Incomplete Neutralization and the (A)symmetry of Paradigm Uniformity

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1. Incomplete Neutralization as Paradigm Uniformity

Positional neutralization is a cross-linguistically common pattern, with final devoicing in languages like German (Lombardi, 1999) being the parade example:

(1) Final devoicing in German
   a. /vɛʀd/ → [vɛʀt] 'become.IMP'
   b. /vɛʀd-ən/ → [vɛʀdən] 'become.INF'

In languages with this pattern, devoicing is often incomplete, such that devoiced obstruents retain some of the cues to voicing. As a result, devoiced obstruents are often measurably distinct from their underlyingly voiceless counterparts; for example, [vɛʀt] ← /vɛʀd/ 'become.IMP' is distinct from [vɛʀt] ← /vɛʀt/ 'be worth.IMP'. This phenomenon has been documented in a range of languages for a variety of cues, including duration of the preceding vowel, consonant closure duration, release duration, and voicing during closure (Port & O'Dell, 1985; Slowiaczek & Dinnsen, 1985; Port & Crawford, 1989; Warner et al., 2004; Kharlamov, 2014). Languages vary in the specific cues for which neutralization is incomplete, and the contrast between obstruents with different underlying specifications for voicing may be greater or smaller depending on the design of the experiment; overall, though, the phenomenon of incomplete neutralization is now robustly established in the literature.

One proposed explanation for incomplete neutralization is that it is a kind of paradigm uniformity (e.g., Braver 2013); this hypothesis is illustrated in Figure 1a. On this account, the [t] of [vɛʀt] is not fully devoiced because it is influenced by the morphologically related word [vɛʀdən], in which the corresponding segment is voiced. If this explanation is correct, a second question naturally follows: could [vɛʀdən] be similarly influenced by [vɛʀt]? If so, then we would expect the [d] of [vɛʀdən] to be slightly *devoiced* compared to a non-alternating [d] in a word like [ɛʀdə] 'earth'.

This 'symmetrical' version of the paradigm uniformity hypothesis is illustrated in Figure 1b. This converse of incomplete neutralization has not been much discussed in the literature; the only example I am aware of is Ernestus & Baayen (2007), who explicitly predict that this phenomenon should exist but leave experimental verification to future research.[1]

In this paper, I present the results of two experiments that test whether the converse of incomplete neutralization illustrated in Figure 1b obtains. Experiment 1 explores final devoicing in Afrikaans; Experiment 2 is an analogous study of vowel reduction in Russian. Although both experiments find evidence of incomplete neutralization of the ordinary sort, neither one demonstrates its symmetrical counterpart. I conclude that sub-phonemic paradigm uniformity is fundamentally asymmetrical: contrasting forms may influence (partially) neutralized forms, as in classical incomplete neutralization; but neutralized forms do not influence contrasting forms in the same way.

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[1] Braver (2013) develops a formal analysis of incomplete neutralization that involves unique bases within inflectional paradigms and is therefore incompatible with Figure 1b, but does not discuss this specific prediction explicitly.

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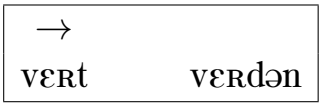
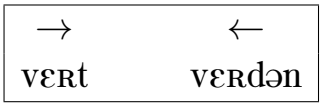
Figure 1: Two hypotheses about the structure of sub-phonemic paradigm uniformity.



(a) Asymmetrical paradigm uniformity



(b) Symmetrical paradigm uniformity

Throughout, I refer to the 'underlying forms' of target segments. This is a convenient shorthand for distinguishing between alternating and non-alternating segments of various types, and is not intended to represent a theoretical claim about the nature of these alternations. As discussed below, the results of these experiments are compatible with a model that posits underlying and surface representations, but they are compatible with other approaches as well.

2. Experiment 1: Final Devoicing in Afrikaans

2.1. Design

Like many Germanic languages, Afrikaans has final devoicing of obstruents:

(2) Final devoicing in Afrikaans
   a. /hud/ → [hut] 'hat'
   b. /hud-ə/ → [hudə] 'hats'

The stimuli for this experiment consisted of 28 nouns. Of these, 14 end with a final stop, either /t/ (e.g., /sprut/ 'freckle') or /d/ (e.g., /hud/ 'hat'). All of these nouns form the plural with the suffix [-ə]; in the singular, there is no suffix, and final /d/ is devoiced. The other 14 nouns end with either /t/ or /d/ followed by /ə/ (e.g., /rutə/ 'route', /rudə/ 'rod'). Because the stops in these nouns are not stem-final, they do not alternate. All these nouns form the plural by adding the suffix [-s]. Here and throughout, the four specific examples given here are used to represent the entire relevant classes of stimuli; the full list of target stimuli is provided in the appendix.

In addition to the 28 target stimuli, there were 28 fillers; all were nouns, including many nouns with irregular plurals (e.g., *vrou* ∼ *vrouens* 'woman ∼ women').

Participants were 9 native speakers of Afrikaans living in the Salt Lake Valley; all reported that they had lived in majority-Afrikaans-speaking communities until at least their 20s. The recording took place in a quiet room; participants saw singular and plural forms of the stimuli displayed together on a laptop and read them one at a time, without a frame sentence. The reason for displaying singular and plural forms together was to make paradigmatically related forms as contextually salient as possible and maximize the chances that they would be able to influence each other. A null result could then be interpreted fairly confidently as evidence that the converse of incomplete neutralization illustrated in Figure 1b does not occur even under the best of circumstances, while a statistically significant result could serve as the basis for future work exploring the precise conditions under which such influence is possible.

2.2. Results

There are two crucial comparisons to examine in the resulting data. First, we can test for ordinary incomplete neutralization by comparing singular /hud/ and singular /sprut/; we expect that the two will be measurably different for at least some of the cues associated with voicing. Second, and most importantly, we can test for the converse of incomplete neutralization shown in Figure 1b by comparing /hud-ə/ and /rudə-s/. If the symmetrical hypothesis is correct, then we expect that the /d/ of /hud-ə/ will be slightly less voiced than the /d/ of /rudə-s/, because only the former alternates with a (mostly) voiceless stop in its paradigm.

All of the analyses below report results from mixed-effects models that predict a cue to voicing (e.g., preceding vowel duration) from a fixed effect of either `Voicing` or `AlternatingC` (depending on the comparison being made); a fixed effect of `LogFrequency` (using frequencies from Protea Boekhuis & CTexT 2015); and random effects of `Subject`, `Lemma`, `Vowel`, and `Consonant`[2]. Four acoustic cues were analyzed: duration of the preceding vowel, consonant closure duration, release duration, and number of glottal pulses during closure.

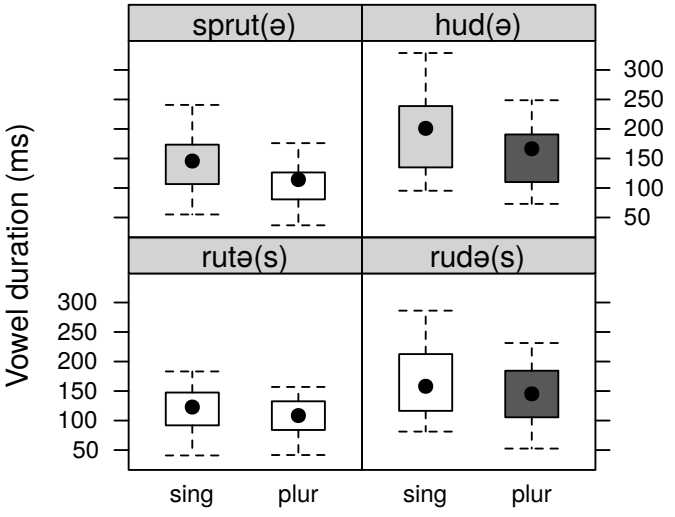


Figure 2: Vowel duration by stop voicing, stop type (alternating/non-alternating), and number. Each sub-plot is labeled with an example of a stimulus from that condition. Light gray boxes highlight the crucial comparison for incomplete neutralization; dark gray boxes highlight the crucial comparison for its converse.

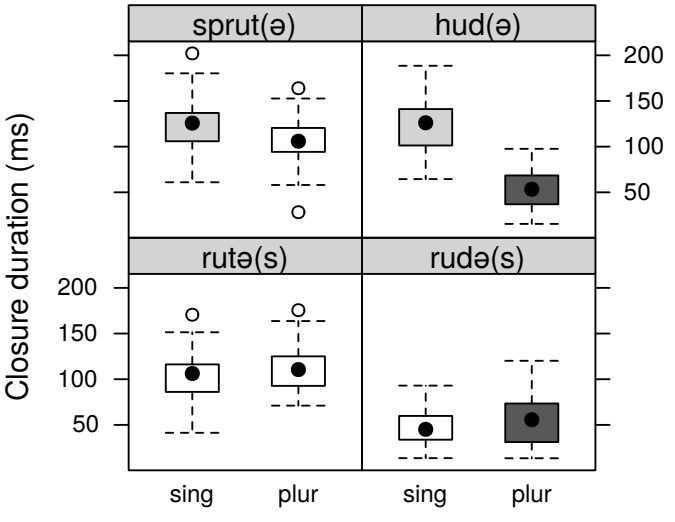


Figure 3: Consonant closure duration by condition. Each sub-plot is labeled with an example of a stimulus from that condition. Light gray boxes highlight the crucial comparison for incomplete neutralization; dark gray boxes highlight the crucial comparison for its converse.

[2] `Consonant` codes the identity of the sonorant consonant (/n/, /l/, or /r/) immediately preceding the target stop, if present, in words such as *tent* 'tent'.

Figure 2 shows the results for vowel duration. Comparing /hud/ and /sprut/ (light gray boxes), we see that neutralization is incomplete: vowels before underlyingly voiced /d/ are about 50 ms longer than before underlyingly voiceless /t/ ($p = 0.00359$). However, there is no evidence for the symmetrical hypothesis of Figure 1b (dark gray boxes): vowels before alternating /d/ as in /hud-ə/ are *not* shorter than vowels before non-alternating /d/ as in /rudə-s/ ($p = 0.313$).

Figure 3 shows the results for consonant closure duration. Comparing /hud/ and /sprut/, we see that neutralization is complete: the closure of underlyingly voiced /d/ is *not* shorter than the closure of underlyingly voiceless /t/ ($p = 0.991$). There is also no evidence for the symmetrical hypothesis of Figure 1b: the closure of alternating /hud-ə/ is not longer than the closure of non-alternating /rudə-s/ ($p = 0.155$). For this model only, model comparison supported an interaction between `AlternatingC` and `Subject`: a model with random slopes for `AlternatingC` by `Subject` is superior to a model with only random intercepts by `Subject` ($p = 0.000244$). This seems to be driven by a very large effect of `AlternatingC` for one subject, but in the wrong direction: for this subject, /hud-ə/ has *shorter* closure durations than /rudə-s/. More generally, in the random-intercept model, every subject but one exhibited a trend in the wrong direction (shorter closures for /hud-ə/); thus, the overall null result is not due to a significant trend in the expected direction for a subset of subjects being washed out in the larger dataset by subjects with small or no effects.

The results for release duration and for the number of glottal pulses during closure are qualitatively similar to those for consonant closure duration: neutralization of both cues is complete, and there is no evidence for a distinction between alternating and non-alternating /d/.

In contrast to these results, van Rooy et al. (2003) found that underlying voicing distinctions in Afrikaans are associated with differences in all four cues (vowel duration, closure duration, release duration, and number of glottal pulses). However, in that study, subjects read sentences that contained minimal pairs contrasting only in the voicing of the final obstruent; in the present study, there were few minimal pairs and none were presented together. Using minimal pairs is known to increase the incompleteness of neutralization (Kharlamov, 2014) and is a likely explanation for the different outcomes of the two studies.

2.3. Conclusions

Taken together, these results support the asymmetrical hypothesis of Figure 1a: although (partially) neutralized obstruents are influenced by their contrastive counterparts elsewhere in the paradigm, contrastive forms are not influenced by their neutralized counterparts. Although this conclusion is based on a null result (namely, the fact that there is no significant difference between alternating and non-alternating /d/), it is unlikely that this null result is due to inadquate power; the study was powerful enough to detect incomplete neutralization of vowel duration.

The finding that only contrastive forms within a paradigm may influence others is compatible with at least two different interpretations. First, Albright (2002, 2010) has argued that inflectional paradigms have a unique base, and that this base is the most informative member of the paradigm. Although Albright's proposal is intended to account for high-level phonological and morphological patterns, the spirit of the hypothesis is consistent with the sub-phonemic differences observed here. Second, these results are also compatible with the classical model of morphological alternations as the result of phonological rules applied to underlying forms. On this account, incompletely neutralized forms are being faithful to an underlying form; they only appear to be attracted to contrastive forms elsewhere in the paradigm because those forms happen to be identical to the underlying form in the relevant ways.

3. Experiment 2: Vowel Reduction in Russian

3.1. Design

Although much of the published experimental literature on incomplete neutralization focuses on final devoicing (with a sizeable minority on English flapping), there are other patterns of positional neutralization where neutralization might be similarly incomplete. One such example is vowel reduction in Russian, which has been extensively studied in the formal phonological literature but for which only one previous study (Padgett & Tabain, 2005) has tested whether neutralization is complete.

Simplifying a great deal, the set of possible vowel contrasts is reduced in unstressed syllables in Russian, such that /a, o/ → [a] and /i, e/ → [i]. This stress-dependent reduction leads to a variety of morphological alternations; among nouns, for example, some forms have a lexically specified stress shift in suffixed forms, leading to reduction of the stem vowel; other forms maintain stress on the stem throughout the paradigm:

(3) Vowel reduction in Russian nouns
  a. /kot/ 'cat'
    (i) [ˈkot] 'cat.NOM.SG'
    (ii) [kaˈtom] 'cat.INST.SG'
  b. /grot/ 'grotto'
    (i) [ˈgrot] 'grotto.NOM.SG'
    (ii) [ˈgrotam] 'grotto.INST.SG'

The stimuli for Experiment 2 consisted of 46 monosyllabic Russian nouns, 23 with stress shift in suffixed forms and 23 without stress shift; each noun had one of four stem vowels (/a/, /o/, /i/, /e/). Participants were 8 native speakers of Russian living in the Salt Lake Valley, all but one of whom reported that they had not lived in a non-majority-Russian-speaking community until at least their 20s.[3] The procedure was the same as in Experiment 1, but with nominative and instrumental singular forms of each noun instead of singular and plural forms.

3.2. Results

F1 and F2 were measured at the center of each vowel in each token; formants were subsequently normalized using the NEAREY1 procedure of Adank et al. (2004). Figure 4 plots the normalized vowel space for all subjects and stimuli combined; nominative forms are shown in the top graph and instrumental forms in the bottom graph. Stimuli with a stress shift in the instrumental are plotted in gray; stimuli with stress always on the stem are plotted in black.

As in Experiment 1, there are two crucial comparisons to examine. First, to test for ordinary incomplete neutralization, we can compare instrumental forms for nouns with a stress shift with different underlying stem vowels (e.g., [kaˈtom] vs. [vraˈt͡ɕom] ← /vrat͡ɕ-om/ 'doctor'). If neutralization is incomplete, we expect the [a] of [kaˈtom] to be slightly higher or further back (or both) than the [a] of [vraˈt͡ɕom]. Second, to test the symmetrical hypothesis of Figure 1b, we can compare the nominative forms of nouns with and without a stress shift (e.g., [ˈkot] vs. [ˈgrot]). The symmetrical hypothesis predicts that the alternating [o] of [ˈkot] should be slightly lower or further forward (or both) than the non-alternating [o] of [ˈgrot].

All of the analyses below report results from mixed-effects models that predict either F1 or F2 (both normalized) from a fixed effect of either `Vowel` or `StressShift` (depending on the comparison being made); and random effects of `Subject`, `Lemma`, and `Palatal`[4].

For back vowels (/a/ and /o/), neutralization is incomplete: comparing stress-shifting stimuli with /a/ and /o/ in the instrumental (gray symbols in the bottom graph), we see that /o/ is associated with a lower F2 ($p = 0.00599$; the difference for F1 is not significant, $p = 0.985$). However, there is no evidence for the symmetrical hypothesis: alternating and non-alternating /o/ in the nominative (gray and black symbols in the top graph) are distinguished neither by F1 ($p = 0.107$) nor by F2 ($p = 0.376$).

No comparisons involving front vowels were statistically significant; neutralization in instrumental forms is complete, and there is no evidence for the symmetrical hypothesis in nominative forms.

[3] One subject reported having lived in England for 3 weeks as a teenager.

[4] The factor `Palatal` encodes whether the final consonant of the stem is palatal; see below for further discussion. Model comparison did not support an additional effect of `Consonant` nested under `Palatal` for any of the models tested.

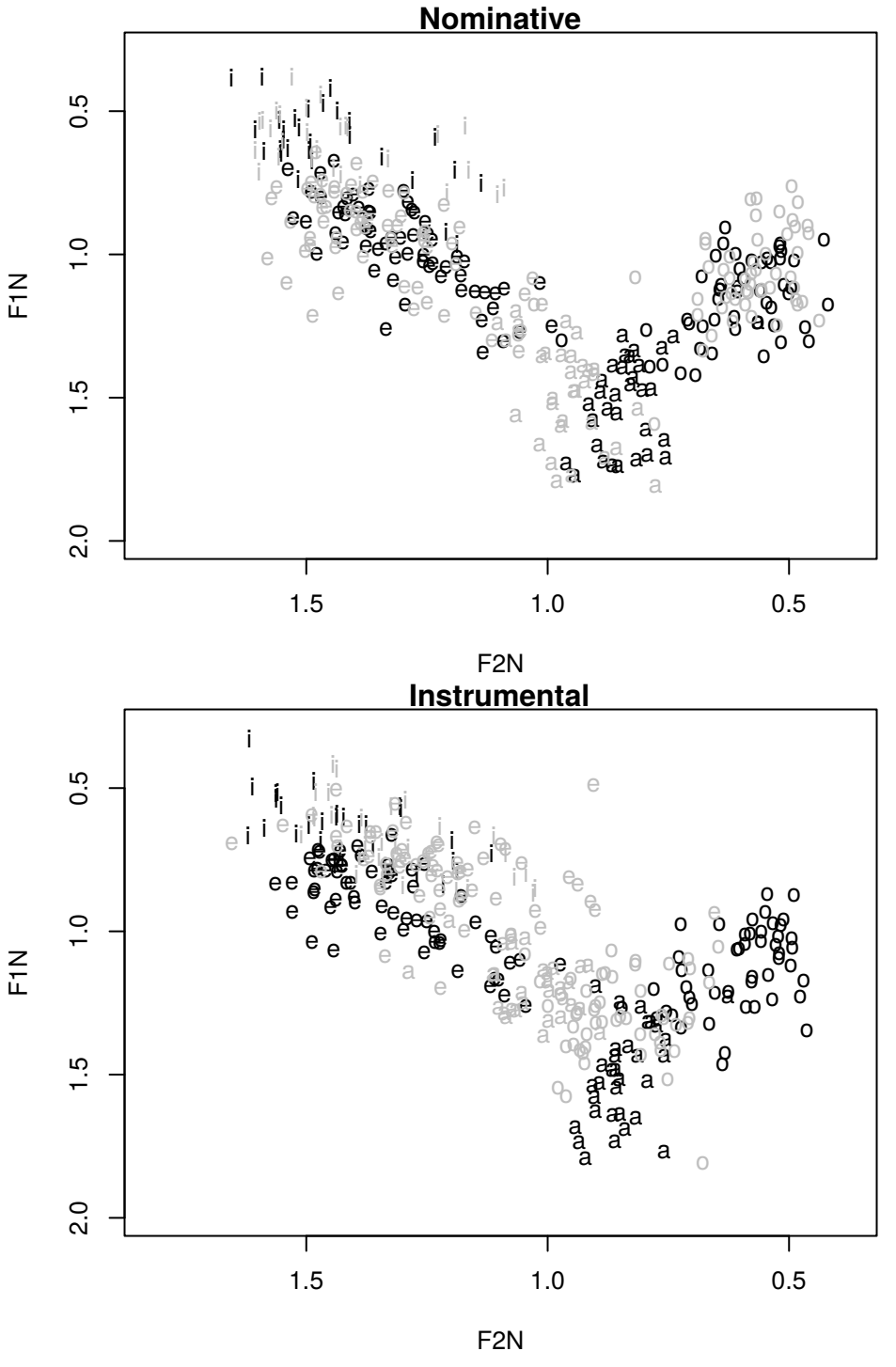


Figure 4: Stem vowels of Russian stimuli in the normalized F2 × F1 space. Black symbols plot nouns with stress on the stem; gray symbols plot nouns with stress on the suffix.

3.3. Conclusions

Experiment 2 demonstrates that neutralization of vowel distinctions in unstressed syllables in Russian is incomplete. Padgett & Tabain (2005) also found evidence of incomplete neutralization; curiously, however, that study found incomplete neutralization for /i/ ∼ /e/ only, while the present study finds incomplete neutralization for /a/ ∼ /o/ only. It is clear that further research on the phonetics of Russian vowel reduction is needed.

The finding of incomplete neutralization is complicated by a potentially serious confound: all of the stress-shifting stimuli with /a/ as the stem vowel end in a palatal consonant, while only one of the stress-shifting stimuli with /o/ does. (A confound along these lines was unavoidable in creating the stimulus list due to the lexical statistics of Russian.) It is possible, then, that the observed difference between /kot-om/ and /vrat͡ɕ-om/ is really an effect of the palatalization of the following consonant, not incomplete neutralization. Moreover, the direction of the effect is exactly what would be predicted by this alternative explanation: underlying /a/ is further forward than underlying /o/, consistent with the expected fronting effects of an adjacent palatal consonant. Note, however, that the effect of `Vowel` was significant even when `Palatal` was included as a random effect in the model, suggesting that the underlying vowel does indeed influence F2 beyond the overall effect of the palatal status of the following consonant. (When `Palatal` was included as a fixed effect, neither `Palatal` nor `Vowel` was significant, indicating the difficulty of separating the two factors.) Thus, although it is possible that the incomplete neutralization observed here is spurious, there is reason to be cautiously optimistic that the finding is genuine.

By contrast, the results of Experiment 2 offer no support for the symmetrical hypothesis of Figure 1b: there is no evidence that alternating and non-alternating /o/ (or /e/) are distinct. Nor is there evidence that such an effect could be found for a subset of subjects; model comparison did not support random slopes for `StressShift` by `Subject`. I conclude that the asymmetrical hypothesis of Figure 1a is correct: a neutralized form may be influenced by a contrastive form, but not vice versa.

4. General Discussion

Experiments 1 and 2 provide no support for the symmetrical hypothesis of Figure 1b. Although both Afrikaans and Russian show evidence of incomplete neutralization – Afrikaans by maintaining slightly longer vowels before final /d/ than before final /t/, and Russian by realizing unstressed /o/ slightly further back than unstressed /a/ – neither language showed a distinction between alternating and non-alternating segments in contrastive contexts for any of the cues examined. Taken together, these results are most consistent with the asymmetrical hypothesis of Figure 1a: a form that maintains a contrast is able to influence forms that neutralize that contrast, but not vice versa.

As noted above, this state of affairs is consistent with the classical generative model in which all the surface forms of a morphological paradigm are derived from a single underlying form (plus affixes or other morphological operations). On this account, the apparent special status of contrastive members of a paradigm is epiphenomenal: the underlying form – which is the true 'basin of attraction' for all members of the paradigm – includes all the relevant contrasts that appear across surface forms in the paradigm; surface forms that maintain contrasts only appear to be the 'target' because they are more similar to the underlying form. Alternatively, these results also appear to be quite similar, on a sub-phonemic level, to the proposal of Albright (2002, 2010) that inflectional paradigms have a single unique base, and that this base is the most informative member of the paradigm (roughly, the member that maintains the most contrasts).

The results presented here do not distinguish between these two explanations for the asymmetrical nature of incomplete neutralization, and an important direction for future work is to attempt to tease them apart. The ideal setting for distinguishing between the two accounts is an inflectional paradigm in which no single member of the paradigm exhibits every possible contrast. As it happens, the Russian nouns studied in Experiment 2 are an example of precisely this situation. For nouns with a stress shift in oblique forms, the nominative singular is the most informative member of the paradigm with respect to the quality of the stem vowel. However, Russian also has final devoicing; therefore, for obstruent-final nouns, it is the oblique forms that are informative with respect to the voicing of the final obstruent.

Further work is currently underway exploring what incomplete neutralization looks like in this system where there is no single member of the paradigm that is maximally informative with respect to all contrasts.

Appendix: Stimuli

Experiment 1: Final Devoicing in Afrikaans

Consonant	Stem-Final?	Singular	Plural	IPA	Gloss
[t]	Yes	*skeet*	*skete*	/skiət/	'flaw'
		sproet	*sproete*	/sprut/	'freckle'
		voet	*voete*	/fut/	'foot'
		hart	*harte*	/ɦɑrt/	'heart'
		fort	*forte*	/fɔrt/	'fortress'
		tent	*tente*	/tɛnt/	'tent'
		sigaret	*sigarette*	/səxɑrɛt/	'cigarette'
	No	*ete*	*etes*	/iətə/	'meal'
		boete	*boetes*	/butə/	'fine'
		roete	*roetes*	/rutə/	'route'
		halte	*haltes*	/ɦɑltə/	'stopping place'
		holte	*holtes*	/ɦɔltə/	'cavity'
		lente	*lentes*	/lɛntə/	'spring'
		operette	*operettes*	/ɔpərɛtɛ/	'operetta'
[d]	Yes	*eed*	*ede*	/iəd/	'oath'
		kleed	*klede*	/kliəd/	'garment'
		hoed	*hoede*	/ɦud/	'hat'
		saad	*sade*	/sɑːd/	'seed'
		bord	*borde*	/bɔrd/	'plate'
		tand	*tande*	/tɑnd/	'tooth'
		hond	*honde*	/ɦɔnd/	'dog'
	No	*bede*	*bedes*	/biədə/	'prayer'
		rede	*redes*	/riədə/	'reason'
		roede	*roedes*	/rudə/	'rod'
		gade	*gades*	/xɑːdə/	'spouse'
		orde	*ordes*	/ɔrdə/	'order'
		skande	*skandes*	/skɑndə/	'shame'
		sonde	*sondes*	/sɔndə/	'sin'

Experiment 2: Vowel Reduction in Russian

Backness	Vowel	Shift?	Nominative	Instrumental	IPA	Gloss
Back	[a]	No	брак	браком	/brak/	'marriage'
			крах	крахом	/krax/	'crash'
			сват	сватом	/svat/	'matchmaker'
			трап	трапом	/trap/	'ladder'
		Yes	врач	врачом	/vrat͡ɕ/	'doctor'
			грач	грачом	/grat͡ɕ/	'rook'
			плащ	плащом	/plaɕ͡ɕ/	'cloak'
			ткач	ткачом	/tkat͡ɕ/	'weaver'
	[o]	No	грот	гротом	/grot/	'grotto'
			жмот	жмотом	/ʐmot/	'miser'
			кок	коком	/kok/	'cook'

			снос	сносом	/snos/	‘demolition’
			сок	соком	/sok/	‘juice’
			срок	сроком	/srok/	‘time’
			флот	флотом	/flot/	‘fleet’
		Yes	клоп	клопом	/klop/	‘bug’
			кот	котом	/kot/	‘cat’
			крот	кротом	/krot/	‘mole’
			плот	плотом	/plot/	‘raft’
			поп	попом	/pop/	‘pope’
			скот	скотом	/skot/	‘cattle’
			хвощ	хвощом	/xvoɕɕ/	‘horsetail’
Front	[i]	No	бит	битом	/bʲit/	‘bit’
			лик	ликом	/lʲik/	‘face’
			рис	рисом	/rʲis/	‘rice’
			шик	шиком	/ʂik/	‘chic’
		Yes	бич	бичом	/bʲitɕ/	‘scourge’
			кит	китом	/kʲit/	‘whale’
			шиш	шишом	/ʂiʂ/	‘fig’
			щит	щитом	/ɕɕit/	‘shield’
	[e]	No	бес	бесом	/bʲes/	‘devil’
			блеф	блефом	/blʲef/	‘bluff’
			век	веком	/vʲek/	‘age’
			свес	свесом	/svʲes/	‘overhang’
			склеп	склепом	/sklʲep/	‘crypt’
			смех	смехом	/smʲex/	‘laughter’
			чек	чеком	/ʈʂek/	‘check’
			шеф	шефом	/ʂef/	‘chef’
		Yes	жнец	жнецом	/ʐnʲets/	‘reaper’
			жрец	жрецом	/ʐrʲets/	‘priest’
			клещ	клещом	/klʲeɕɕ/	‘tick’
			лещ	лещом	/lʲeɕɕ/	‘bream’
			лжец	лжецом	/lʐets/	‘liar’
			льстец	льстецом	/lʲstʲets/	‘flatterer’
			меч	мечом	/mʲetɕ/	‘sword’
			швец	швецом	/ʂvʲets/	‘sewer’

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