Hungarian speakers use morphological dependencies in inflecting novel forms

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Abstract Theories of morphology must account for lexicalized variation: lexical items that differ unpredictably in their inflection must be memorized individually and differ in their stored representation. When tested on such cases, adult speakers usually follow the "law of frequency matching" (Hayes et al. 2009), extending gradient phonological patterns from the lexicon. This paper looks at lexicalized variation in the Hungarian possessive: first, I show that a noun's choice of possessive is partially predicted by its plural form as well as its phonological shape. Then, using a novel nonce word paradigm, I show that Hungarian speakers productively apply this cooccurrence pattern between the plural and possessive. I treat lexicalized variation as indexed by diacritic features marking lexical entries and propose that Hungarian speakers have learned a gradient cooccurrence relation between diacritic features indexing their plural and possessive forms, extending the sublexicon model of Gouskova et al. (2015). This approach also allows for a flexible analysis of inflection classes in languages like Russian as emergent clusters of frequently cooccurring features.

Keywords: frequency matching; diacritic features; inflectional paradigms; productivity; wug test; Hungarian

1 Introduction

Any theory of morphology must account for lexical idiosyncracy: lexical items that differ unpredictably in their inflections must differ in their stored representation. For example, the Hungarian words [paːr] 'pair' and [kaːr] 'damage' arbitrarily take distinct possessive suffixes ([paːr-jɒ] and [kaːr-ɒ]), so the lexicon must somehow distinguish them.

In this paper, I focus on one type of arbitrary inflection: cooccurrence patterns between exponents of inflectional paradigms. These are often captured through inflection class features, markings on lexical items that divide them into groups "whose members each select for the same set of inflectional realizations" (Aronoff 1994: 64). Using a nonce word study in Hungarian, I argue that inflection class features alone cannot account for all the cooccurrence patterns that exist in the lexicon (Ackerman et al. 2009; Ackerman & Malouf 2013) and are learned by speakers: we also need correlations *between* features (cf. Halle & Marantz 2008). In this light, inflection classes themselves need not be reified as features, but can emerge from independently needed mechanisms.

1.1 Inflection class features

One common approach to exceptional lexical items is to mark them with diacritic features (see e.g. Chomsky & Halle 1968; Halle 1973; Corbett & Baerman 2006).[1] These have been used in different morphophonological domains, including marking parts of the lexicon as more or less phonotactically restrictive (Itô & Mester 1999; Ito & Mester 2008) and singling out words that exceptionally undergo or are resistant to phonological alternations (Chomsky & Halle 1968; Pater 2010; Gouskova 2012). This paper focuses on *morphological* features that group together words showing the same pattern of exponence in their inflectional paradigms (Aronoff 1994; Corbett & Baerman 2006).

Morphological features are useful for languages like Russian, which divide nouns into inflectional classes. Table 1 presents some case endings for the two main class endings of Russian feminine nouns, labelled II and III by Corbett & Fraser (1993).

class *example*	II 'aunt'	III 'whip'
nominative	tʲotʲ-a	pletʲ
dative	tʲotʲ-e	pletʲ-i
instrumental	tʲotʲ-oj	pletʲ-ju

Table 1: Some singular case forms for Russian feminine (class II and III) nouns

Any analysis of these classes requires lexical marking, since a noun's class is not fully predictable from its phonology alone (Thelin 1975; Corbett 1982; Steriopolo 2008). Features capture the inflectional patterns:[2] the underlying forms of nouns include class features, which partition the lexicon as shown in (1).

(1) *Lexical entries for Russian nouns*

a. II: /tʲotʲ$_{\text{II}}$/ 'aunt', /tʃert$_{\text{II}}$/ 'characteristic', /dolʲ$_{\text{II}}$/ 'portion', …

[1] There are two main alternatives. First, inflected forms that cannot be derived through fully productive means may be stored in their entirety (Prasada & Pinker 1993; Bermúdez-Otero 2012; 2013). Second, lexical differences can be encoded through abstract phonological or syntactic structure (e.g. Lightner 1965; Trommer 2021; Caha 2021; Janků 2022).

[2] Though see Caha (2021) and Janků (2022) for an alternative.

b. III: /plet$^{j}_{\mathrm{III}}$/ ‘whip’, /tetrad$^{j}_{\mathrm{III}}$/ ‘notebook’, /ploɕːad$^{j}_{\mathrm{III}}$/ ‘square’, …

These class features may be stand-ins for a more complex combination of features (Müller 2004; Privizentseva 2022); the key point is that the two classes differ in *some feature*.

How do these features ensure the correct surface forms? In Distributed Morphology, they delimit the application of rules of realization that spell out case and number (Halle 1994; Embick & Marantz 2008). A greatly simplified set of rules for Russian is in (2); see Halle (1994) and Müller (2004) for more complete analyses.

(2) *Vocabulary insertion rules for some Russian case endings*

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

Inflection class features allow for the productive generation of previously unseen forms. Suppose a Russian speaker sees a new word in the dative, like [grid^{j}-i] ‘princely retinue’, a real but obscure word. Dative *-i* is associated with class III ((2e)), so the speaker stores the word as /grid$^{j}_{\mathrm{III}}$/. The instrumental of this word, in turn, would have to be [grid^{j}-ju] ((2f)). Because the inflection class features apply across multiple rules, the inference from dative to instrumental is deterministic.

1.2 Inflectional patterns beyond inflection classes

Not all inflectional patterns are appropriate for inflection class features. Table 2 shows the patterns of plural and possessive in Hungarian, the case study for this paper. Unlike in Russian, the two forms may vary independently of each other.

noun	dɒl	tʃont	vaːlː	hold
gloss	‘song’	’bone’	‘shoulder’	‘moon’
plural	dɒl-ok	tʃont-ok	vaːlː-ɒk	hold-ɒk
possessive	dɒl-ɒ	tʃont-**j**ɒ	vaːlː-ɒ	hold-**j**ɒ

Table 2: Possible combinations of Hungarian plural and possessive suffixes

Most Hungarian nouns (with back vowel harmony; see Section 2.1) have plural *-ok*, while *-ɒk* appears with a small class called “lowering stems”. In the possessive, nouns may take *-ɒ* or *-jɒ* (henceforth *-V* and *-jV*, abstracting from vowel harmony), and both are very frequent. Lowering stems cannot be identified by their phonological form, nor, in many cases, can a noun’s possessive (Siptár & Törkenczy 2000; Rácz & Rebrus 2012). Thus, both require lexical marking, as in (3). Lowering stems are marked with [lower]; nouns taking *-jV* and *-V* are marked with [+j] and [−j], respectively. Unlike in Russian, these lists overlap.

(3) *Lexical entries for Hungarian nouns*

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

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

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

Each feature is associated with rules in (4) to get the right output forms.

(4) *Rules of realization for the Hungarian plural and possessive (simplified)*

a. PL ⟷ ɒk / [lower] __ c. POSS ⟷ jɒ / [+j] __

b. PL ⟷ ok / d. POSS ⟷ ɒ / [−j] __

These cross-classifying features (cf. Baerman et al. 2017) do not allow for the deterministic formation of novel inflected forms. Suppose a Hungarian speaker comes across the obscure plural [maːl-ɒk] 'belly furs'. Plural *-ɒk* is associated with [lower] ((4a)), so the word is stored as /maːl$_{\text{[lower]}}$/. However, neither of the possessive rules, (4c) and (4d), reference this [lower] feature. Because each feature is narrowly targeted, the grammar alone does not provide a link from a noun's plural to its possessive.[3] What do speakers do in such cases of lexical variability?

1.3 How to infer unknown forms

Speakers generally extend gradient patterns from the lexicon (see Jarosz (2022) for a summary). Studies like Hayes et al. (2009), Becker et al. (2011), and Gouskova et al. (2015) show how speakers stochastically generate novel forms according to their *phonological* characteristics. The Hungarian possessive shows some phonological patterns, which Rácz & Rebrus (2012) describe: for example, nouns that end in palatals and sibilants categorically take *-V*, while nouns ending in consonant clusters and/or non-sibilant alveolars prefer *-jV*, though not categorically. In this paper, I show that Hungarian speakers extend many gradient phonological patterns to nonce words. Rácz & Rebrus also mention a *morphological* generalization about the possessive: irregular nouns, including lowering stems, prefer *-V*, though not categorically (as seen in Table 2). I show that speakers likewise match this tendency for nonce words.

Models like Gouskova et al. (2015) capture gradient phonological patterns as generalizations between phonological and morphological features like (5a). I propose likewise storing morphological dependencies as generalizations between two morphological features, as in (5b) (Halle & Marantz (2008) make a similar proposal for Polish).

(5) *Phonological and morphological generalizations over the distribution of Hungarian possessives*

a. Nouns ending with [+consonantal][+consonantal] (that is, nouns ending in clusters) tend to have [+j]

b. Nouns with [lower] (that is, lowering stems) tend to have [−j]

Feature cooccurrence relations encode inflectional patterns more flexibly than inflection class features. Given that we need the former, we can do without the latter. That is, Russian-style inflection classes can be *emergent*: a descriptive term for a set of very strong, even inviolable, cooccurrence relations between clusters of features indexing individual affixes. I discuss this in Section 5.4.

1.4 Road map

In Section 2, I provide a detailed background on the Hungarian plural and possessive. In Section 3, I present a corpus data showing the phonological and morphological factors predicting the distribution of possessive *-V* and *-jV* in the Hungarian lexicon. In Section 4, I present a nonce word study showing that Hungarian speakers productively extend these phonological and morphological generalizations to novel forms. Section 5

[3] Bárczi & Országh (1959–1962) list both *-V* and *-jV* as acceptable possessive suffixes for this word.

describes a theory of phonological and morphological generalization based on Gouskova et al. (2015). I also show how inflection classes can emerge in this model from cooccurrence relations between pairs of paradigm cells. Section 6 concludes.

2 A fuller picture of the Hungarian possessive and lowering stems

In the introduction, I described lexical variation in two Hungarian suffixes: the possessive and the plural. In this section, I present more details about this variation and about a related source of suffix alternations, vowel harmony. This provides background for the quantitative studies in Section 3 and Section 4.

2.1 Vowel harmony alternations

Hungarian words have either back or front harmony, and suffix vowels alternate accordingly. The mid suffixes also show rounding harmony: front-harmonizing suffixes with mid vowels have rounded and unrounded variants to match the last vowel of the stem. These alternations, for short vowels, are shown in Table 3; see Siptár & Törkenczy (2000: 63–73) for more details.

height	*back*	*front*		*example suffix*			*example words*		
		rounded	*unrounded*				haːz 'house'	føld 'land'	kɛrt 'garden'
high	u	y		*-unk/-ynk*	1PL	'our'	haːz-unk	føld-ynk	kɛrt-ynk
mid	o	ø	ɛ	*-hoz/-høz/-hɛz*	ALL	'to'	haːz-hoz	føld-høz	kɛrt-hɛz
low	ɒ	ɛ		*-bɒn/-bɛn*	INESS	'in'	haːz-bɒn	føld-bɛn	kɛrt-bɛn

Table 3: Hungarian suffix vowel harmony alternations (from Siptár & Törkenczy 2000: 65)

Examples in this paper have back harmony. This chart can be used to find the front-harmonizing version of each suffix. Thus, the front-harmonizing equivalents of possessive *-ɒ* and *-jɒ* are *-ɛ* and *-jɛ*. Regular-stem plural *-ok* (from the mid vowel set) has two front-harmonizing variants, depending on rounding, *-øk* and *ɛk*, while the lowering stem plural *-ɒk* (from the low vowel set) only has one front-harmonizing variant, *-ɛk*. Words with front unrounded harmony can only have plural *-ɛk* and thus cannot be distinguished on the surface as lowering stems. Siptár & Törkenczy (2000: 225) nonetheless mark some nouns with front unrounded harmony as lowering stems on the basis of other properties that correlate (more or less reliably) with lowering stem status. Since this difference is not marked in my corpus and cannot be entirely inferred, I assume that all words with front unrounded harmony are undetermined for stem class. In the nonce word experiment (Section 4), I treat stimuli with front unrounded harmony as fillers.

A stem's harmony class is usually but not always predictable from its vowels (Siptár & Törkenczy 2000; Hayes & Londe 2006; Hayes et al. 2009; Rebrus et al. 2012; 2019)—thus, some nouns must be explicitly marked for harmony class. I assume that vowel harmony is handled *in the phonology proper*: *-ɒ* and *-ɛ* are surface variants of a single underlying form inserted in the context of [−j], and words taking *-V* are marked with a unified [−j] feature. Likewise, [+j] marks words taking *-jɒ* or *-jɛ*.

2.2 The possessive

2.2.1 Morphosyntactic details

The full paradigm of possessives for the four words in Table 2 are shown in Table 4 (see Rounds 2008: 135–137). Hungarian distinguishes between the person and number of possessors, as well as the number of the possessed noun, so [dɒl-om] means ‘my song’, while [dɒl-ɒ-i-m] means ‘my songs’, and so on.

noun	dɒl		tʃont		vaːlː		hold	
gloss	‘song’		’bone’		‘shoulder’		‘moon’	
possessor	*singular*	*plural*	*singular*	*plural*	*singular*	*plural*	*singular*	*plural*
1SG	dɒlom	dɒlɒim	tʃontom	tʃont**j**ɒim	vaːlːɒm	vaːlːɒim	holdɒm	hold**j**ɒim
2SG	dɒlod	dɒlɒid	tʃontod	tʃont**j**ɒid	vaːlːɒd	vaːlːɒid	holdɒd	hold**j**ɒid
3SG	dɒlɒ	dɒlɒi	tʃont**j**ɒ	tʃont**j**ɒi	vaːlːɒ	vaːlːɒi	hold**j**ɒ	hold**j**ɒi
1PL	dɒlunk	dɒlɒink	tʃontunk	tʃont**j**ɒink	vaːlːunk	vaːlːɒink	holdunk	hold**j**ɒink
2PL	dɒlotok	dɒlɒitok	tʃontotok	tʃont**j**ɒitok	vaːlːɒtok	vaːlːɒitok	holdɒtok	hold**j**ɒitok
3PL	dɒluk	dɒlɒik	tʃont**j**uk	tʃont**j**ɒik	vaːlːuk	vaːlːɒik	hold**j**uk	hold**j**ɒik

Table 4: Hungarian possessive paradigms for some back-harmonizing words

There are two main points of variation among these paradigms. The first is the alternation between [o] and [ɒ] (underlined in Table 4) in the 1SG, 2SG, and 2PL singular. This is the same lowering stem alternation as in the plural, and will be addressed in Section 2.3. The second is the variable presence of [j] (bolded in Table 4) in singular nouns with 3SG and 3PL possessors and plural nouns with all possessors.[4] This is the possessive morpheme, with allomorphs, *-V* and *-jV*. Its vowel deletes before 3PL *-uk*.

Under the standard syntactic analysis (cf. Bartos 1999; É. Kiss 2002; Dékány 2018), *-V* and *-jV* are realizations of a Poss head, which has a zero allomorph when adjacent to a first- or second-person possessor marker. (The marker for third singular possessors is null.) Thus, I gloss *-V* and *-jV* as POSS (not 3SG), while *-(V)m*, *-(V)d*, etc. mark 1SG, 2SG, and so on.

2.2.2 Marked and default allomorphs

In the introduction ((4), repeated here): I assumed that both *-V* and *-jV* are marked and neither is a default:

(4) *Rules of realization for the Hungarian possessive (simplified)*
   c. POSS ↔ jɒ / [+j] __
   d. POSS ↔ ɒ / [−j] __

Although Prasada & Pinker (1993), Marcus et al. (1995), and Yang (2016) assume that productive default rules drive language acquisition and usage, there are cases of lexical variation where children fail to form a productive rule, memorizing each word individually (Dąbrowska 2001; Schuler et al. 2021). If the Hungarian possessive is one such case, it would yield the rules in (4). Rácz & Rebrus (2012), however, argue that *-jV* is a productive default: it is becoming more frequent (Rounds 2008) and is used for most (Kiefer 1985; Rebrus et al. 2017), if not all (Rácz & Rebrus 2012), recent loanwords that do not end in sibilants or palatals. My experimental results do not support this claim: as

[4] In general, [j] is either present or absent throughout the paradigm. One very rare exception is [bɒraːt] ‘friend’, which takes *-jV* in the singular ([bɒraːt-jɒ] ‘her friend’) and *-V* in the plural ([bɒraːt-ɒ-i] ‘her friends’).

in previous nonce word studies (e.g. Gouskova et al. 2015), they use *-V* and *-jV* for the same nonce words and do not treat *-jV* as a default (see Section 4.7).

Thus, I keep the assumption that *every* word is marked for its possessive. In Section 5, I propose that generalizations over the distribution of *-V* and *-jV* are learned over the sets of lexical entries that have [−j] and [+j], respectively. This falls out naturally if all words have one or the other (see Gouskova et al. 2015: 44–46).

2.3 Lowering stems and the plural

In the introduction, I treated lexical variation in the plural as allomorph selection, in which a class of nouns called "lowering stems", marked with a [lower] feature, selected *-ɒk* instead of the usual *-ok*:

(4) *Rules of realization for the Hungarian plural (simplified)*
  a. PL ⟷ ɒk / [lower] __
  b. PL ⟷ ok /

This analysis is sufficient for the purposes of this paper, but it obscures the actual nature of lowering stems and its complicated interaction with vowel harmony. In this section, I provide more details about the morphophonology of lowering stems and discuss alternate analyses. In any analysis, nouns that have *-ɒk* in the plural are lexically marked by a feature. This is the crucial assumption for this paper, which argues that speakers have learned to correlate the lowering stem feature with the feature indexing possessive allomorphy.

2.3.1 Lowering stems beyond the plural

In Section 2.2, I showed that the 1SG, 2SG, and 2PL possessor markers undergo the same lowering stem alternation as the plural. I repeat these possessive forms and the plural of the regular stem [dɒl] 'song' and the lowering stem [vaːlː] 'shoulder' here, also including forms of [kɒpu] 'gate'. The non-possessed plural and the three possessive markers show the same pattern. The suffix is a bare consonant (or *-tok*) after a vowel, including the vowel-final noun [kɒpu] and the possessed plural *-i*. Otherwise, this consonant is preceded by a "linking vowel" (cf. Siptár & Törkenczy 2000: 219), which is mid after [dɒl] and low after [vaːlː] (see Table 3 above).

noun	dɒl		vaːlː		kɒpu	
gloss	'song'		'shoulder'		'gate'	
possessor	*singular*	*plural*	*singular*	*plural*	*singular*	*plural*
none	dɒl	dɒlok	vaːlː	vaːlːɒk	kɒpu	kɒpuk
1SG	dɒlom	dɒlɒim	vaːlːɒm	vaːlːɒim	kɒpum	kɒpuim
2SG	dɒlod	dɒlɒid	vaːlːɒd	vaːlːɒid	kɒpud	kɒpuid
2PL	dɒlotok	dɒlɒitok	vaːlːɒtok	vaːlːɒitok	kɒputok	kɒpuitok

Table 5: Lowering stem alternations in the plural and possessive markers

The analysis in (4) requires all of these suffixes to have three allomorphs: with no vowel, [o], and [ɒ]. A more parsimonious analysis would insert the bare form of each suffix with a feature, [LV],[5] indicating that it undergoes linking vowel alternations:

[5] The linking vowel in these suffixes is not predictable from phonotactics, and so must be marked (Siptár & Törkenczy 2000: 219).

(6) *Rules of realization for linking vowel suffixes (better version)*
   a. PL $\leftrightarrow$ $k_{[LV]}$
   b. 1SG $\leftrightarrow$ $m_{[LV]}$
   …

Readjustment rules can then insert the appropriate linking vowel after consonants:

(7) *Readjustment rules for linking vowels*
   a. Ø → ɒ / [lower] __ [LV]
   b. Ø → o / C __ [LV]

This analysis is a more elegant approach to lowering stems than the rules in (4), and correctly predicts that a noun that has a low linking vowel in one suffix (e.g. the plural) will have a low linking vowel in all suffixes. In both analyses, nouns that take *-ɒk* in the plural are marked with a [lower] diacritic.[6] Thus, for my purposes, they make equivalent predictions: speakers should be able to learn a dependency between [lower] and the [−j] feature marking possessives that take *-V*.

2.3.2 The representation of lowering stems

The analysis in the previous section assumes that the lowering alternation is encoded *morphologically*: lowering stems are marked with [lower], and suffixes with linking vowels have an [LV] feature. Siptár & Törkenczy (2000) instead propose (in Section 8.1.4) an abstract *phonological* analysis: lowering stems have a floating low feature [+open$_1$] and linking vowel suffixes have an underlying vowel unspecified for height. This vowel surfaces as low in the presence of [+open$_1$], otherwise it surfaces as mid after consonants and deletes after vowels.

These analyses represent two approaches to morphophonologically exceptional morphemes. In my analysis, exceptional lexical items are marked with a diacritic indexing a morpheme-specific rule or constraint (e.g. Inkelas et al. 1997; Pater 2010; Gouskova 2012; Rysling 2016). Siptár & Törkenczy (2000) instead use defective segments and subsegmental units that cannot surface in their underlying form, but behave differently from full segments (e.g. Lightner 1965; Rubach 2013; Trommer 2021).

The two approaches are not mutually exclusive (for example, Chomsky & Halle (1968) use both), and the choice between them is often one of elegance and coverage. Moreover, both have been criticized on similar grounds: Pater (2006) and Gouskova (2012) argue that underspecification accounts can overgenerate and be hard to learn, while Bermúdez-Otero (2012; 2013), Haugen (2016), and Caha (2021) argue that arbitrary lexical marking and readjustment rules are unrestrained and weaken our theory of grammar. In this case, the two analyses are largely equivalent: for Siptár & Törkenczy (2000), the floating feature has no phonological effect beyond producing a low linking vowel.[7]

The present paper argues that Hungarian speakers learn generalizations over the [lower] feature on lowering stems. In the analysis of Siptár & Törkenczy (2000), the floating [+open$_1$] feature is unique to lowering stems. This is compatible with my main hy-

[6] One possibility is that lowering stems are phonologically predictable, showing "height harmony". This is not the case: most noun stems with low vowels are not lowering stems, and many lowering stems have non-low vowels.

[7] "Self-lowering" (Siptár & Törkenczy 2000: 228–229) verbal suffixes, which show a vowel–zero alternation whose vowel is always low, could potentially distinguish the two analyses. However, Siptár & Törkenczy (2000) argue that the "self-lowering" alternation is morphological (allomorph selection) rather than phonological (underspecification), converging with my analysis for these cases.

pothesis that speakers learn generalizations over features that index unpredictable morphophonological behavior.

This section provided qualitative background on the morphophonology of Hungarian possessives and plurals. In the next section, I discuss their quantitative distribution.

3 Possessive allomorphy in the Hungarian lexicon

The goal of this paper is to show that Hungarian speakers extend gradient patterns in their lexicon to nonce words, in particular the morphological generalization that lowering stems prefer possessive *-V*. To do this, I must first show what the lexical patterns are. Thus, this section presents a corpus study of the Hungarian lexicon that serves as the foundation for the nonce word study in Section 4.

3.1 Representing the Hungarian lexicon

In this section I discuss the corpus that I use to represent the Hungarian lexicon. I discuss the consequences of my corpus construction in Section 3.2.3 and Section 4.7.

My source of data is Papp (1969), a morphological dictionary of Hungarian which I transcribed manually. I use Papp (1969) for its comprehensive tagging of derivational morphology, but it has disadvantages: it is over 50 years old and reflects lexicographic work rather than pure corpus data. A comparison with the Hungarian National Corpus (Oravecz et al. 2014) shows that the two sources are closely correlated in their distribution of possessive allomorphs, so I conclude that the benefits of this dictionary outweigh any potential negatives.

Under standard assumptions in Distributed Morphology, lexical information like allomorph selection is stored for roots and affixes, not complex stems (Embick & Marantz 2008). Thus, if speakers are generalizing over the frequency of types in the lexicon (cf. Bybee 1995; 2001; Pierrehumbert 2001; Albright & Hayes 2003; Hayes & Wilson 2008; Hayes et al. 2009), derived words and compounds with the same head (rightmost affix or root) should not count as separate types. Root-based storage predicts that words ending in the same suffix should take the same possessive, which is largely true in Hungarian (Rácz & Rebrus 2012). I adopt the assumption of root-based storage by limiting my corpus to monomorphemic nouns. In Section 4.7, I argue that this corpus more accurately reflects the behavior of Hungarian speakers than a corpus including complex nouns.

Although adjectives can also take possessive suffixes, I limit my corpus to nouns. Unlike nouns, most adjectives are lowering stems (Siptár & Törkenczy 2000: 229–230), and some forms behave differently depending on the syntactic environment (Rebrus & Szigetvári 2018), so including adjectives would complicate the relationship between lowering stems and possessive allomorphy. I excluded vowel-final words, since these categorically take *-jV*and would be undefined for a number of the factors in my regression. I also removed the few words ending in orthographic *h*, which is phonologically complicated (see Siptár & Törkenczy (2000: 274–276) for discussion). Finally, I excluded nouns with variable or unknown possessive to allow for binary coding of the possessive variable (*-V* vs. *-jV*). This leaves 2,427 noun types.

3.2 Corpus study: the distribution of *-V* and *-jV* in the lexicon

In this section, I show that possessive allomorphy, though lexically specific, is not fully random: like other cases of lexically specific variation (e.g. Hayes et al. 2009; Becker et al. 2011; Gouskova et al. 2015), the distribution of *-V* and *-jV* shows gradient tendencies. These previous works have focused on *phonological* generalizations, which I show for the Hungarian possessive as well. This allows me to test the hypothesis that speakers are productively applying this distribution to new forms in Section 4. I further demonstrate that the *morphological* effect of stem class is present in the lexicon independent of phonological factors, similarly allowing me to test the hypothesis that speakers are productively applying this effect to new forms.

3.2.1 Methods

I fitted two linear regressions on my corpus with possessive suffix as the dependent variable. The first regression includes predictors representing a stem's phonological form: the place and manner of its final consonant, the height and length of its final syllable's vowel, its vowel harmony class, the complexity of its final coda, and whether it is monosyllabic.[8] Word-final consonant quality affects possessive allomorphy in Hungarian (Rácz & Rebrus 2012). Becker et al. (2011) showed that the quality of the last vowel is not relevant for Turkish lexically marked consonant voicing alternations, but given that harmony class affects Hungarian possessive selection (Rácz & Rebrus 2012), I included other factors of vowel quality as well.

The second regression includes the same set of phonological predictors, plus the morphological factor of stem class. Stems were classified as lowering, non-lowering, variable, or indeterminate (nouns with front unrounding harmony, see Section 2.1). The models were assembled by forward stepwise comparison using the `buildmer` function in R from the package of the same name (R Core Team 2022; Voeten 2022). This function adds factors to the model one at a time such that each additional factor improves the model's Akaike Information Criterion (AIC), which measures how well the model fits the data while penalizing model complexity (that is, number of factors). One additional factor, the roundedness of the final syllable's vowel, did not significantly improve the model and was left out.

3.2.2 Results

3.2.2.1 Phonology

Table 6 contains the full model with phonological factors listed in the order in which they were added to the model (which roughly corresponds to their importance). Most of the examined factors are significant. The most influential are the place and manner of the final consonant. This effect strength is probably driven by the categorical effects of sibilants and palatals, which have the strongest negative effect size (favoring *-V*). However, other places and manners have significant effects as well. Other phonological factors are also significant, e.g. front-harmonizing words take *-jV* less than back-harmonizing words, and nouns ending in geminates prefer *-jV* relative to nouns ending in singleton consonants. The model predicts a word's possessive quite well ($R^2 = .68$).

[8] Hungarian has fixed word-initial stress, so this factor also marks whether the suffix is attaching to the stressed syllable.

	β coef	*SE*	*Wald z*	*p*
Intercept	**3.02**	**.32**	**9.55**	**<.0001**
C Manner (default: plosive)				
fricative	**−1.44**	**.39**	**−3.73**	**.0002**
sibilant	**−10.69**	**.80**	**−13.36**	**<.0001**
nasal	**−1.95**	**.27**	**−7.16**	**<.0001**
approximant	**−4.08**	**.30**	**−13.47**	**<.0001**
C Place (default: alveolar)				
labial	**−2.02**	**.26**	**−7.94**	**<.0001**
palatal	**−8.88**	**1.10**	**−8.06**	**<.0001**
velar	**−3.26**	**.29**	**−11.19**	**<.0001**
Harmony (default: back)				
front	**−2.03**	**.18**	**−10.96**	**<.0001**
variable	**2.26**	**.97**	**2.33**	**.0197**
V Height (default: mid)				
high	**1.73**	**.22**	**7.89**	**<.0001**
low	0.28	.19	1.50	.1342
V Length (default: short)				
long	**1.40**	**.17**	**7.98**	**<.0001**
Coda (default: singleton)				
geminate	**2.47**	**.40**	**6.25**	**<.0001**
cluster	0.04	.21	0.18	.8602
Syllables (default: monosyllabic)				
polysyllabic	**1.15**	**.17**	**6.67**	**<.0001**

Table 6: Regression model with phonological predictors of possessive *-jV*, with significant effects bolded

This regression takes an input word and calculates a coefficient x which measures the predicted probability P that that word takes *-jV*, $P = \frac{e^x}{1+e^x}$. This coefficient is the sum of the β coefficients of the intercept and a word's value for each factor when it differs from the default. The model can predict the possessive of nonce words as well. For example, the nonce word [lufɒn] has a coefficient of $\beta_{\text{Intercept}} + \beta_{\text{C place: nasal}} + \beta_{\text{V height: low}} + \beta_{\text{Syllables: polysyllabic}} = 3.02 - 1.95 + 0.28 + 1.15 = 2.50$, corresponding to a probability of $\frac{e^{2.50}}{1+e^{2.50}} = .924 = 92.4\%$: if this were a real word, its possessive would likely be [lufɒn-jɒ]. I refer to these coefficients as *phon_odds* and use them as predictors of the nonce word experiment in Section 4.6.

3.2.2.2 Phonology and morphology

Adding stem class to the model significantly improves it ($\chi^2 = 112.9$, $p < .0001$), raising the correlation to $R^2 = .71$. Stem class is significant and the most important factor after final C manner and place. Otherwise, the new model, shown in Table 7, is very similar to the phonological model in Table 6: the same phonological factors are added to the model (though in a slightly different order), and the effect sizes are quite similar. The effect of lowering stems is strongly negative: independent of their phonology, lowering stems are more likely to take *-V*. The effect of undetermined stem class is smaller and not significant. As discussed in Section 2.1, this class comprises nouns with front unrounded harmony, so its effect should be masked by the factor of harmony.

	β coef	*SE*	*Wald z*	*p*
Intercept	**3.53**	**.33**	**10.60**	**<.0001**
C Manner (default: plosive)				
fricative	**−1.03**	**.44**	**−2.37**	**.0179**
sibilant	**−11.07**	**.80**	**−13.86**	**<.0001**
nasal	**−2.07**	**.28**	**−7.39**	**<.0001**
approximant	**−4.06**	**.31**	**−13.10**	**<.0001**
C Place (default: alveolar)				
labial	**−2.22**	**.27**	**−8.35**	**<.0001**
palatal	**−9.25**	**1.13**	**−8.22**	**<.0001**
velar	**−3.54**	**.31**	**−11.55**	**<.0001**
Stem class (default: non-lowering)				
lowering	**−3.71**	**.44**	**−8.44**	**<.0001**
undetermined	−0.25	.25	−0.98	.3278
variable	**−2.76**	**.69**	**−4.00**	**<.0001**
V Height (default: mid)				
high	**1.85**	**.23**	**8.09**	**<.0001**
low	**0.77**	**.21**	**3.66**	**.0003**
Harmony (default: back)				
front	**−1.98**	**.27**	**−7.41**	**<.0001**
variable	**2.25**	**1.04**	**2.17**	**.0297**
Coda (default: singleton)				
geminate	**2.43**	**.41**	**5.97**	**<.0001**
cluster	−0.08	.22	−0.36	.7161
V Length (default: short)				
long	**1.30**	**.19**	**6.97**	**<.0001**
Syllables (default: monosyllabic)				
polysyllabic	**0.79**	**.18**	**4.31**	**<.0001**

Table 7: Regression model with phonological and morphological predictors of possessive -*jV*, with significant effects bolded

I confirmed that stem class is indepedent of the phonological effects by testing its variance inflation factor (VIF) using the `check_collinearity` function from R's `performance` package (Lüdecke et al. 2021). This measures whether different factors are describing the same effect. Stem class had a low correlation with the other factors (see James et al. 2013), meaning that its effect on possessive allomorphy cannot be reduced to some combination of phonological factors.

3.2.3 Discussion

The corpus study shows that a number of phonological factors are good predictors of a noun's choice of possessive, as is lowering stem class. However, some of these results differ from those of Rácz & Rebrus (2012), who address a subset of the phonological factors in my analysis. I compare their main findings with mine in Table 8, highlighting the differences.

	rate of -jV according to...	
phonological factor	Rácz & Rebrus (2012)	Table 6
harmony class	back > front	back > front
final coda	vowel = 100% > **complex** > **singleton**	geminate > **singleton** ≈ **cluster**
final C place	**labial** > **alveolar** > velar ≫ palatal = 0%	**alveolar** > **labial**, velar, palatal

Table 8: Comparison of phonological effects on possessive allomorphy from Rácz & Rebrus (2012) and my analysis

There are two main differences: first, Rácz & Rebrus (2012) find that nouns ending in complex codas take *-jV* at a higher rate than those ending in singleton consonants. They refer to these as "clusters", but they group geminates and clusters together, and attribute the effect to derivational suffixes that end in geminates. I make a finer-grained distinction and find that the difference is driven by geminates. Second, Rácz & Rebrus (2012) find that nouns ending in labial stops take *-jV* more than nouns ending in alveolar stops, while I find the opposite place effect. The discrepancy is due to choice of corpus: Rácz & Rebrus (2012) attribute the high rate of labial *-jV* to the comparative suffix *-bː*, which prefers *-jV*. My corpus includes neither adjectives nor derived words, so it lacks these comparative adjectives. All in all, the differences between my analysis and that of Rácz & Rebrus (2012) can be attributed to different choices in coding and corpus construction. In Section 4, I use the phonological model in Table 6, and discuss its accuracy as a representation of the lexicon in Section 4.7.

4 A nonce word study of the Hungarian morphological dependency

In Section 3, I described the gradient phonological and morphological effects on the distribution of possessive allomorphs. In this section, I present a novel experimental paradigm testing whether Hungarian speakers productively apply these generalizations. While previous nonce word studies have focused on phonological generalizations (e.g. Hayes et al. 2009; Becker et al. 2011; Gouskova et al. 2015), I show that speakers apply a morphological generalization as well: nonce words are assigned *-V* more often when presented as lowering stems (with plural *-ɒk*).

4.1 Predictions

I hypothesize that speakers form the possessives of novel words by taking both their phonology and their morphology (specifically, their plural) into account. I first show that speakers observe phonological effects, then show the effect of stem class.

Hayes et al. (2009) propose the "law of frequency matching": when adult speakers are asked to extend variable lexical patterns, they usually do so by choosing stochastically in a way that roughly matches the frequency of each variant in the lexicon. This pattern is also found in artificial language studies (e.g. Hudson Kam & Newport 2005), and I expect to see it in the present experiment (see Jarosz (2022) for discussion). Since my primary concern is the morphological dependency, I focus on phonological frequency matching in the aggregate and only discuss particular phonological effects where necessary to explain the effects of morphological sensitivity.

As discussed in Section 2.2, Rácz & Rebrus (2012) argue that *-jV* is the productive default for most words. If this is true, speakers should categorically assign *-jV* to most words rather than showing frequency matching.

4.2 Participants

Subjects were recruited through Prolific (https://app.prolific.co/) and had to be born in Hungary and raised as monolingual Hungarian speakers. I recruited 30 participants for the stimulus norming study and 91 for the stimulus testing study. One additional subject was rejected for poor quality, and an additional 48 subjects were recruited for earlier versions of the stimulus testing study; their data are not presented here.

4.3 Stimuli

I trained the UCLA Phonotactic Learner (Hayes & Wilson 2008) on the corpus of Hungarian nouns used in Section 3.1. Part of the program's output included a "sample salad" of 1,968 nonce words. Of these, I selected all words with the shape (C)VC(C) or (CV)CVC(C) that were not coincidentally real words. I also removed disyllabic disharmonic words (with one front vowel and one back vowel). This left a final set of 317 nonce word stimuli which ranged impressionistically from perfect to phonologically questionable (e.g. [ɲɒsm]). Each word was presented in the singular and plural, in the latter case with either a regular or lowering plural suffix.

4.4 Procedure

This experiment was split into two studies. First, subjects rated the 317 nonce word stimuli for plausibility as Hungarian words. The ratings obtained in this study were used to select a smaller set of stimuli for the main experiment, in which subjects selected possessive forms.

4.4.1 Stimulus norming and selection

Participants completed 50 trials, each with a different stimulus. Each trial had a frame sentence containing the target stimulus twice. In its first occurrence, the stimulus appeared in bare nominative form; the second time, the stimulus had a plural suffix (and sometimes additional suffixes as well). Most stimuli were shown with regular plurals (e.g. *-ok*), but 8 randomly chosen trials instead showed stimuli as lowering stems (e.g. with plural *-ɒk*). Participants rated each stimulus as a potential Hungarian word on a scale of 1 to 5.

These ratings were used as inputs to a Python script that selected a set of stimuli with a high average rating and a phonological distribution similar to the base corpus. I examined high-ranking sets manually and selected a set with 81 stimuli to use for the main testing phase.

4.4.2 Morphological dependency testing

Participants each completed 35–50 trials, which had the format shown in Figure 1. First, the stimuli were presented in the same frame sentences as in the stimulus norming experiment. In Figure 1, the nonce word [lufɒn] has a regular plural *-ok*, but in 8–12 trials, the stimuli were presented as lowering stems, e.g. plural [lufɒn-ɒk]. As an attention check, participants had to correctly select the plural form appearing in the first sentence. Next, a second frame sentence appeared, in which participants had to select 1SG and possessive forms. As discussed in Section 2.3, the 1SG suffix has the same regular and lowering stem variants as the plural, so the linking vowel should match that of the plural: in this case, [lufɒn-om].[9] The choices included both back and front variants; the possessive should have the same harmony class as the plural (in this case, [lufɒn-ɒ] or [lufɒn-jɒ]). Trials in which speakers chose a discordant 1SG or antiharmonic possessive were discarded.

A good **lufɒn** is one who knows how to make other **lufɒnok** laugh.
(lufɒnok: back regular)

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

lufɒnøk	lufɒnɒk	lufɒnɛk	**lufɒnok**
front regular	back lowering	front lowering	back regular

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

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

lufɒnɒm	lufɒnɛm	lufɒnøm	**lufɒnom**
back lowering	front lowering	front regular	back regular

lufɒnɛ	lufɒnjɛ	**lufɒnɒ**	**lufɒnjɒ**
front *-V*	front *-jV*	back *-V*	back *-jV*

Figure 1: Trial for Hungarian stimulus testing study, with forms annotated for harmony and stem class and acceptable answers bolded

4.5 Analysis

I discarded discordant trials (as described above) and trials with filler stimuli with front unrounded harmony, which do not show the lowering stem alternation (see Section 2.3 for discussion). This left a total of 2,398 trials with 57 stimuli.

As in the corpus study, I fitted two mixed logistic regressions whose dependent variable is the possessive suffix selected by the participant (*-V* vs. *-jV*). The first regression describes how participants used a nonce word's phonology to assign its possessive. If speakers are matching the distribution of the lexicon, then the experimental results should correlate with the *phon_odds* coefficients for nonce words showing their likelihood of *-jV* according to the phonological model of the lexicon in Table 6 (see Section 3.2.2 for details). Thus, the first regression includes the *phon_odds* coefficients for the nonce words and a random intercept for participant.

The second model includes these two factors as well as stem class: whether a nonce word was presented with a regular plural *-ok* or a lowering stem plural *-ɒk* in a given trial. This tests whether participants show sensitivity to the morphological dependency.

4.6 Results

[9] The possessive morpheme *-V/-jV* does not appear in first singular possessive forms, only the possessor marker (see Section 2.2).

4.6.1 Phonology

In Table 9, we see the effects of the mixed logistic regression predicting participant responses given a random intercept for participant and a fixed effect of *phon_odds* calculated from the phonological model of the lexicon in Table 6.

Random effect	*variance*	*SD*		
Participant	0.55	.74		
Fixed effects	*β coef*	*SE*	*Wald z*	*p*
Intercept	**0.67**	**.10**	**7.03**	**<.0001**
Phon_odds	**0.34**	**.01**	**22.76**	**<.0001**

Table 9: Effects of mixed logistic model with predictions of the phonological model of the lexicon (Table 6) for experimental use of possessive *-jV*, with significant effects bolded

This model shows an overall biase towards *-jV* (since the intercept is positive): there were 1031 responses of *-V* and 1367 of *-jV*. The results also show a correspondence between predicted rates and actual rates: the coefficient for *phon_odds* is positive. However, the effect size is much smaller than 1: an increase of 1 in *phon_odds* corresponds to a predicted increase in the experimental likelihood of a *-jV* response of only .34, although the two operate on the same scale. This means that the overall range of likelihood predicted by the experimental model is much narrower than that predicted by the model of the lexicon.

We see the difference between the lexical and experimental models in Table 10, which shows the two words predicted to be most ([olu:nt]) and least ([jøs]) likely to take *-jV* and the word with a predicted rate closest to 50% ([ʃok:ol]). The two extremes, [jøs] and [olu:nt], are predicted by Table 6 to be essentially categorical in the lexicon, but showed mixed responses in the experiment. Correspondingly, the model trained on the experimental results (Table 9) predicts that one variant should be dominant, but not effectively categorical.

nonce word	*predicted likelihood of -jV in lexicon model (Table 6)*	*experimental rate of -jV*		*predicted likelihood of -jV in experiment model (Table 9)*
jøʃ	0.006%	17.4%	(38/46)	6.7%
ʃok:ol	52.097%	67.5%	(27/40)	66.8%
olu:nt	99.934%	94.7%	(36/38)	96.0%

Table 10: Predicted likelihood of *-jV* for nonce according to models trained on lexicon (Table 6) and experimental results (Table 9)

Figure 2 shows the relationship between the predicted likelihood of each nonce word taking *-jV* and its experimental rate of *-jV*. Both axes are shown in terms of log odds (that is, the coefficients) in order to make the relationship linear. A rate of 0 corresponds to a log odds of negative infinity, so the nonce word *fátyúsz* [fa:cu:s], which speakers assigned *-V* in every trial, should be at negative infinity. It is included at the bottom edge of the graph in Figure 2. Figure 3 shows the same data plotted on scales of raw probability. The graphs also include a line corresponding to the fit of the model in Table 9.

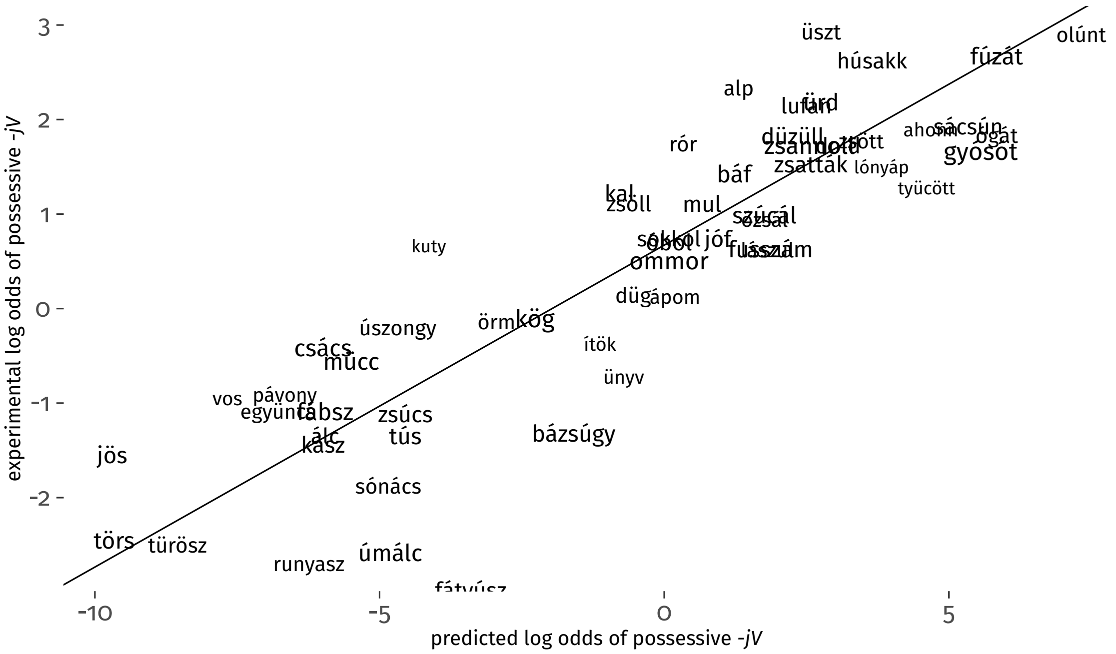

Figure 2: The relationship between predicted and experimental log odds of possessive *-jV* for individual nonce words, sized according to number of trials, with a line showing the fit of the experimental model in Table 9

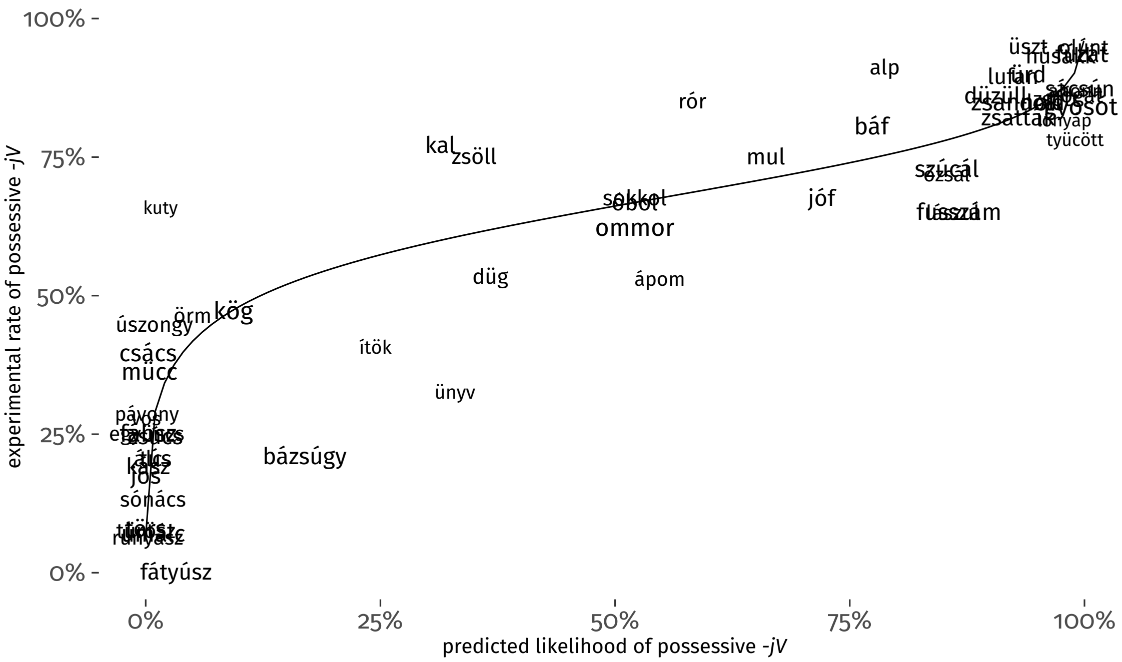

Figure 3: The relationship between predicted likelihood and experimental rate of possessive *-jV* for individual nonce words, sized according to number of trials, with a line showing the fit of the experimental model in Table 9

A nonce word with a higher predicted likelihood of *-jV* generally has a higher experimental rate of *-jV*, and the relationship is linear (Figure 2): the phonological model of the lexicon fits the experimental results well Figure 3 shows that the experimental results are less extreme than the predicted likelihood, especially on the low end: nouns ending in palatals and sibilants, which categorically take *-V* in the lexicon and thus had a near-zero predicted likelihood of *-jV*, were assigned *-jV* in the experiment up to nearly 50% of the time. Nonce words with a very high predicted likelihood of *-jV* had a high experimental rate of *-jV*.

4.6.2 Phonology and stem class

Table 11 shows the effects of the regression including the factor of stem class (that is, the plural shown on the nonce word in a given trial) alongside *phon_odds* and the random intercept for participant.

Random effect	*variance*	*SD*		
Participant	0.54	.74		
Fixed effects	*β coef*	*SE*	*Wald z*	*p*
Intercept	**0.74**	**.10**	**7.48**	**<.0001**
Phon_odds	**0.34**	**.02**	**22.77**	**<.0001**
Stem class (default: non-lowering)				
lowering	**−0.33**	**.13**	**−2.62**	**.0086**

Table 11: Effects of mixed logistic model with predictions of the phonological model of the lexicon (Table 6) and stem class for experimental use of possessive *-jV*, with significant effects bolded

This second model shows that nonce words were assigned *-jV* significantly less often when they were presented as lowering stems than when they were presented as having regular plurals. This model performs significantly better than the model without the morphological factor shown in Table 9 ($\chi^2 = 6.88$, $p = .009$).

To get a better sense of the data, let us look at the behavior of the individual nonce words. Figure 4 and Figure 5 show the same data as Figure 2 and Figure 3, but each nonce word is now split between trials when it was presented as a regular stem (in black), and a lowering stem (in gray). The lowering stem words are always smaller than the regular words because each word had fewer lowering stem trials. A line connects the two conditions for each word, going leftward from the regular word to the lowering stem word because the model predicts a lower likelihood of *-jV* for lowering stems. Probabilities of 0 and 1 correspond to log odds of (negative) infinity, so words with categorical behavior in one condition are shown at the bottom and top edges of Figure 4 and connected with a dashed line. The graphs show lines corresponding to the fit of the model in Table 11 for regular (black) and lowering stem (gray) conditions.

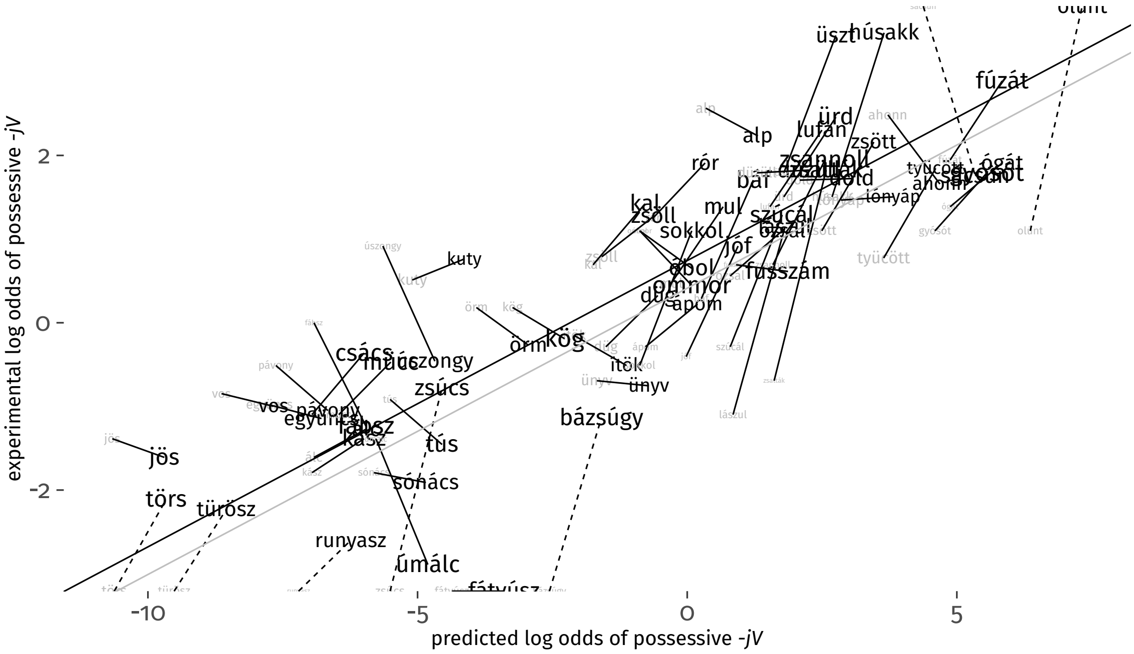

Figure 4: The relationship between predicted and experimental log odds of possessive *-jV* for individual nonce words presented with regular (black) and lowering (gray) plurals, sized according to number of trials, with a line showing the fit of the experimental model in Table 9

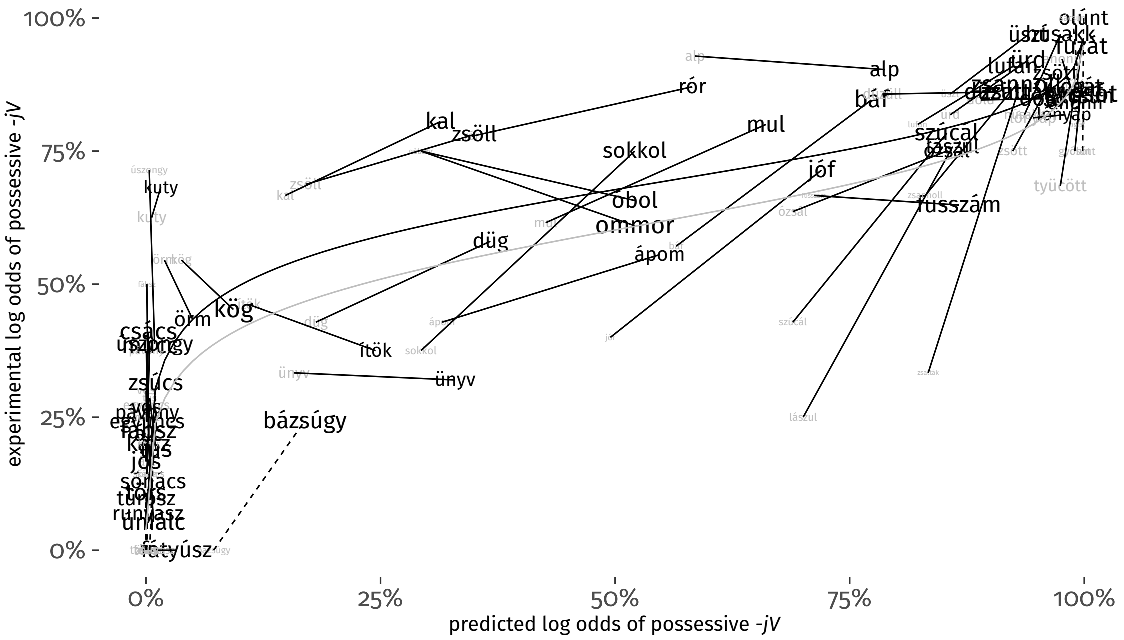

Figure 5: The relationship between predicted likelihood and experimental rate of possessive *-jV* for individual nonce words presented with regular (black) and lowering (gray) plurals, sized according to number of trials, with a line showing the fit of the experimental model in Table 9

Most of the lines in these figures slope downward and to the left, indicating that most nonce words had a lower experimental rate of *-jV* when presented as a lowering stem. This is especially true in the top right section of the graph—that is, nonce words with a higher rate of *-jV*. On the other hand, nouns with a lower expected rate of *-jV* are more likely to have a *higher* rate of *-jV* when presented as a lowering stem. These words, which end in palatals and sibilants, behaved unexpectedly: they categorically take *-V* in the lexicon but showed moderate rates of *-jV* in the experiment. Indeed, if we remove stimuli ending in sibilants or palatals, the model does better (Table 12). The effect size of *phon_odds* is almost exactly the same, but the effect of stem class is substantially stronger, at −.57 compared to −.33 in Table 9. The intercept is also higher, as expected given that this data set excludes nouns with lower rates of *-jV*.

Random effect	*variance*	*SD*		
Participant	0.54	.74		
Fixed effects	*β coef*	*SE*	*Wald z*	*p*
Intercept	**0.91**	**.12**	**7.84**	**<.0001**
Phon_odds	**0.33**	**.03**	**10.53**	**<.0001**
Stem class (default: non-lowering)				
lowering	**−0.57**	**.15**	**−3.83**	**.0001**

Table 12: Effects of mixed logistic model with predictions of the phonological model of the lexicon (Table 6) and stem class for experimental use of possessive *-jV* for stimuli not ending in palatals or sibilants, with significant effects bolded

As before, the model including stem class is a significantly better fit than the model whose only fixed effect is *phon_odds*, whose effects I do not show here ($\chi^2 = 14.28$, $p = .0002$).

4.7 Discussion

4.7.1 Speakers show sensitivity to stem class

The experiment supports my main hypothesis: Hungarian speakers observed the morphological dependency in the lexicon, assigning possessive *-V* more often to nonce words when they were presented as lowering stems (with plural *-ɒk*). Thus, my experiment serves as a proof of concept for nonce word studies manipulating the inflection of novel forms. Lowering stem nouns generally comprise a closed class, but speakers nonetheless extended the lexical generalization that lowering stems prefer *-V*. It is unsurprising that speakers can apply patterns for unproductive stem classes like lowering stems, because there exist rare lowering stems, like [maːl] 'belly fur' discussed in Section 1.2, that a speaker might first encounter as an adult. This morphological effect is the primary result; the remainder of this discussion will be devoted to issues of phonological frequency matching.

4.7.2 How did speakers match the frequency of the lexicon?

In general, Hungarian speakers match the phonological distribution of *-V* and *-jV* in the lexicon quite closely with novel words. However, my results showed a less extreme distribution than the lexicon—in particular, nouns ending in sibilants and palatals categorically take *-V* in the lexicon but were sometimes assigned *-jV*. I cannot explain this discrepancy, though one possibility is noise: I had trouble getting participants to pay attention to the relevant details, suggesting that the task was fairly difficult.

It is clear, though, that subjects applied gradient patterns from the lexicon, counter to the claim by Rácz & Rebrus (2012) that novel words categorically take one possessive suffix (see Section 2.2): *-V* for nouns ending in palatals and sibilants, *-jV* otherwise. One possible reason for this is that the experimental task may be different from what speakers do in real life. Even if so, I have shown that speakers store and can apply generalizations about possessive allomorphy that are both phonological and morphological in nature. The primary purpose of my study is to probe these generalizations, and in this, it is successful. It also aligns with most nonce word studies, which find matching of lexically variable patterns (see discussion in Schuler et al. 2021).

Alternately, the claim of productive defaults in the literature may be overstated. A search of the Hungarian National Corpus (Oravecz et al. 2014) reveals occasional uses of *-jV* with sibilant-final loanwords: one speaker forms the possessive of the Britney Spears song "Sometimes" as [saːmtaːjmz-jɒ]. Thus, speakers sometimes generate the "non-productive" forms in spontaneous text. Perhaps speakers show frequency matching when inflecting totally novel words, but these quickly stabilize to the default as the more likely form dominates and spreads. More research is required to reconcile my results with the lexical behavior of nouns newly entering the Hungarian lexicon.

4.7.3 Are speakers generalizing over roots or stems?

In Section 3.1, I argued for a corpus of roots (i.e. monomorphemic words) over a stem-based corpus that counts every derived form and compound separately. Phonological models trained on the two corpora yield similar phonological effects, but very different baseline rates of *-jV* (that is, model intercepts). Most derived forms take *-V* (Rácz & Rebrus 2012), so the stem-based corpus has a much lower overall rate of *-jV*. Although the phonological effects from the stem-based corpus are somewhat better predictors of the experimental results, comparing the rates of *-V* and *-jV* makes it clear that participants are matching the distribution of roots, not stems. We see this in Table 13, which compares the experimental rates of *-jV* across final consonant place and manner (the most important phonological effects). With the exception of sibilants and palatals, which are equally unexpected for all accounts, the rates across monomorphemic words are a much better fit.[10]

	experiment (responses)			*lexicon (types)* *monomorphemic nouns*			*lexicon (types)* *all nominals*		
	-V	*-jV*	*% -jV*	*-V*	*-jV*	*% -jV*	*-V*	*-jV*	*% -jV*
labial	112	212	65.4%	117	156	57.1 %	1781	565	24.1 %
alveolar	745	957	56.2%	712	816	53.4%	12 041	2214	15.5%
palatal	93	61	39.6%	275	1	0.4%	2035	3	0.1 %
velar	81	137	62.8%	126	224	64.0%	2796	667	19.2%
plosive	207	599	74.3%	200	660	76.7%	4993	2318	31.7%
fricative	49	77	61.1 %	36	30	45.5%	567	54	8.7%
sibilant	550	127	18.8%	496	2	0.4%	7886	2	0.0%
nasal	91	174	65.7%	180	267	59.7%	2136	503	19.1 %
approximant	134	390	74.4%	318	238	42.8%	3072	572	15.7%
all	1031	1367	57.0%	1230	1197	49.3%	18 653	3449	15.6%

Table 13: Type frequency of *-jV* in two versions of the lexicon and experimental frequency of *-jV* responses, by final C place and manner

I take Table 13 as empirical support for my assumption, discussed in Section 3.1, that Hungarian lexical entries are roots and affixes, not complex stems, and that Hungarian speakers are counting over these roots. This root-based storage, used in Distributed Morphology (e.g. Halle & Marantz 1993; Embick & Marantz 2008), fits with the theory of morphological dependencies I present in Section 5.

5 Sublexicon models and morphological dependencies

To account for the results in Section 4.6, we need a theory that can apply patterns of allomorphy from the lexicon productively to new words. In particular, this theory must be able to learn *morphological* patterns like the correlation between lowering stems and possessive *-V*. In Section 1.3, I argued that using diacritic features on lexical items provides an easy symbolic representation for lexically specific morphological behavior that can be used in generalizations. Moreover, as discussed in Section 4.7, these generalizations should be made over roots, not stems. In this section, I sketch out such a theory, based on the sublexicon model of phonological analogy (Gouskova et al. 2015). I extend this basic model with a novel set of morphological constraints that allow for generalizations over cases of lexically specific allomorphy. As before, I assume Distributed Morphology (Halle & Marantz 1993), which uses root-based storage and diacritic features.

[10] The substantially higher rate of *-jV* for approximants in the experiment is because no nonce words ended in the palatal approximant [j], which always takes *-V* in the lexicon.

5.1 The basic sublexicon model

The sublexicon model (Allen & Becker 2015; Gouskova et al. 2015; Becker & Gouskova 2016) encodes phonological generalizations in lexically specific variation. This allows learners to pick up on the partial phonological predictability determining a given lexical item's choice of allomorph. As such, it follows in the path of previous models, like the Minimal Generalization Learner (Albright & Hayes 2003), that use phonological analogy to determine the set of lexical items to which a given morphophonological rule applies (see Guzmán Naranjo (2019) for an overview).

In the sublexicon model, the learner divides the lexicon into *sublexicons* that pattern together. These sublexicons correspond with the morphological features described in Section 1.2 and Section 2: [lower] for lowering stems, [−j] for nouns that take possessive -*V*, and [+j] for nouns that take -*jV*. These groupings are repeated below:

(3) *Lexical entries for Hungarian nouns*

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

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

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

5.2 Sublexical phonotactic grammars

Hayes & Wilson (2008) present a model of phonotactic learning in which a learner captures generalizations over a language's surface forms through a constraint-based phonotactic grammar. In their proposal, the learner keeps track of sounds or sequences of sounds (defined in terms of features) that are rare or absent in the lexicon and proposes constraints against them, weighting them in accordance with the strength of the generalization. For example, in Hungarian, adjacent obstruents generally agree in voicing (Siptár & Törkenczy 2000), so words with a voiced obstruent followed by an unvoiced obstruent will appear far less than expected from the frequency of voiced and unvoiced obstruents on the whole. Accordingly, the learner should generate a phonotactic constraint, *[−son,+voice][−voice], which penalizes voiced obstruents before voiceless consonants, and weight it heavily.[11] This is how the speaker knows that surface forms with mixed-voice obstruent clusters are unlikely in Hungarian.

The sublexicon model extends the notion of phonotactic learning to capture generalizations over subsets of the lexicon that pattern together—that is, sublexicons. The learner induces a phonotactic grammar for each sublexicon, capturing patterns specific to that sublexicon. As discussed in Section 3.2.3, Hungarian nouns ending in sibilants and palatals categorically take possessive -*V*, while nouns ending in vowels always take -*jV*. The sublexical grammar for the [+j] sublexicon should include heavily weighted constraints penalizing final sibilants and palatals, and the [−j] sublexicon should penalize word-final vowels.

[11] Hayes & Wilson (2008) released an implementation of their learning model, the UCLA Phonotactic Learner. In practice, it does capture many strong phonotactic tendencies, but also learns many constraints that strike linguists as phonologically unnatural and do not correspond to the phonotactic knowledge of real speakers (Hayes & White 2013). When applied to the Hungarian data, the Phonotactic Learner also failed to learn many moderate tendencies that speakers displayed sensitivity to. In this section, I focus on the conceptual framework of sublexical phonotactic grammars rather than any particular model of how they are learned.

These sublexical grammars are then reflected in speakers' behavior. When a speaker wishes to form the possessive of a novel word, they evaluate the stem against each sublexicon's grammar, where each sublexical grammar yields a score for that word. The better a word fares on the [+j] sublexicon relative to the [−j] sublexicon, the more likely it is to be placed into this sublexicon, and thus take *-jV*.

In Figure 6 and Figure 7, we see two nonce words from the experiment in Section 4, [ruɲɒs] (orthographically *runyasz*) and [fuːzaːt] (*fúzát*), tested on toy sublexical grammars with the constraints described above. Here, [ruɲɒs] is penalized by *[+strident]#, penalizing word-final sibilants, in the [+j] sublexicon, but not by the constraint against word-final vowels in the [−j] sublexicon; [fuːzaːt] accrues no penalities. I assume that all three constraints have a weight of 5.

constraint *weight*	*[+strident]# 5	*[+palatal]# 5	total
ruɲɒs	−5	0	−5
fuːzaːt	0	0	0

Figure 6: Evaluation of nonce words *runyasz* and *fúzát* on the [+j] sublexical grammar

constraint *weight*	*[+syllabic]# 5	total
ruɲɒs	0	0
fuːzaːt	0	0

Figure 7: Evaluation of nonce words *runyasz* and *fúzát* on the [−j] sublexical grammar

Since [ruɲɒs] has a better score on the [−j] sublexical grammar than the [+j] sublexical grammar, it is much more likely to be placed into the former and form its possessive with *-V*. Specifically, this is a maximum entropy model (Hayes & Wilson 2008): a word's likelihood of being placed into a sublexicon is proportional to its (negative) score raised to the power of e. Here, the probability of [ruɲɒs] being assigned to the $[+j]$ sublexicon is $\frac{e^{-5}}{e^{0}+e^{-5}} = .0067 = .67\%$. On the other hand, since [fuːzaːt] has the same score on both sublexicons, it has a 50% chance of being assigned to each.

The sublexicon model is designed to capture generalizations over the phonological shape of each sublexicon's members. In Section 4, I showed that speakers also observe a morphological generalization: lowering stems are more likely to have possessive *-V*. In a feature-based analysis, this means that [lower] and [−j] are likely to cooccur on lexical items. A feature-based analysis casts this as a cooccurrence relation between features: if a lexical entry has a [lower] feature, it is also likely to have a [−j] feature. In the next section, I extend the sublexicon model to accommodate these relations.

5.3 A sublexicon model with morphology

In my proposal, each sublexicon's grammar has constraints penalizing diacritic features alongside those penalizing phonological features. For example, every member of the [+j] sublexicon has [+j] (by definition), but very few have [lower], since lowering stems rarely take *-jV*. Since [lower] is underrepresented in the [+j] sublexicon, the [+j] sublexical grammar should contain a heavily weighted constraint *[lower] penalizing nouns with both [lower] and [+j]. The [−j] sublexicon, comprising words that take *-V*, will also have a *[lower] constraint, but it will not be as strong, since lowering stems are better represented among -*V* words (though still uncommon).

Figure 8 and Figure 9 show the evaluation of our two nonce words on the toy grammars, now containing *[lower]. This constraint has a heavier weight in the [+j] grammar than in the [−j] grammar (2 and 1, respectively). Here, the speaker knows that the plurals of these words are [ruɲɒs-ɒk] and [fuːzaːt-ɒk], so she has marked both with [lower].

constraint *weight*	*[+strident]# 5	*[+palatal]# 5	*[lower] 2	total
$\text{ruɲɒs}_{\text{[lower]}}$	−5	0	−2	−7
$\text{fu:za:t}_{\text{[lower]}}$	0	0	−2	−2

Figure 8: Evaluation of nonce lowering stems *runyasz* and *fúzát* on the [+j] sublexical grammar with *[lower]

constraint *weight*	*[+syllabic]# 5	*[lower] 1	total
$\text{ruɲɒs}_{\text{[lower]}}$	0	−1	−1
$\text{fu:za:t}_{\text{[lower]}}$	0	−1	−1

Figure 9: Evaluation of nonce lowering stems *runyasz* and *fúzát* on the [−j] sublexical grammar with *[lower]

The *[lower] constraint brings the likelihood of [+j] (and possessive -*jV*) being assigned to /$\text{ruɲɒs}_{\text{lower}}$/ slightly further, from .67% to .25%. For /$\text{fu:za:t}_{\text{lower}}$/, the effect is more visible: the likelihood of [+j] goes from 50% to $\frac{e^{-2}}{e^{-1}+e^{-2}} = .269 = 26.9\%$. This shows how the sublexicon model can accommodate the effects found in the nonce word experiment, both phonological and morphological: nonce words ending in sibilants are less likely to be assigned -*jV* (that is, be placed in the [+j] sublexicon), as are words shown as lowering stems. These effects can all be assessed in a single calculation, correctly allowing them to compound or cancel out.

5.4 Inflection classes as emergent clusters of morphological constraints

In Section 1.3, I laid out the main problem in this paper: Hungarian speakers use the plural form of a word to infer its possessive, but this inference is not built directly into the formal feature set and rules of realization for the Hungarian plural and possessive. This was contrasted with Russian, in which inflection class suffixes directly code relations between allomorphs. I repeat the basic inflection class analysis of Russian below:

(2) *Vocabulary insertion rules for some Russian case endings*

c.	NOM ⟷ a / II __	f.	NOM ⟷ Ø / III __
d.	DAT ⟷ e / II __	g.	DAT ⟷ i / III __
e.	INS ⟷ oj / II __	h.	INS ⟷ ju / III __

(1) *Lexical entries for Russian nouns*

a. II: /$\text{t}^{\text{j}}\text{ot}^{\text{j}}{}_{\text{II}}$/ ‘aunt’, /$\text{tʃert}_{\text{II}}$/ ‘characteristic’, /$\text{dol}^{\text{j}}{}_{\text{II}}$/ ‘portion’, …

b. III: /$\text{plet}^{\text{j}}{}_{\text{III}}$/ ‘whip’, /$\text{tetrad}^{\text{j}}{}_{\text{III}}$/ ‘notebook’, /$\text{ploɕ:ad}^{\text{j}}{}_{\text{III}}$/ ‘square’, …

These analyses posit a categorical difference between Russian and Hungarian: the hard-coded feature structure of the former allows inference of new inflected forms from known ones, whereas the latter does not. However, linguists like Ackerman et al. (2009) Baerman et al. (2017) argue that the difference between the two languages is one of *degree*, rather than kind: Russian has a greater degree of inflectional cohesion than Hungarian (at least in the corners discussed in this paper), in that forms are more informative of one another than in Hungarian.

The morphological sublexical constraints bring this insight into our formal theory with a more flexible approach to inflection classes. Consider an analysis of Russian where each affix is governed by its own narrowly targeted feature, as in the Hungarian case:

(8) *Vocabulary insertion rules for Russian cases (without inflection classes)*

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

Of course, rather than having a single inflection class feature, each lexical entry now has one feature for each of its affixes:

(9) *Lexical entries for Russian nouns (without inflection classes)*

a. II: /$\text{t}^\text{j}\text{ot}^\text{j}_{\text{[N:a,D:e,I:oj]}}$/ ‘aunt’, /$\text{tʃert}_{\text{[N:a,D:e,I:oj]}}$/ ‘characteristic’, /$\text{dol}^\text{j}_{\text{[N:a,D:e,I:oj]}}$/ ‘portion’, …

b. III: /$\text{plet}^\text{j}_{\text{[N:Ø,D:i,I:ju]}}$/ ‘whip’, /$\text{tetrad}^\text{j}_{\text{[N:Ø,D:i,I:ju]}}$/ ‘notebook’, /$\text{ploɕ:ad}^\text{j}_{\text{[N:Ø,D:i,I:ju]}}$/ ‘square’, …

In this analysis, what defines a class II noun is that it has the [N:a], [D:e], and [I:oj] features; likewise, class III nouns share the features [N:Ø], [D:i], and [I:ju]. Under this approach, there is no symbolic unit of representation corresponding to an inflection class. Instead, inflection classes are *emergent*: since these features tend to cooccur on the same words, the learner’s sublexical grammars for each feature would have clusters of extremely strong morphological constraints enforcing inflection class cohesion. For example, the [D:I] sublexical grammar would have very heavily weighted constraints *[N:a] and *[I:oj].

The lexical items in (9) contain more redundancies than one with inflectional class features II and III, but offer two advantages. First, even in a language with relatively well-ordered classes like Russian, there is some bleeding between the classes (Parker & Sims 2020). For example, nouns like [vremʲa] ‘time’ have *-i* in the dative like class III ([vremenʲ-i], with a stem extension), but instrumental *-em* ([vremenʲ-em]), which is the usual ending for class I and IV. These nouns need special marking in any case, but an emergent class analysis does not require any new features, only an unusual combination of already existing features (like [N:a,D:i,I:em]). Second, this analysis provides a path for learning inflection classes: they emerge from features tracking the distribution of individual affixes—which, my results show, are independently necessary. In contrast, an analysis with features like II and III requires speakers to formally arrive at the right combinations of rules and endings. Thus, an emergent class analysis requires fewer pieces of theoretical machinery and allows for a formal unification of relatively canonical inflection class systems like Russian (cf. Corbett & Baerman 2006) and more variable cases of feature cooccurrence like the Hungarian plural and possessive.

6 Conclusion

Correlations between inflected forms of a word are often captured through inflection class features that categorically group together shared inflectional realizations (Aronoff

1994). In this paper, I argued that a more flexible approach is needed to explain my results: Hungarian speakers extend gradient phonological and morphological generalizations about the distribution of possessive allomorphs in the lexicon to nonce words. To account for this, I proposed an extension to the sublexicon model (Gouskova et al. 2015): the lexicon is split up into sublexicons of words that share a morphological realization, and each sublexicon is described by a grammar penalizing the cooccurrence of certain phonological and morphological diacritics in lexical entries. This model allows speakers to classify novel words according to their known phonological and morphological characteristics.

The results presented here are a proof of concept for a new nonce word experimental paradigm investigating the relationships between inflected forms. They also suggest an alternate analysis of traditional inflection class languages like Russian, more in line with the perspective adopted by Ackerman et al. (2009) and Ackerman & Malouf (2013): the difference between Russian and Hungarian is one of degree, not of kind, so inflection classes should be treated as emergent clusters of narrowly targeted morphological features. More research exploring these relations in generative morphology is needed, and the results presented here can serve as a stimulus for further studies exploring different kinds of inflectional patterns.

Abbreviations

ALL = allative, DAT = dative, INESS = inessive, INS = instrumental, NOM = nominative, PL = plural, POSS = possessive, SG = singular, 1SG = first person singular possessor marker, etc.

Data availability

All data and analysis code referenced in this study can be found at: https://osf.io/mdra8/?view_only=3794e1a584f34fc8a26a7f7b38e8f251.

Ethics and consent

The studies conducted in this paper were deemed exempt by the Institutional Review Board of the author's university, IRB-FY2022-5933.

Competing interests

The author has no competing interests to declare.

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