid quality of yers is captured systematically. Cross-linguistic evidence for *MID comes from vowel harmony in languages such as Shona (Beckman 1997), unstressed vowel reduction in languages such as Portuguese and Russian (Crosswhite 1999), and vowel inventory systems (Crothers 1978, Flemming 1995, Hall 2011). Non-mid vowels surface faithfully (as in [dúp]∼[dúbə] ‘oak (nom/gen sg)’), since MAX-V dominates all other constraints that could favor the deletion of other vowels. Even if *MID is not universal, there is evidence for its presence in the phonotactics, and the constraint would be available to Russian speakers. Mid vowels are targeted for alternation in Russian for the same reason that other languages avoid them altogether: they are marked for dispersion-theoretic reasons (Crosswhite 1999). The other constraints we use are also typologically well-motivated: the constraint against word-final clusters, the SSP, and faithfulness to initial syllables are all familiar from other languages.

We predict that given a novel paradigm with vowel-zero alternations, Russian speakers will accept it if the grammar can produce it. Generalizations about quality (*Mid) and position (*CC#, SSP, Max-Vσ1) should be extended to new paradigms. In our theory of lexically restricted alternations, constraints are indexed to morphemes in the process of learning the lexicon (Pater 2008, Becker et al. 2011). When the learner detects an inconsistency in the target language (e.g., mid vowels delete in some words but not in other phonologically similar words), the relevant constraints are cloned to resolve the inconsistency. Morphemes are indexed to the appropriate higher or lower ranked clone of a constraint. Thus, when a Russian speaker is presented with a new morpheme that has deletion, e.g., [matón]~[matn-á], it will be checked for consistency with *Mid$_{yer}$ $\gg$ Max-V or Max-V $\gg$ *Mid$_{reg}$ (see (14)). In this derivation, the winner depends on the treatment of the word as yer word or a non-yer word. Both deletion and retention of the vowel are allowed by the grammar, so the deletion candidate is acceptable.

(14) Derivation of a novel polysyllable with a mid vowel

/maton-a/	Max-Vσ1$_{p.yer}$	*Mid$_{yer}$	Max-Vσ1$_{m.yer}$	Max-V	*Mid$_{reg}$
a. ☞matón-ə		(*)			(*)
b. ☞matn-á				*	

Since Max-V dominates all constraints that might favor the deletion of non-mid vowels in nouns (e.g., *Peak/HighV or Parse-σ), we predict that speakers will not be able to grant optimal status to nonce word alternations such as [karút]~[kart-á], in which high vowels delete (see (15)). The only thing this grammar allows is retention of the vowel. The candidate with deletion has no constraint that's sufficiently highly ranked to prefer it.

(15) Derivation of a novel word with a non-mid vowel

/karut-a/	MAX-Vσ1$_{p.yer}$	*MID$_{yer}$	MAX-Vσ1$_{m.yer}$	MAX-V	*MID$_{reg}$	*PEAK/HIGHV
a.☞karut-á						*
b. kart-á				*!		

Since *MID$_{yer}$ is dominated by constraints against CC# and CRC clusters, nonce word alternations that create such clusters should also be rejected. Finally, deletion in the word-initial syllable violates MAX-Vσ1, which most yer words are not allowed to violate. As shown in (16), the grammar admits both deletion and retention of the vowel, but deletion requires the word to be treated as part of the smallest minority: it has to be associated with the higher clone of *MID (just like [maton]), but also with the lower ranking clone of MAX-Vσ1. Since people are biased towards favoring majority patterns (Hayes et al. 2009 and others), we expect them to not reject nonce yer monosyllables outright but to disprefer them nonetheless.

(16) Derivation of a novel monosyllable with a mid vowel in it

/tom-a/	MAX-Vσ1$_{p.yer}$	*MID$_{yer}$	MAX-Vσ1$_{m.yer}$	MAX-V	*MID$_{reg}$
a. ☞tóm-ə		(*)			(*)
b. ☞tm-á	(*)		(*)	*	

Our morpheme-by-morpheme account can be contrasted with two alternatives. In discussing the alternatives, we will focus on whether the theories account for the phonological generalizations about yer deletion, and which aspects of deletion they predict to be extended to nonce words.

2.2 Alternative I: abstract segment-by-segment marking

The first alternative we consider is the segment-by-segment theory of lexically restricted alternations. Most existing analyses of yers (Lightner 1972, Pesetsky 1979, Rubach 1986, Kenstowicz and Rubach 1987, Melvold 1989, Yearley 1995, Rubach 2000, Matushansky 2002, Halle and Matushansky 2006) are segment-by-segment analyses: they assume that it is not possible to predict which vowels will delete, and that the alternating vowels are marked in the UR.[10] Thus, certain segments are labeled as special in the underlying representation of the morpheme: for example, [$\mathrm{r^j im^j \acute{e} n^j}$] 'belt', a yer word, is underlyingly /$\mathrm{r^j im^j E n^j}$/; capitalization represents some underlying structural or featural defect. On the other hand, [$\mathrm{t^j ul^j \acute{e} n^j}$] 'seal', a regular word, is underlyingly /$\mathrm{t^j ul^j e n^j}$/, with a regular vowel. Analyses differ in the UR defect they posit for yers. Thus, yers are often assumed to be either underlyingly high and lax (Lightner 1972, Halle and Matushansky 2006) or underlyingly moraless (Kenstowicz and Rubach 1987, Yearley 1995). The phonological grammar itself is set up to reroute these segments for special treatment. They will be deleted in some contexts and merged with regular mid vowels in others; a popular traditional approach following Lightner (1972) posits that the context for yer realization is before other yers, and all other yers are deleted.

Segment-by-segment analyses predict that generalizations about quality and position of alternating vowels should not be extended to nonce words—after all, if there were generalizations to be made, the vowels would not need to be marked for deletion in the UR. This must be qualified somewhat, since some segment-by-segment approaches capture one of the generalizations but not the others. Marking yers as non-moraic in the UR misses the mid quality generalization, since any vowel can in principle be labeled as non-moraic in the UR.[11] Conversely, many segment-by-segment analyses assume that yers are realized when they are followed by a yer in the UR but delete otherwise (Lightner 1972 et seq.). This misses the positional generalizations we identified: deletion cannot affect a monosyllable or create a complex coda cluster or a sonority sequencing violation.[12] In order to capture these generalizations, one would have to abandon the core idea underlying the segment-by-segment treatment of lexically restricted alternations. We will argue that both the quality and the positional generalizations are robust, based on our experimental results.

While segment-by-segment analyses can be improved by incorporating categorical restrictions on

[10] Analyses in this spirit have been proposed for many other lexically restricted rules outside Slavic (Marlett and Stemberger 1983, Harris 1985, Inkelas and Orgun 1995, Martínez 2008).

[11] A reviewer suggests that the segment-by-segment analyses can be modified to capture the quality generalization: for example, in the moraless analysis, a faithfulness constraint MSeg-μ-[mid] could be ranked above the constraint against moraless vowels and thus prevent mora insertion on mid vowels alone. While it is possible to modify the segment-by-segment analyses in this way, doing so dissolves the very argument for segment-by-segment marking: after all, if the position and quality of alternating vowels follow from the phonological analysis, why do they need to be marked as special in the UR?

[12] Abstract segment-by-segment marking in the UR also does not entirely resolve the problem of lexically restricted phonology: in Russian, vowel-zero alternation patterns differ in lexical categories, with verbs subject to some constraints and nouns to others (we only examine nouns in this paper). Additional mechanisms are needed to capture such differences.

yer deletion, such as the restriction to mid vowels, it is even harder to see how they can cover trends, such as the trend against deletion in monosyllables. Deletion must be allowed, but dispreferred, and a categorical grammar cannot express this. This problem is not unique to Russian: in Turkish, voicing alternations are allowed but not required both in monosyllables and in polysyllables, but they are less common in monosyllables (Becker et al. 2011). Segment-by-segment analyses (e.g., Inkelas and Orgun 1995) mark alternations on underlying representations, making no predictions about speakers' treatment of novel words. On the other hand, morpheme indexation can capture trends by allowing morphemes to pattern differently.

2.3 Alternative II: suppletive allomorphy and analogy

Another approach to lexically restricted alternations is the suppletive allomorphy theory. In an allomorphy account, regular, non-alternating morphemes have a single allomorph, whereas alternating morphemes have two. Thus, a non-alternating word such as [t^jul^jén^j] 'seal' is stored as /t^jul^jen^j/, whereas a yer word such as 'belt' would be stored as both /r^jim^jen^j/ and /r^jimn^j/. The choice of allomorph can be handled either in a phonological grammar or an analogy module. Analyses of the first type attribute the choice between allomorphs to markedness (this style of account has not been pursued for Russian yers, but see Rubach and Booij 2001 for Polish iotation and Green 2007 for Welsh vowel alternations). A suppletive allomorphy analysis of Russian yer deletion would explain the mid quality generalization by recruiting *Mid to select the vowelless allomorph of the root when a vowel suffix follows ([r^jimn^j-í] $\succ$ [r^jim^jén^j-i] 'belt (nom pl)'). The phonotactic blocking would follow from constraints such as *CC# and SSP dominating *Mid, which would favor the vowelful allomorph in cases where vowelless allomorphs violate the constraints ([r^jim^jén^j] $\succ$ [r^jim^jn] 'belt (nom sg)'). Max-V is undominated, so there is no deletion in words with just one UR, such as the non-alternating [t^jul^jen^j] 'seal'.

(17) Selection of allomorphs in a suppletive account of yer alternations

			MAX-V	*CC#	SSP	*MID
a.	/{rʲimʲén, rʲimn}-i/	rʲimnʲ-í≻ rʲi.mʲénʲ-i				W
b.	/{rʲimʲén, rʲimn}/	rʲimʲénʲ ≻rʲimnʲ		W		L
c.	/tʲulʲenʲ-i/	tʲulʲénʲ-i ≻ tʲulʲnʲ-í	W			L
d.	/mudr-{et͡s, t͡s}-a/	mudr-ʲet͡s-á ≻ mudr-t͡s-á			W	L
e.	/gon-{et͡s, t͡s}/	gan-ʲét͡s ≻ gón-t͡s		W		L

The allomorphy account does not view the alternations as unfaithful mappings and therefore denies any role for faithfulness, so it cannot appeal to the positional constraint MAX-Vσ1 to explain why monosyllables tend to not alternate. There are possible markedness explanations—for example, the allomorphy theory could recruit a minimal word requirement such as FTBIN to favor the vowelful monosyllabic allomorphs both in affixed and unaffixed forms. But this would block alternations categorically in all monosyllables, rather than capture the tendency for monosyllables to not alternate. In order to capture the lexical tendencies, this theory would have to rely on analogy.

One of the reasons for treating these kinds of alternations as phonologically conditioned allomorphy is that they are not usually productively extended to loanwords and novel words: thus, speakers know the phonological conditioning for which allomorphs occur where, but they do not generalize the pattern, because there is no specific grammar that will allow them to do so. It is not clear, therefore, that this theory should even make predictions about nonce word alternations. Yet, as we will show, people do have clear intuitions about nonce words—which we will argue implies grammatical knowledge.

Another concern about this approach is that it treats restricted alternations on a par with truly suppletive allomorphy, whereas the two classes of alternations are not the same typologically.[13] The account in (17) must assume that the insertion of a root allomorph is conditioned at least in part by the phonological properties of an affix. This assumption is problematic from a typological standpoint: uncontroversially suppletive root allomorphy (e.g., *go/went*, *person/people*) can

[13]This is one of many arguments against suppletive allomorphy accounts of phonologically restricted alternations (see Wolf 2012 for more). The original "limited storage" argument against allomorphy and for unique/abstract underlying representations (Chomsky and Halle 1968, Bromberger and Halle 1989) has been challenged by psycholinguistic research (see Vaux 2003 for a detailed literature overview).

be conditioned by the morphosyntactic features of outer morphemes, but not by their phonological properties (Carstairs 1988, Bobaljik 2000, Paster 2006, Wolf 2012). To treat phonologically related words in the same way as suppletive allomorphs would mean predicting phonologically conditioned outwards looking allomorphy, which does not happen. Our approach distinguishes truly suppletive allomorphy from lexically restricted phonology and is in principle compatible with serial root-outwards morpheme insertion (Bobaljik 2000).

Thus, it is not clear that suppletive allomorphy can use the phonological grammar to make predictions about nonce word alternations. Green (2007) suggests an alternative: extension to novel words is done by analogy (see also Pinker and Prince 1988 and Bybee 1995 on analogy in morphological rules of limited productivity). While analogy is an intuitively appealing notion, all concrete implementations to date have not been able to overcome the inherent difficulty of analogizing in the way that humans do. In particular, Albright and Hayes (2003) show that models of analogy fail to recognize *islands of reliability*: phonologically local generalizations about the phonological shape of morphemes that reliably undergo or fail to undergo alternations. In our case, words with complex codas form an island of reliability where no yer alternations are allowed. Instead of analogy, Albright and Hayes (2003) use gradiently applicable grammatical principles that apply to all words, regular or irregular. Our constraint cloning approach similarly applies grammatical principles (in our case, constraint rankings) to subsets of the lexicon. In Section 5.4, we will argue that grammatical principles explain our results better than the standard lexical similarity measures such as neighborhood density and transitional probabilities.

3 A statistical analysis of yers in the Russian lexicon

The goal of this section is to verify the generalizations from the phonological analysis in Section 2.1. We also want to consider accidental but potentially phonologically relevant generalizations about yer morphemes, since such islands of reliability have been known to affect speaker behavior in wug experiments (Albright and Hayes 2003, 2006).

We extracted the 20,563 masculine second declension nouns from Zaliznjak's (1977) dictionary (Usachev 2004) and analyzed the patterning of the yer words in this corpus. We limited ourselves to masculine second declension nouns so as to match the items of Experiment 2 (see Section 5).

Feminine nouns are moreover inconvenient for corpus analysis, since some of them have paradigm gaps in the genitive plural, exactly where the yer is expected (Halle 1973 et seq.). Among the masculines, we found the yer nouns by lining up the nominative singular and genitive plural with a minimum edit distance algorithm, and then marking stem-internal vowel alternations. We marked 1,902 nouns (9%) as containing a yer.

Of the 1,902 alternating nouns, only two had deletion of non-mid vowels: orthographically, "kot͡ʃa̲n∼kot͡ʃn-a" 'head of cabbage (nom/gen sg)' and "zája̲t͡s∼zájt͡s-a" 'hare (nom/gen sg)'. Both of these examples are dubious: [kat͡ʃá̲n] is not a yer word in the standard dialect, and in [zájə̲t͡s], the deleting vowel is unstressed and pronounced as schwa even though it is written as "a" (Gouskova 2012, fn. 4). We therefore do not consider these to be exceptions to the quality generalization.

The 20,563 nouns were coded for a variety of phonological factors. We focused on whether the nouns were *monosyllabic*, had *final clusters* (CC#), and had the potential for *medial SSP* violations (nouns of the form VCRV̲C#, which, if the underlined vowel were deleted, would have a medial CRC cluster). Table 1 shows how the nouns are distributed within each phonological subclass. Each row for each category adds up to 20,563, with 18,661 non-yer words and 1,902 non-yer words. As the table shows, yer words are far less likely than non-yer words to be monosyllabic, to have a CR(V)C# cluster, and no yer words have CC# clusters at all. For example, monosyllables are .7% of yer words, but 8% of non-yer words.

	Non-yer words		Yer words	
	Yes	No	Yes	No
Monosyllabic?	1,494 (8%) nós/nas-óf 'nose'	17,167 (92%) gra.vʲor/gra.vʲor-əf 'engraver'	14 (0.7%) lóp/lb-óf 'forehead'	1,888 (99.3%) ʃa.tʲór/ʃa.tr-óf 'tabernacle'
SSP: CR(V)C#?	3,819 (20%) matrós/matrós-əf 'sailor'	14,842 (80%) mástʲir/mastʲir-óf 'master'	6 (0.3%) ágnʲit͡s/ágnt͡s-əf 'lamb (of god)'	1,896 (99.7%) kastʲór/kastr-óf 'fire'
CC#	3,177 (17%) móst/mast-óf 'bridge'	15,484 (83%) krót/krat-óf 'mole'	0 (0%) *pést/pst-óf hypothetical	1,902 (100%) lóp/lb-óf 'forehead'

Table 1: Percentages of masculine yer and non-yer words in Zaliznjak (1977), by phonological property

To assess the strength of these effects, we developed a regression model. Since the presence of a *complex coda* precludes yers categorically, a basic logistic regression model would be non-identifiable (see Section 5.8 of Gelman and Hill 2007). Instead we used the *bayesglm()* function from the *arm* (Gelman et al. 2011) package in R (R Development Core Team 2011). The model in Table 2 confirms that ending in VCRVC#, VCC# or being monosyllabic are all correlated with a significantly lower probability of having a yer.

	Estimate	SE	z	$p(>\|z\|)$
(Intercept)	-3.90	.28	-13.76	
medial SSP	-1.76	.15	-11.50	$< .0001$
monosyllabic	$-.51$	.07	-7.34	$< .0001$
complex coda	-2.67	.64	-4.18	$< .0001$

Table 2: Regression model for yer words in the Russian lexicon

While only *complex coda* makes the regression model non-identifiable outright, *monosyllabicity* is a property of so few yer words that regression modeling is stretched to its limits. The small number of monosyllabic yer words will not allow us to dig in deeper and find generalizations about these lexical monosyllables. Deletion in monosyllables has been argued to be phonotactically controlled: all 14 of the alternating masculines are CVC, and none are CCVC or CVCC (Gouskova 2012 attributes this to a constraint against #CCC clusters). To the linguist, this seems non-accidental, but the statistical learner will not be able to learn this difference from a handful of items. In other words, the model in Table 2 predicts no difference between CVC and CCVC monosyllables in their ability to host yers. As we show in Section 5, Russian speakers do not distinguish between CVC and CCVC alternations in nonce words, but they do rate alternations of words with complex codas as less acceptable.

We should note that our statistical analysis of the lexicon did not take morphological complexity of polysyllables into account, but, as we will show in Experiment 2, syllable count correlates with ratings even in nonce words that cannot be plausibly analyzed into Russian morphemes. Our lexicon model is a good predictor of the distribution of yers in monomorphemic words, even though it includes polymorphemic words in it.

Finally, we considered the distribution of lexical stress patterns among yer words. There are two reasons to pay attention to stress. First, we are interested in vowel quality, which only contrasts fully when stress is on the alternating vowel. Second, the status of yers in the Russian lexical stress system has been a matter of some debate (Halle and Vergnaud 1987, Melvold 1989, Idsardi 1992, Revithiadou 1999), and it is reasonable to expect that in a system with contrastive stress, deletion of stressed vowels would be disfavored. We considered the possibility that stress alternations or lack thereof may be a factor in our experiments, so we checked the stress properties of yer stems.

The distribution of stress types in Russian is well studied. Zaliznjak (1977) reports that 92% of all nouns have fixed stem stress, 6% have stress on the last syllable, and the remainder have stress alternations between the suffix and the initial syllable or between the suffix and the penult (see Melvold 1989). Among yer morphemes, the distribution is slightly different. Most yer monosyllables have final stress, which is the only logically possible option for them (e.g., [p^{j}ós]∼[ps-á] 'dog (nom/gen sg)'; the only exceptions are feminines such as /$loʒ_{yer}$/ 'lie', which have mobile stress: [lʒ-í]∼[lóʒ-ju] 'lie (gen/inst sg)'). Longer yer words (again, 2nd declension masculines) have 64% fixed stress, 35% final stress, and 1% other types. We excluded words with the [-ok] suffix, which is post-accenting, and then looked at polysyllabic masculines of the 2nd declension that did not end in [-ok]. In that comparison, the percentage of stress types in non-yer words was the same, but among yer words, the percentages were 84% fixed stress, 14% final stress, and 3% other. To anticipate our results, we did not find any effects of stress on yer deletion in either of our rating studies, but we do not rule out the possibility that the somewhat higher prevalence of the final stress pattern among yer words can have an effect on deletion.

To conclude, we confirmed the generalizations from our phonological analysis in Section 2.1, such as SSP blocking of deletion. We also identified some previously unreported generalizations about Russian yer deletion: the absence of final clusters is a robust correlate of yer morphemes, and monosyllables are actually less likely to have alternations than longer words, even though CVC examples such as [l^{j}ón]∼[l^{j}ná] 'linen (nom/gen sg)' are ubiquitous in the literature and might be taken to be typical.

4 Experiment 1: Testing the quality generalization

The main hypothesis we were interested in testing in this experiment is stated in (18).

(18) *The Quality Hypothesis*: Alternations of mid vowels [é,ó] and their unstressed allophones [i,ə] should be rated as more acceptable than alternations of non-mid vowels [í,ú,á] and [u].

A secondary goal of this experiment was to ensure that morphological gender and declension class did not affect speaker judgments.

4.1 Participants

All participants were adult native speakers of Russian ($n = 69$); they participated anonymously and volunteered their time. The experiment was conducted on the web, and participants were recruited online through various Russian language online communities and groups on social networks.[14]

The participants volunteered the following information after they completed the survey: gender (53 females, 15 males, one unreported), age (range 17–64, mean of 28, median 24, 9 unreported), location (30 from Moscow, 15 from other cities in Central Russia, and the rest from elsewhere in Russia and the former Soviet Union), and other languages spoken (15 reported some knowledge of another Slavic language, almost everybody mentioned at least one of the major European languages).

The server log indicated that speakers took on average 15 minutes to complete the survey (median 12 minutes, range 7–48). We also checked each participant's agreement with the group by calculating the correlation between each participant's reponses and the average response of the rest of the group. We found no correlation between agreement level, age, or time of completion.

4.2 Materials

A female native speaker of Moscow Russian[15] recorded the stimuli in a sound-attenuated room using a Marantz PMD660 solid state recorder using a head-mounted Audio-Technica ATM75 microphone. The items were checked by two other linguists who were native speakers of Russian, and they were deemed to sound natural.

The experiment included a total of 146 items (43 pairs of test words and 30 pairs of fillers). The test words included 25 nonce monosyllables and 18 nonce disyllables. The monosyllables were divided into four categories by declension class and gender. Each word appeared as CVC and as CC-V_{affix}, though the morphological status of these forms depends on the declension class and gender. In the nominative singular (i.e., citation) form, Class II feminines and Class I neuters appear as CC-V_{affix}, whereas Class I masculines and Class III feminines appear as CVC. Each

[14]The sites were http://odnoklassniki.ru and http://livejournal.com.
[15]One of the co-authors. Moscow Russian is considered to be the broadcast standard dialect.

word was paired with a declined form: a genitive singular or a genitive plural, depending on the class and gender:

(19) Examples of nominative and oblique monosyllable forms

Class I neut.	gr-ó	(nom sg)	gúr	(gen/acc pl)
Class I masc.	gún	(nom sg)	gn-á	(gen/acc sg)
Class II fem.	zn-á	(nom sg)	zún	(gen/acc pl)
Class III fem.	súl^j	(nom sg)	sl^j-éj	(gen/acc pl)

Each noun was recorded with an agreeing adjective or determiner to disambiguate its gender/declension class. The recorded adjective-noun pairs were paired with context sentences that were presented orthographically alongside the adjective-noun sound files (see the next Section).

Disyllabic nouns were split into two categories: fixed stress and mobile stress. In ten nouns, stress alternated between the final CVC syllable and the affix vowel, following the final stress pattern (e.g., [zutúʃ]∼[zutʃ-á]). The crucial comparison here is between [é] and [ó] on the one hand and [í/ú/á] on the other. For eight nouns, stress was fixed on initial position, so that the alternating vowel in the second syllable was never stressed (e.g., [gásut]∼[gást-ə]). In these words, the crucial comparison is between [i,ə], which are possible allophones of [e,o], and [u], which never occurs as an allophone of a mid vowel in Russian. All monosyllables also followed the final stress pattern, so the alternating vowel appeared as stressed. A full list of all the test items appears in the Appendix.

The consonants on either side of the vowel were chosen so that the cluster resulting from deletion was of a type attested in word-initial position in the language. (The only exception was [t͡ʃin^j]∼[t͡ʃn^{j}ej]; the cluster #t͡ʃn^j does not occur in any existing words, but it is quite close to attested clusters such as #t͡ʃm and #t͡ʃt.)

The 30 fillers had word-final voicing alternations, diminutive suffixes accompanied with consonant mutation, and no alternations at all.

4.3 Methodology

The participants were given written instructions (in Russian) that they would hear made-up words that were similar to words of Russian. Each word would appear in two inflected forms, and the participants' task was to grade the inflected form as a form of the first word they heard. The grading scale was from 1 "very bad" to 7 "excellent," and the numbers from 2 to 6 could be used for intermediate forms. The participants then saw two "excellent" training examples and two "very bad" ones. The "excellent" examples were [vóp]∼[vóp-ə] and [pʃút]∼[pʃud-óm]; the latter was included to ensure that participants saw an example of a word with a stress alternation and a ubiquitous voicing alternation. The "very bad" examples were [bɨ́ʒik]∼[bɨʒík-əmi] and [xakát]∼[xakít-ə]. The first pair has a stress alternation of an unattested type.[16] The second pair has an unattested vowel quality alternation in stressed position. Test word pairs were randomized and randomly interspersed with filler pairs.

The stimuli were presented in pairs: a nominative form followed by an oblique inflected form. Each test word was presented both orthographically in a syntactically appropriate context sentence (e.g., "Here sits ______ $_{Nom sg}$" or "They see ______ $_{Acc\ sg}$" or "They have no ______ $_{Gen\ pl}$") and as a sound file, paired with the adjective. Participants had to listen to each sound file in order to advance to the next stage of the experiment. After both forms appeared, the participant had to click one of seven buttons rating the second form. The instruction was "Please rate the word ______ as a form of the word ______ ."

(20) An example pair of forms and instruction to participants

Вот сидит белый гун. 'Here sits a white *gun* (nom sg).' [sound file: "bʲélɨj gun"]
Они видят белого гна. 'They see a white *gun* (acc sg).' [sound file: "bʲéləvə gna"]

Просим вас оценить слово гна, как форму слова гун.
'Please rate the word 'gn-a' as a form of the word 'gun'

очень плохо	1	2	3	4	5	6	7	отлично
very bad								excellent

4.4 Results

As expected, paradigms with V∼Ø alternations were given higher ratings when the alternating vowel was mid [e,o], and lower ratings when the vowel was high or low [a,i,u]. This is seen in the beanplot in Fig. 1, where the mean ratings for [e,o] (4.48) are overall 1.53 points higher[17] than the

[16] Prior work suggests that moving stress in Russian from its fixed location in lexically stressed words can result in significantly degraded grammaticality judgments (Gouskova 2010).
[17] The rating data from Experiments 1 and 2 are available at http://becker.phonologist.org/projects/russian/.

mean ratings for the high and low vowels (2.95).[18]

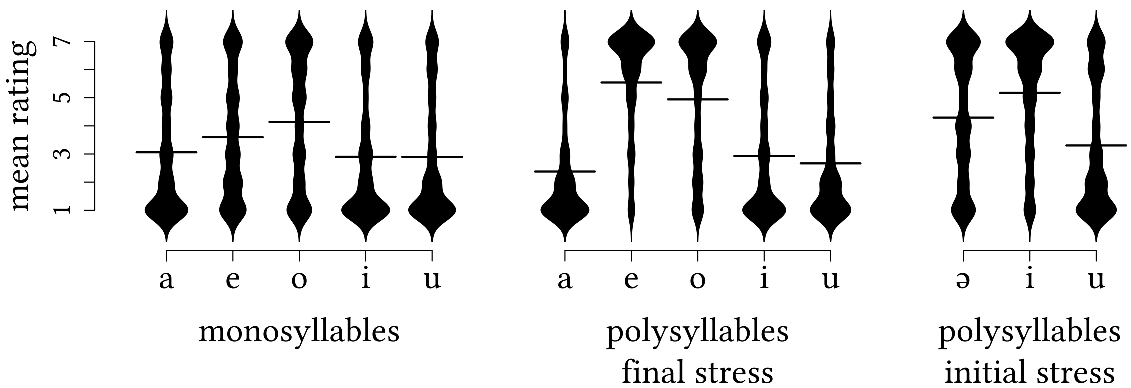

Figure 1: Density plots for rating of V∼Ø alternation by monosyllabicity and stress

The first two panels in Fig. 1 show that mid vowels are more acceptable as yers than non-mid vowels, and that the effect is stronger in the finally stressed polysyllables, reflecting the trend in the lexicon (Section 3), where yer alternations are more common in polysyllables. The third panel shows that in unstressed position, deletion of [i] and [ə] is more acceptable than deletion of [u], the only vowel found in unstressed position that cannot be an allophone of [e] or [o]. In initial stress polysyllables, [i] stands for orthographic "e", whereas [ə] combines the results for orthographic "o" and "a".

These effects were tested in a mixed effects regression model that was fitted in R (R Development Core Team 2011) using the *lmer()* function of the *lme4* package Bates and Maechler 2009. A base model was fitted with *rating* as a dependent variable, and with two predictors as fixed effects: *mid*, a binary factor that contrasted [e], [o] and unstressed [a] with all other vowels, and *monosyllabic*, a binary predictor that contrasted monosyllables and polysyllables, and the interaction of these two factors. We used a fully crossed model, with random by-item and by-participant slopes for *mid*monosyllabic* . The predictors were normalized with the *scale()* function to reduce collinearity in the model. The final model enjoys low collinearity measures ($\varkappa$=1.40, VIF≤1.03, all correlations< .16). The resulting model is given in Table 3 with p-values estimated directly from the t-scores, as

[18] A beanplot is a vertical density plot with a horizonal line to mark the mean. The thickest part of the bean corresponds to the greatest number of ratings at that level; thus, the most common rating given to polysyllables with final stress in which the vowel [e] alternates with zero is "7", with "6" somewhat less common, and the rest of the ratings still less common. These graphs do not include error bars because they show the overall rating distribution for each category and are more informative than barplots or boxplots for rating data.

no other method is available at the moment.

	Estimate	SE	t	p
(Intercept)	3.60	.14	26.43	
mid	.74	.11	6.99	$< .0001$
monosyllabic	$-.20$	.10	-2.02	$< .05$
mid:monosyllabic	$-.31$	.09	-3.38	$< .001$

Table 3: Regression model for nonce word ratings, Experiment 1

Additionally, several other factors were considered and were found not to make significant improvements to the model. These included grammatical factors, such as the gender of the nouns, the position of the alternating vowel in the paradigm (nom or gen/acc), the position of stress, and the identity of the consonants that precede or follow the alternating vowel (which were considered individually and in natural classes). While all of these factors could imaginably influence speakers' reactions to the novel nouns, we didn't have any particular expectation about the direction or size of these effects, and we were not suprised that they didn't have much predictive power.

In addition to the grammatical factors, we considered two lexicon-based factors: log bigram probability of each word (i.e., the sum of the log frequencies of each segment given the preceding segment), and neighborhood density of each word (Luce and Pisoni 1998). We generated these measures for the base (nom) and for the derivative (gen/acc). We used two word-lists as lexical bases: Sharoff (2005), a 32,000 item list that is derived from a large corpus, and Usachev (2004), a 93,000 item list that is derived from Zaliznjak's (1977) dictionary. We thus got 8 predictors (2 word-lists * 2 morphological categories * 2 lexicon-based factors). None of these 8 predictors made a significant improvement to the model, either on its own, or with its interaction with *mid* or *monosyllabic*. This is not surprising given the accumulating body of evidence for the irrelevance of such lexicon-based measures in paradigmatically-oriented tasks (Bybee 1995, Albright and Hayes 2002, Hay et al. 2003, Becker et al. to appear); recall that we asked participants to rate the goodness of paradigmatic relationships, not the goodness of either member of the paradigm.

To summarize, we saw that mid vowels alternating with zero were rated significantly higher than non-mid vowels, and that this difference was bigger in polysyllables than it was in monosyllables.

5 Experiment 2: Testing context effects

The hypotheses we tested in this experiment are summarized below. Medial SSP Blocking is predicted by our phonological analysis. The second hypothesis is an expectation based on our analysis of the lexicon in Section 3: since yer morphemes never have final clusters even in their base forms, such words should be rejected as alternators.

(21) *Medial SSP Blocking Hypothesis*: Alternations that create medial SSP-violating CCC clusters should be rated lower than alternations that create SSP-obeying CCC clusters.

(22) *Coda Cluster Blocking Hypothesis*: Alternations in monosyllabic roots with CC clusters in unaffixed forms (CVCC∼CCC-V) should be rated lower than alternations in two-consonant roots (CVC∼CC-V) or in monosyllables with onset clusters (CCVC∼CCC-V).

5.1 Participants

The participants were recruited in the same way as in Experiment 1 (see Section 4.1). All participants were adult native speakers of Russian ($n = 118$); they participated anonymously and volunteered their time.

The participants volunteered the following information after they completed the survey: gender (59 females, 52 males, 10 unreported), age (range 17–60, mean of 30, median 27, 25 unreported), location (53 from Moscow, 7 from St. Petersburg, and the rest from elsewhere in Russia and the former Soviet Union), and other languages spoken (12 reported some knowledge of another Slavic language, almost everybody mentioned at least one of the major European languages). The server log indicated that speakers took on average 18 minutes to complete the survey (median 11 minutes, range 7–176).

We also asked participants whether they had taken Experiment 1, with 29 saying yes, 83 no, and 6 unreported. We assume the unreported people had not taken Experiment 1. There were no systematic differences between the participants who took the first experiment and those who didn't. There was very high agreement between the groups, as confirmed by a comparison of the average ratings per item for each group. The correlation is excellent, with most items lying close to the identity line (Pearson's product-moment correlation, $r = .86, p < .0001$).

5.2 Materials

The materials for this experiment were recorded by the same speaker and on the same equipment as in Experiment 1 (see §4.2). There were 66 pairs of stimuli altogether. Since we found that the order of presentation of vowelled vs. vowelless forms did not affect the ratings, we presented the vowelled stimuli first. All the new forms were of the masculine second declension. This declension has a null affix in the nominative (e.g., [ʒus^{j}él]) and an /-a/ affix in the genitive/accusative (e.g., [ʒusl-á]. We kept the number of back and front yers equal within each group, to the extent that this was possible. In addition to the 60 pairs that tested new hypotheses, we included six control words with deletion of [u], three CuC monosyllables and three CVCuC disyllables. These were included to ensure that we were getting consistent results between groups. Recall that [u] was the worst alternator in our last experiment. All of our test items are listed in the Appendix.

There were 42 pairs for testing the effects of syllable structure constraints. In six pairs, deletion yielded medial CCC clusters that could be syllabified into C.CC without violating the Sonority Sequencing Principle. In another six pairs, deletion yielded a medial CCC cluster with a sonorant as C2, which cannot be syllabified without violating the SSP. There were 10 pairs of words where deletion yielded an initial CCC cluster: five with an initial cluster in the null-affix form, as in CCVC, and five with a final cluster in the null-affix form. Finally, there were 10 pairs each of monosyllabic CVC words that had initial CC clusters after deletion; in 10 of them, the first consonant was an obstruent, and in the other 10, it was a sonorant. The number of front and back yers was about even, although there were slightly more back yers than front ones, to reflect the lexical tendencies.

(23) Examples of stimuli for testing the syllable structure hypotheses

	Null affix	Vowel affix	N of pairs
Medial SSP-obeying CCC	k^{j}iftór	k^{j}iftrá	6
Medial SSP-violating CCC	kasn^{j}ét	kasntá	6
Initial CCC, base CCVC	sp^{j}ér	sprá	5
Initial CCC, base CVCC	sótr	strá	5
Initial SSP-obeying CC	ʃér	ʃrá	10
Initial SSP-violating CC	m^{j}ék	mká	10

We also included 18 pairs to control the effects of stress. There were six pairs with fixed stress, six pairs with stress alternating and never falling on a yer, and six pairs with stress alternating between the yer syllable and the affix. Each set included 3 words with /e/ and 3 words with /o/ yers.

(24) Examples of stress alternation stimuli

	Null affix	Vowel affix	N of pairs
Fixed stress on first syllable	bák^{j}et	bákta	6
Alternating stress, not on yer	tóp^{j}es	topsá	6
Alternating stress, on final syllable	ʒus^{j}él	ʒuslá	6

There were 52 pairs of fillers, which either had no alternations at all or had voicing alternations, attested stress alternations, unattested stress alternations, and unattested vowel quality alternations.

5.3 Methodology

The methodology was the same as in Experiment 1 (see Section 4.3). Since we had more test items, we did not present each participant with the entire set, in order to keep the duration of Experiment 2 approximately the same as that of Experiment 1. Each participant heard only a subset of the 138 items, in 69 trials of inflected pairs (44 test items and 25 fillers). The test items were distributed so that each participant heard 4 randomly drawn paradigms out of each of the three sets of 6 stress CVC(C)VC disyllables, 4 paradigms out of each of the two CVCCVC disyllable sets, 7 paradigms out of each set of 10 CVC monosyllables, 3 paradigms out of each set of 5 CVCC and CCVC monosyllables, and 4 paradigms with [u] ($4 * 3 + 4 * 2 + 7 * 2 + 3 * 2 + 4 = 44$).

5.4 Results

Reaffirming the results from Experiment 1, participants rated paradigms with deletion of [u] significantly lower than those with [e] or [o], as shown in Figure 2 below (on average, 2.8 vs. 3.3 on the 1–7 scale), with [e] and [o] equally acceptable as deleted vowels. Additionally, monosyllabic stems were rated slightly but significantly lower than polysyllabic ones (3.2 vs 3.4).

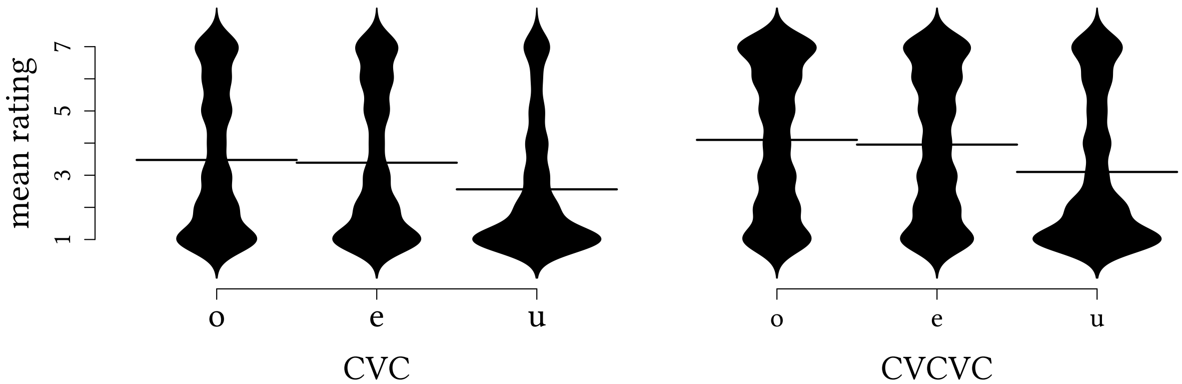

Figure 2: Vowel quality effects in mono- and polysyllables

Looking at items with [e] and [o], we focus on the monosyllables first. As seen in the left panel of Figure 3, deletion in stems with complex codas (CVCC) was rated significantly worse than deletion in a stem with simplex coda (CVC and CCVC) (2.2 vs 3.4). Both CCVC and CVCC give rise to tri-consonantal clusters in the genitive, but CCVC items were only rated slightly lower than CVC (3.2 vs. 3.4).[19] Among the polysyllables, items whose genitive violates SSP, such as [kasnʲét]∼[kasnt-á], were rated significantly worse than others (1.7 vs. 3.9). Items with an SSP-obeying CCC medial cluster, such as [pʲiltʲér]∼[pʲiltr-á], were only rated slightly worse than items with no CCC cluster at all (3.6 vs. 4.0).

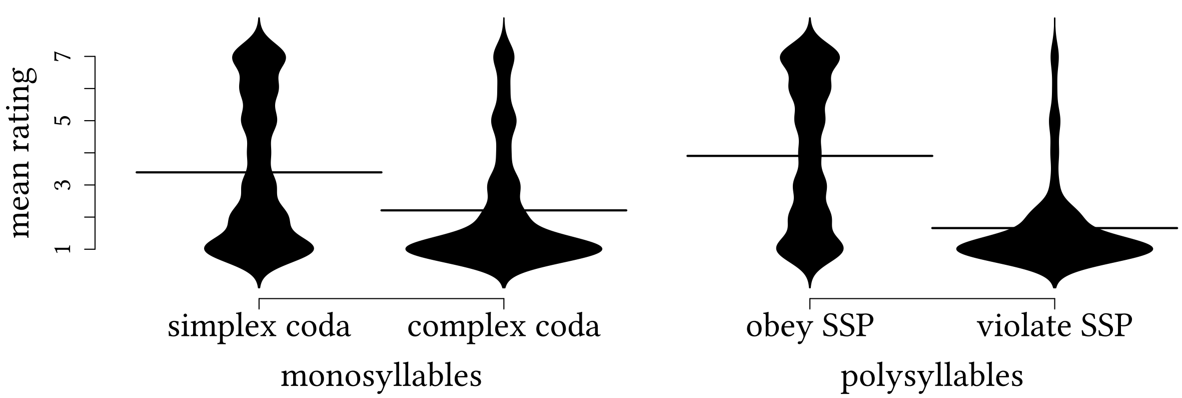

Figure 3: Effects of syllable structure in mono- and polysyllables

[19]The individual items' ratings are: [kest] 2.58, [stek] 2.51, [ketr] 1.37, [spol] 3.57, [motʃ] 2.48, [mset] 3.22, [sotr] 2.55, [sper] 3.57, [vosp] 2.17, [vsop] 3.07. Even within those CVCC and CCVC wugs whose clusters are almost completely matched, the CVCC wugs are comparatively worse: for [fsp], [fsop] 3.07≻[vosp] 2.17, for [spr/str], [sper] 3.57≻[sotr] 2.55). Our statistical model includes a by-item random slope, so the individual variance is taken into account.

The effect of stress was small overall. Among CVCVC items, those with stress fixed on the stem-initial vowel were rated best (4.3), followed by those with final stress throughout (4.2), and rated lowest were items with initial stress in the base and final stress in the genitive (3.5).

The statistical analysis was again done with the *lmer()* function in R. A base model was fitted with *rating* as a dependent variable and *item* and *participant* as random effects. The following predictors were added to the base model, one at a time:

- *monosyllabic* (a binary factor that was true for monosyllabic items)
- *medial.SSP* (a binary factor that was true for genitives with an intervocalic CRC cluster that could not be syllabified as C.RC or CR.C without an SSP violation)
- *complex.coda* (a binary factor that was true for CVCC nominatives)
- *vowel* (a binary factor that was true for [u] and false for [e,o])

Adding each of these four predictors in order made a significant improvement to the model. The only interaction to consider was that of *monosyllabic* and *vowel*, and it did not improve the model. The model was not improved by considering stress or the presence of CCC clusters in either monosyllables or polysyllables. To reduce the correlations in the model, all variables were normalized using R's *scale()* function, and *monosyllabic* was residualized against *medial.SSP* and *complex.coda*, so its effect is measured above and beyond the predictive power of *medial.SSP* and *complex.coda*. Then, we added the four predictors as by-participant random slopes, which further improved the model significantly (a fully crossed model did not converge). The resulting model, shown in Table 4, enjoys low collinearity scores ($\varkappa = 1.2$, VIF$\leq$1.02, all correlations$< .12$). The p-values for the final model were estimated based on the t-score.

	Estimate	SE	t	p
(Intercept)	3.29	.12	26.65	
medial.SSP	$-.57$	.08	-7.01	$< .0001$
complex.coda	$-.35$	.08	-4.62	$< .0001$
vowel=u	$-.24$	.08	-2.91	$< .005$
monosyllabic	$-.23$	.08	-2.82	$< .005$

Table 4: Regression model for nonce word ratings, Experiment 2

As we did with Experiment 1, we checked the effect of lexicon-based predictors: log transitional probabilities and neighborhood densities for the base and the derivative, again using the same two dictionaries as before. We thus got 8 predictors (2 word-lists, 2 morphological categories, 2 lexicon-based factors). In addition to these 8 predictors, we also calculated log transitional probabilities and neighborhood densities of the base and derivative in a list of 8,000 yer-containing words we extracted from Usachev (2004), as it stands to reason that a word may be a yer word if many of its neighbors are yer words. With these four predictors, we had a total of 12 lexicon-based predictors.

We measured the ability of these 12 predictors to model the ratings we got by making 12 superset models that have our four grammatical predictors from Table 4 and one of the lexicon-based predictors. Of those, 11 predictors made no significant contribution to the model (ANOVA model comparison, all $\chi^2 < 1$, all $p > .1$), but the neighborhood density of the base that was calculated based on the yer words did make a significant improvement (ANOVA model comparison, $\chi^2(1) = 5.56$, $p < .05$). This contribution, however, is a mere fraction of the contribution of the grammatical predictors (ANOVA model comparison, $\chi^2(4) = 55.17$, $p < .0001$). The magnitude of the difference between these models suggests that an account that relies on analogy would achieve only a small portion of the empirical coverage of our account. In other words, while lexicon-based predictors are not completely useless at predicting the participants' treatment of novel words, their contibution is very weak relative to our grammar-based analysis.

6 Discussion and conclusions

Our examination of the lexicon confirmed two new generalizations about yer deletion: monosyllables are relatively unlikely to alternate, and words with coda clusters and CRC clusters are almost categorically prohibited from doing so. This is part of the speakers' phonological knowledge, and our experimental results suggest that Russian speakers demonstrate this knowledge when asked to rate novel words with yer alternations. Speakers know that mid vowels can be deleted, whereas low and high vowels cannot. Speakers also know that deletion cannot create a cluster that violates the Sonority Sequencing Principle medially—even though such clusters are attested in existing Russian words. Yer deletion is lexically restricted in Russian, but the patterns are still grammatically governed. Moreover, our results suggest that the phonological grammar must specify these aspects of yer deletion. Traditional analyses that view the mid vowel quality as accidental (Kenstowicz and Rubach 1987, Yearley 1995; see Section 2.2) would have difficulty explaining the findings of Experiment 1. The effects of syllable structure that we found in Experiment 2 present a similar problem for the quasi-historical analyses whereby yers are realized before other yers, as opposed to syllabically defined contexts (Lightner 1972, Halle and Matushansky 2006, and others).

Purely phonological accounts such as Gouskova (2012) do not account for all of our findings, however—speakers do form some generalizations about yer morphemes from trends in the lexicon. No phonological account that we know of predicts that CVCC words would be rated worse than CCVC and CVC words in our Experiment 2. Gouskova's account actually predicts that CVC should be a better alternator than CVCC and CCVC, since in the latter two, deletion creates an initial CCC cluster, which is phonotactically relatively ill-formed. The model of the lexicon in Section 3 explains the effect we found, however. There are very few CVC yer words in the Russian lexicon, and no CCVC or CVCC yer words. On the other hand, there are plenty of disyllabic and polysyllabic yer words, and they supply the crucial evidence about the status of CC# clusters in alternating words. Monosyllables are significantly less likely to have deletion than polysyllables—this is an effect not unique to Russian (Becker et al. 2011, to appear), and we did indeed find that monosyllabic wugs were rated as worse alternators than disyllabic ones. The degraded status of CVCC is projected from the behavior of disyllables in the lexicon: they are not allowed to have coda clusters, so neither are wugs.

Properties such as lack of coda clusters in yer words are islands of reliability in the sense of Albright and Hayes (2003): phonotactic generalizations that happen to hold of yer morphemes, even though they are violated in the language as a whole. Albright and Hayes show that such generalizations robustly guide people's behavior in wug experiments testing morphological rules, and we confirmed this finding in our study of a phonological alternation. Phonological analyses of yer deletion recognize the importance of coda cluster avoidance (Szpyra 1992, Yearley 1995, Gouskova 2012): yers are, after all, retained when the alternative is a coda cluster. The surprising finding in Experiment 2 is that speakers reject alternations that affect words with coda clusters even when the coda clusters are not created by yer deletion (CVCC∼CCC-a). This suggests that Russian speakers form a phonotactic generalization about yer morphemes that is not only responsible for blocking deletion but holds statically of unaffixed forms.

The generalization that yer morphemes cannot end in CC# applies both to the output of deletion (i.e., */sotor/→[sotr]) and to the input to it (i.e., */sotr-a/→[str-á]). Our OT analysis in Section 2.1 solves only the output part of this problem, because in our account, *CC# dominates *Mid_{yer} and blocks deletion. The asymmetry between CVCC and CCVC alternators in our experiment, on the other hand, is based on inputs—it is a source-oriented generalization (Albright and Hayes 2003). Source-oriented generalizations are known to be problematic, and we will not solve the problem here, but we will speculate about how to pursue a solution. In Russian, indexation to *Mid_{yer} implies satisfaction of *CC#, and the behavior of our Russian speakers suggests that they have learned that yer morphemes are subject to stricter phonotactic constraints than the rest of the language. Phonotactic constraints about the language as a whole are learned fairly early, certainly before restricted alternations are acquired (Jusczyk et al. 1994). If *CC# is demoted below faithfulness for the language as a whole in this phase of learning (Prince and Tesar 2004, Hayes 2004), then phonotactic learning has to restart when the learner detects inconsistencies in alternation patterns that require constraint cloning. This phonotactic re-learning will be redone just for the alternating morphemes, since for these, *CC# has to dominate all faithfulness constraints, not just Max-V. The result of phonotactic learning for morpheme subclasses is a phonologically stratified lexicon (Ito and Mester 1995 et seq.).

Finally, our findings allow us to assess suppletive allomorphy theories of lexically restricted alternations. Such theories come in two flavors: phonologically conditioned allomorphy, where the markedness constraints select the most suitable allomorph for the context, and analogy, where the choice of allomorph is based on what similar morphemes do in the same context (see Section 2.3). The phonologically conditioned allomorphy theory can explain various phonological properties of the alternation (using much of the same machinery, e.g., the constraint *Mid, that a phonological alternation account would use), but it cannot make predictions about how novel words will behave. The reason for this is that there are many markedness constraints in the grammar, and there is no way of localizing the selector effect to just the constraints that happen to be relevant to Russian yers. The relevant generalizations about the shape of allomorphs could be extracted by analogy, but there is a well-known problem with this solution: it is difficult to zero in on just the relevant aspects of the morphemes' shapes. We tested measures of lexical similarity such as lexical neighborhood density and transitional probabilities, and while not completely useless, their ability to predict speakers' ratings of wugs was far more limited than grammatical measures. Our results show that speakers use grammatical principles to organize their lexicon, even those lexical patterns that are limited in scope.

Appendix

Test words used in Experiment 1

(25) Monosyllables (25 pairs)

Vowel	Fem class I	Masc Class II	Neut Class II	Fem class III	Fem class III
i/ɨ	gl-á, g^{j}íl	ʃɨ́r, ʃr-á	zr-ó, z^{j}ír	t͡ʃin^j, t͡ʃn^j-ej	bɨ́s^j, bz^j-éj
u	zn-á, zún	gún, gn-á	gr-ó, gúr	súl^j, sl^j-éj	zúr^j, zr^j-éj
e/o	xl-á, x^{j}él	k^{j}él, kl-á	zm-ó, z^{j}ém	g^{j}ér^j, gr^j-éj	t^{j}óʃ, tʃ-éj
o	tm-á, tóm	ʒóm, ʒm-á	gn-ó, gón	pól^j, pl^j-éj	kól^j, kl^j-éj
a	kt-á, kát	ʃáp, ʃp-á	xr-ó, xár	kás^j, ks^j-éj	xál^j, xl^j-éj

(26) Disyllables (8 pairs, initial stress, all masculines)

Vowel	IPA	Orthography	IPA	Orthography
<o>, [ə]	káʃəp, káʃp-ə	кашоп	lótəp, lótp-ə	лотоп
<e>, [i]	vút^{j}ir, vútr-ə	вутер	pós^{j}in, pósn-ə	посен
<e>, [i]	mɨ́k^{j}it, mɨ́kt-ə	мыкет	ʒús^{j}il, ʒúsl-ə	жусел
<a>, [ə]	kásəp, kásp-ə	касап		
<y>, [u]	gásut, gást-ə	гасут		

(27) 10 disyllables (10 pairs, final stress)

Masc (class II)	Orthography	Fem (Class I)	Orthography
dumɨ́l^j, duml^j-á	думыль	gidl-á, gid^{j}íl	гидил
karút, kart-á	корут	zutʃ-á, zutúʃ	зутуш
rɨʃón, rɨʃn-á	рышон	rap^{j}j-á, rap^{j}éj	рапей
tag^{j}él, tagl-á	тогел	xark-á, xarók	хорок
xutám, xutm-á	хутам	rudn-á, rudán	рудан

Test words used in Experiment 2

(28) Stress alternations in disyllables (6 pairs of each type)

Alternating, not on yer (6 pairs)		Nonalternating, initial (6 pairs)		Alternating, final (6 pairs)	
tópʲis, taps-á	топес	bákʲit, bákt-ə	бакет	tʲipʲés, tʲips-á	типес
dúfʲir, dufr-á	дуфер	gúʃɨr, gúʃr-ə	гушер	ʒusʲél, ʒusl-á	жусел
dásʲip, dasp-á	дасеп	káʃəp, káʃp-ə	кашеп	lʲikʲép, lʲikp-á	ликеп
kʲípən, kʲipn-á	кипон	dóləp, dólp-ə	долоп	matón, matn-á	матон
lúsəx, lusx-á	лусох	rʲékət, rʲékt-ə	рекот	pʲikót, pʲikt-á	пикот
vútər, vutr-á	вутор	pʲéxən, pʲéxn-ə	пехон	rɨʃón, rɨʃn-á	рышон

(29) Medial CCC clusters (all with alternating final stress)

no SSP violation (6 pairs)		SSP violation (6 pairs)	
paʃtʲél, paʃtl-á	паштел	kasnʲét, kasnt-á	каснет
piltʲér, pʲiltr-á	пилтер	taglʲét, tagld-á	тоглед
guptʲén, guptn-á	гуптен	patrʲén, patrn-á	патрен
kʲiftór, kʲiftr-á	кифтор	lasvóp, lasfp-á	ласвоп
sʲigdóf, sʲigdv-á	сигдов	munlót, munlt-á	мунлот
munkór, munkr-á	мункор	masróʃ, masrʃ-á	масрош

(30) Initial CC and CCC clusters

#CC, no SSP violation	#CC, SSP violation	#CCC, from /CCVC/	#CCC, from /CVCC/
ʃér, ʃr-á	mʲék, mk-á	stʲék, stk-á	kʲést, kst-á
kʲél, kl-á	vʲét, ft-á	msʲét, mst-á	mótʃ, mtʃ-á
tʲés, ts-á	lʲék, lʲk-á	spʲér, spr-á	sótr, str-á
pʲéʃ, pʃ-á	rʲép, rp-á	fsóp, fsp-á	vósp, fsp-á
kór, kr-á	mʲés, ms-á	spól, spl-á	kʲétr, ktr-á
tʲóʃ, tʃ-á	vók, fk-á		
pór, pr-á	lʲóp, lʲp-á		
zóm, zm-á	lók, lk-á		
pók, pk-á	rón, rn-á		
xól, xl-á	nók, nk-á		

(31) Control stimuli with deletion of [u] (6 pairs)

gún, gn-á	gasút, gast-á
zró, zúr	dumúlʲ, dumlʲ-á
búnʲ, bnʲ-éj	gʲidl-á, gʲidúl

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