

Are Neutral Roots in Uyghur Really Neutral? Evaluating a Covert Phonemic Contrast*

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1 Introduction

Diachronic processes sometimes eliminate a surface contrast between two phonemes. In certain cases, languages that undergo such a neutralization continue to exhibit phonological alternations that appear to be sensitive to the original contrast, even though it is no longer manifested in surface forms. Compton & Drescher (2011) describe one such case, where a distinction between historical */i/ and */ə/ in Proto-Eskimo has been neutralized to surface [i] in many dialects of modern Inuit. In a subset of these dialects, however, instances of surface [i] that correspond to historical */i/ trigger palatalization of following consonants, while instances of [i] that correspond to historical */ə/ do not.

Compton & Drescher suggest that these dialects have maintained a *covert phonemic contrast* between “strong /i/” (corresponding to */i/) and “weak /i/” (corresponding to */ə/).¹ Although the two are claimed to be phonetically identical, the former is specified for the feature [CORONAL], which drives the palatalization process, while the latter is not. This is an instance of what Kiparsky (1973) called “the diacritic use of phonological features” (p. 16): an underlying featural contrast is used to condition phonological behavior, despite corresponding to no observable phonetic differences in the conditioning segments themselves.

It is unclear how well such abstract analyses characterize speakers’ mental grammars and competence (e.g., Sapir, 1933/1949; Ohala, 1974). While a covert contrast analysis accounts for the data by recapitulating the diachronic processes that led to the apparently idiosyncratic behavior of different roots, speakers do not in general have access to such information. These analyses therefore make strong claims about both cognitive representations (that speakers have localized the source of the idiosyncrasy to a distinction between two sounds that are identical on the surface) and learning (that there is some learning mechanism that leads to such a representation). Given the existence of alternative theoretical mechanisms for representing idiosyncratic phonological behavior, such as indexed constraints (e.g., Kraska-Szlenk, 1997; Fukazawa, 1999; Ito & Mester, 1999; Pater, 2010; Moore-Cantwell & Pater, 2016), we must ask when a covert contrast analysis is justified. That is, what analysis provides explanatory adequacy (Chomsky, 1965)?

This paper looks at the specific case of so-called neutral roots in Uyghur (Turkic: China), whose idiosyncratic behavior with respect to the backness harmony system has been analyzed as stemming from a covert vowel contrast. Based on considerations of the structural properties of the language and the results of an experimental study, we suggest that an analysis based on lexical exceptionality is more parsimonious than the traditional analysis, unifying the treatment of neutral roots with other cases of exceptionality in the harmony system and accounting for a relationship between the patterning of roots and their frequency. We close by discussing implications for covert contrast analyses in general.

2 Background

2.1 Backness harmony in Uyghur Like most Turkic languages, Uyghur exhibits *backness harmony*, which, broadly speaking, requires certain vowels and consonants in suffixes to agree for the feature [back] with the final vowel of the root (e.g., Lindblad, 1990; Hahn, 1991a,b; Abdulla et al., 2010). Typical examples

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¹ This is also broadly referred to as near-merger or near-neutralization.

of the harmony process are shown in (1) and (2). For a more comprehensive description, see Mayer (2021).

(1) *Front harmonizing roots*

øj-gæ /*-ɤɑ	‘home-DAT’
tyr-dæ /*-da	‘type-LOC’
munbær-dæ /*-da	‘podium-DAT’

(2) *Back harmonizing roots*

pul-ɤɑ /*-gæ	‘money-DAT’
ot-ɤɑ /*-kæ	‘fire-DAT’
ætrap-tɑ /*-tæ	‘area-LOC’

2.2 Transparent vowels The vowels /i e/ in Uyghur are *transparent* to harmony: when preceded by harmonizing vowels they allow the backness of these vowels to “pass through” them.²

(3) *Front roots with transparent vowels*

mæstʃit-tæ /*-ta	‘mosque-LOC’
y mid-lær /*-lar	‘hope-PL’
mømin-gæ /*-ɤɑ	‘believer-DAT’

(4) *Back roots with transparent vowels*

student-lɑr /*-lær	‘student-PL’
uniwersitet-tɑ /*-tæ	‘university-LOC’
ɑmil-ɤɑ /*-gæ	‘element-DAT’

2.3 Harmonizing consonants In addition to undergoing backness harmony, a subset of the dorsal consonants /k g q ɸ/ also act as weak harmony triggers. Roots with only transparent vowels take front suffixes when they contain the velar sounds /k g/, as in (5), and take back suffixes when they contain the uvular sounds /q ɸ/, as in (6).³

(5) *Roots with only front dorsals*

kishi-lær /*-lar	‘person-PL’
negiz-gæ /*-ɤɑ	‘basis-DAT’

(6) *Roots with only back dorsals*

qiz-lɑr /*-lær	‘girl-PL’
jiɸin-dɑ /*-dæ	‘meeting-LOC’

In cases where a harmonizing consonant intervenes between a suffix and a vowel that conflicts in backness, the vowel takes precedence, as shown in (7).

(7) *Harmony conflicts between a vowel and a following dorsal*

mæntiq-qæ	‘logic-DAT’
æqil-gæ	‘intelligence-DAT’
rak-lar	‘cancer-PL’
pakit-lar	‘fact-PL’

² We omit further discussion of /e/ because it occurs only in loanwords and as the output of a vowel reduction process.

³ Abdulla et al. (2010) suggest that /ɣ/ also acts as a back trigger, though its role in the harmony system is more equivocal as it does not undergo harmony.

2.4 Neutral roots Roots with no harmonizing vowels or consonants, or *neutral roots*, vary in whether they take front or back suffixes. The majority of such roots take back suffixes, as in (8), but a minority take front suffixes, as in (9).

(8) *Neutral roots that take back suffixes*

sir-lar/*-lær	‘secret-PL’
din-ɤɑ/*-gæ	‘religion-DAT’
hejt-tɑ/*-tæ	‘festival-LOC’
peʔil-lar/*-lær	‘verb-PL’
tip-qɑ/*-kæ	‘type-DAT’

(9) *Neutral roots that take front suffixes*

biz-gæ/*-ɤɑ	‘us-DAT’
bilim-gæ/*-ɤɑ	‘knowledge-DAT’
welisipit-lær/*-lar	‘bicycle-PL’

2.5 The diachronic origins of transparent vowels Scholars generally agree that Old Turkic and Chagatay (the direct ancestor of Uyghur and Uzbek) had a phonemic contrast between */i/ and */u/ in initial syllables (Lindblad, 1990; Hahn, 1991a,b; Bodrogligeti, 2001; Erdal, 2004).⁴ This contrast appears to have had a low functional load: the number of true minimal pairs was small, with most of the pairs of roots differing in this vowel contrast also containing dorsals that differed in backness (Erdal, 2004).

Thus no roots were harmonically neutral, and front and back dorsals co-occurred with front and back vowels respectively. At some point in its history, Uyghur lost the distinction between */i/ and */u/, which complicated the harmony system, introducing transparent vowels, neutral roots, and consonants as weak harmony triggers. Although roots that had */u/ continued to take back suffixes and the most frequent roots that previously had */i/ continued to take front suffixes (e.g., /biz/ ‘we’, /bir/ ‘one’, /itʃ-/ ‘drink’), many less frequent roots that contained */i/ began over time to take the default back form of suffixes (Lindblad, 1990). Uyghur appears to be typologically unusual in that the default harmony value is [+back], despite the transparent vowels being phonetically [-back]. In languages such as Mongolian and Finnish, which have similar transparent vowels, transparent roots generally behave as [-back] (Lindblad, 1990).

It is worth noting that neutral roots have exhibited some degree of variation in their suffixing behavior for a long time. Erdal (2004) notes that roots such as /tiz/ ‘knee’, which takes back suffixes in Modern Uyghur, surface with both front and back suffixes in Old Turkic.

2.6 Previous analyses of transparent vowels The analyses of Uyghur backness harmony in Lindblad (1990) and Hahn (1991a,b) essentially recapitulate the historical development of the transparent vowels. These analyses suggest that /i e/ have phonemic back counterparts /u ʌ/, which are neutralized on the surface by a post-lexical fronting process. Hahn (1991b) writes that these underlying front and back counterparts “share the same set of allophones and are orthographically represented alike” (p. 34).

A pair of serial derivations under this analysis are shown in (10).

	<i>Derivation of /stur-lAr/ ‘secret-PL’</i>	<i>Derivation of /biz-DA/ ‘us-LOC’</i>
(10)	1. Underlying form /stur-lAr/	1. Underlying form /biz-DA/
	2. Harmony <u>stur</u> -lar	2. Harmony <u>biz</u> -dæ
	3. Fronting sir-lar	3. Fronting –
	4. Surface form [sirlar]	4. Surface form [bizdæ]

Under this analysis, backness harmony in Uyghur is exclusively driven by vowels. Velars and uvulars undergo harmony when they occur in suffixes like the dative, which has the front allomorphs [-kæ]/[-gæ]⁵ and the back allomorphs [-qɑ]/[-ɤɑ], but do not serve as triggers. The apparent behavior of dorsals as harmony triggers stems from co-occurrence restrictions between the underlying [back] values of the neutral vowels and the dorsals: that is, we get back suffixes in forms like [qiz-lar] ‘girl-PL’ not because of the /q/, but because the

⁴ Though see Johanson (1998) for a critical perspective.

⁵ And [-qæ] when it occurs following a root-final uvular with a preceding front vowel.

vowel is underlying /u/. This underlying vowel quality determines both the backness of the dorsal in the root, as well as the backness of the suffix.⁶

McCollum (2021) looks for acoustic evidence of allophonic and phonemic contrasts between /i/ and /u/. He demonstrates on the basis of phonetic measurements that there are differences in the phonetic quality of transparent vowels in suffixes following front and back vowels respectively: these vowels tend to be produced further back in the presence of a preceding back vowel, and further front in the presence of a preceding front vowel, suggesting that harmony spreads locally through transparent vowels, at least at the phonetic level. Evidence for a phonemic distinction between /i/ and /u/ was less compelling: McCollum found that while several speakers displayed a correlation between the F2 of transparent vowels in roots and whether they attached back or front suffixes to the root, most speakers did not show a clear relationship between the two.

The study in McCollum (2021) investigates only six roots elicited from nine speakers: /tʃi/ ‘tooth’, /ilim/ ‘knowledge’, /jil/ ‘year’, /qij/ ‘winter’, /pil/ ‘elephant’, and /ʃilim/ ‘glue’. This paper will examine the acoustic properties of transparent vowels using a larger number of roots and speakers.

3 A priori arguments against a phonemic distinction between /i/ and /u/

Before turning to the experimental study, we present an argument against a phonemic distinction between /i/ and /u/ on the basis of phonological contrast. Although proving a phonemic contrast between segments is often complicated, one of the simplest diagnostics is minimal word pairs that differ only in the substitution of one segment for another. For example, the pair /at/ ‘horse’ and /ot/ ‘fire’ demonstrate that /a/ and /o/ are phonemically contrastive in Uyghur.

Assuming the post-lexical fronting analysis described in the previous section, we might expect there to be homophones containing only neutral vowels that differ in the backness of suffixes they take: for example, a hypothetical pair of words like /sip/ and /sup/ which surface as [sip-lær] and [sip-lar] respectively when the plural suffix is added and post-lexical fronting is applied.

Uyghur appears to have no such homophones. The closest thing to this is a small set of noun/verb pairs that are semantically related, but differ in backness. The verb forms in this example include the derivational suffix /-lA/, which derives verbs from noun roots, the gerund /-f/, and the infinitive marker /-mAQ/. The alternations between [-læ] and [-li] are caused by a vowel reduction process.

(11) Verb/noun pairs with differing harmony

/iʃ-lAr/	→ [iʃ-lar]	‘work-PL’
/iʃ-lA-mAK/	→ [iʃ-li-mæk]	‘work-VERBALIZER-INF’ (to work)
/iʃ-lA-f/	→ [iʃ-læ-f]	‘work-VERBALIZER-GER’ (working)
/tʃiʃ-lAr/	→ [tʃiʃ-lar]	‘tooth-PL’
/tʃiʃ-lA-mAK/	→ [tʃiʃ-li-mæk]	‘tooth-VERBALIZER-INF’ (to bite)
/tʃiʃ-lA-f/	→ [tʃiʃ-læ-f]	‘tooth-VERBALIZER-GER’ (biting)
/iz-lAr/	→ [iz-lar]	‘trace-PL’
/iz-lA-mAK/	→ [iz-li-mæk]	‘trace-VERBALIZER-INF’ (to search)
/iz-lA-f/	→ [iz-læ-f]	‘trace-VERBALIZER-GER’ (searching)

Comparison with related languages that have no transparent vowels, such as Turkish and Tatar, suggests that these roots may have uniformly taken front suffixes at an earlier stage before */i/ and */u/ merged in Uyghur (cf. Turkish /iʃ/ ‘work’, /tʃiʃ/ ‘tooth’, /iz/ ‘trace’ and Kazan Tatar /eʃ/ ‘work’, /teʃ/ ‘tooth’, /ez/ ‘trace’). Reconstructions of Proto-Turkic also corroborate this view (Clauson, 1972).⁷

This pattern suggests that the verb stems have become roots in their own right, maintaining their original harmonizing behavior due to the presence of a harmonizing vowel in the /-lA/ suffix. The unsuffixed noun roots, on the other hand, participated in the general shift of neutral roots to take back suffixes.

⁶ This analysis does not appear to align well with native speaker intuitions, at least in certain respects: in standard approaches to Uyghur pedagogy (as experienced by third author MY during her childhood) and descriptions of backness harmony by Uyghur linguists (e.g., Abdulla et al., 2010), dorsals are portrayed as the conditioning factor for suffix choice.

⁷ Though Erdal (2004) suggests that the root /iz/ at its earliest stages was */uʒ/, before changing to */iz/.

We can quantify the utility of a contrast between two phonemes in the phonological system of a language by considering its *functional load*. Metrics of functional load seek to quantify the informativeness of a contrast between two phonological units, with a higher functional load indicating a more informative contrast (e.g., Hockett, 1955; Kučera, 1963). Functional load has been calculated based on the number of minimal pairs over a particular contrast (e.g., Wedel et al., 2013), or by comparing the change in the entropy of a corpus after the contrast has been neutralized (e.g., Surendran & Niyogi, 2006). Assuming that entropy is calculated at the word level, both methods will produce a functional load of 0 for the /i/-/u/ contrast: there are no minimal pairs between these vowels, and thus neutralizing the contrast between them does not lead to an increase in entropy.

It is not always the case that a phonemic contrast will have a non-zero functional load: the contrast between English /ɪ/ and /h/ similarly has a functional load of 0 (e.g., Surendran & Niyogi, 2006; Lin, 2019), as does the contrast between /ɪ/ and /ɜ/ (e.g., Surendran & Niyogi, 2006), but these are still generally considered to be separate phonemes. Note, however, that there are complicating factors at play in these cases. First, /h/ and /ɪ/ have non-overlapping distributions in English, with the former occurring only in syllable onsets and the latter only in syllable codas, making minimal pairs unlikely. Second, some degree of phonetic similarity is usually assumed to be a prerequisite of an allophonic alternation (e.g., Peperkamp et al., 2006). The pairs above have little in common from this perspective. Third, overall phoneme frequency has been shown to correlate with minimal pair counts (Wedel et al., 2013): the English phoneme /ɜ/, in addition to having a relatively restricted distribution, also has relatively low frequency, and thus a small number of minimal pairs and an accordingly low average functional load (e.g., Surendran & Niyogi, 2006; Lin, 2019).

The purported contrast in Uyghur does not have any of these confounds: the licit environments for /i/ and /u/ are identical (at least in the neutral roots considered here); they are phonetically similar (indeed, identical on the surface according to past analyses), and quite frequent (approximately 50% of roots in the corpora in Mayer (2021) contain [i]). Although to our knowledge there has been no proposed metric of expected minimal pairs and/or functional load given a phonemic contrast, the complete lack of minimal pairs would be surprising in this case.⁸

4 Acoustic properties of neutral roots: An experimental study

Although the previous section provided synchronic structural evidence against a covert contrast analysis of neutral roots in Uyghur, this does not rule it out as a possibility. Indeed, an analysis positing a covert contrast between /i/ and /u/ is descriptively sufficient, in that it allows us to capture the patterning of backness in suffixes attached to neutral roots in a principled way. The question that this section will address is whether empirical evidence can be furnished to support a covert contrast analysis.

A source of empirical evidence for evaluating between these hypotheses might be found in the phonetic details of these vowels. Benus & Gafos (2007), for example, claimed that neutral roots in Hungarian, which has a similar set of transparent vowels to Uyghur, have systematic and significant differences in tongue position that correlate with their preferred suffix backness: that is, the transparent vowels in harmonically neutral roots that take back suffixes are produced somewhat backer than those same vowels in neutral roots that take front suffixes, even in unsuffixed contexts where this difference cannot be accounted for by vowel-to-vowel coarticulation (though for a critical discussion of these results see Blaho & Szeredi, 2013).

Subtle differences such as this might, in principle, stem from two different sources. One is that they reflect incomplete neutralization of a covert contrast, in line with the proposals like Lindblad (1990) and Hahn (1991b). Sub-phonemic distinctions have been shown to emerge following the collapse of two phonemically-distinct segments due to sound change (e.g., Yu, 2007) or allophonic neutralization (e.g., Port & O'Dell, 1985). Such differences would serve as both a subtle phonetic correlate of an underlying distinction between /i/ and /u/ in Uyghur, and a possible source of information that would guide learners towards a grammar containing this distinction.

The second possibility is that these systematic differences do not reflect a covert phonemic contrast, but rather are the consequence of coarticulation in suffixed forms being generalized to unsuffixed forms under an exemplar-based model of lexical storage (e.g., Pierrehumbert, 2001). Under such models, speakers build an 'exemplar cloud' of root tokens they have perceived, and set their acoustic production targets based

⁸ Note, as mentioned earlier, that even in the ancestor languages of Uyghur where a phonetic distinction between /i/ and /u/ was thought to apply, this contrast had a low functional load, perhaps accounting for its eventual disappearance.

on the aggregate acoustic properties of these tokens. Because neutral roots are frequently produced with harmonizing suffixes, and these suffixes can induce front/back coarticulation on root vowels (e.g., Öhman, 1966), the exemplar clouds of neutral roots that take back suffixes will, overall, contain backer vowels than the clouds of neutral roots that take front vowels, resulting in backer productions even in unsuffixed contexts (Benus & Gafos, 2007).⁹

Thus although the presence of an acoustic distinction between vowels in Uyghur neutral roots that take front suffixes and those that take back suffixes does not provide conclusive evidence for a phonological grammar that contains a covert contrast between /i/ and /ɯ/, its existence would provide a phonetic basis for localizing the harmonic behavior of neutral roots to their constituent vowels. The experiment in this section is designed to look for subtle acoustic variance in neutral roots based on their harmonizing behavior.¹⁰

4.1 Factoring out coarticulation A challenge in looking for small phonetic differences of this kind is controlling for coarticulation. As described in the previous section, the backness of vowels in neutral roots with harmonizing suffixes attached (e.g., tokens like [sir-lar] ‘secret-PL’ or [welisipet-lær] ‘bicycle-PL’) or in roots with a mix of harmonizing and neutral vowels (e.g., [taksi] ‘taxi’, [mæstʃit] ‘mosque’) may be influenced by those harmonizing vowels. This kind of coarticulatory influence does not amount to a phonemic contrast (though it may lead to the development of one; see, e.g., Hyman, 1976; Ohala, 1981). The tendency of neighboring vowels to exert a phonetic influence on one another is strong, particularly if doing so does not eliminate a phonemic contrast (e.g., Öhman, 1966; Alfonso & Baer, 1982; Choi & Keating, 1990; Benus & Gafos, 2007; Cole et al., 2010). Uvulars are also known to exert a backing effect on vowels (e.g., Alwan, 1986; Bessell, 1992; Sylak-Glassman, 2014; Gallagher, 2016; Evans et al., 2016).

Thus to demonstrate an inherent difference in the phonetic realization of underlying /i/ and /ɯ/, rather than one conditioned by neighboring sounds, evidence must come from *unsuffixed* forms of neutral roots. The experiment below focuses on the phonetic properties of such roots and how these properties correlate with suffix choice, though we also investigate coarticulation in the presence of harmonizing suffixes.

4.2 Methodology The 29 target roots used in this study are shown in Table 1. These roots were selected because they contain no harmonizing elements and are relatively common.

Word	Definition	Expected Harmony	Word	Definition	Expected Harmony
/bir/	‘one’	F	/pil/	‘elephant’	B
/biz/	‘we’	F	/pir/	‘master’	B
/tʃij/	‘tooth’	B	/rim/	‘Rome’	B
/dil/	‘soul’	B	/sinip/	‘classroom’	B
/din/	‘religion’	B	/sirt/	‘outside’	B
/filim/	‘film’	F/B	/sijir/	‘milk-cow’	B
/itʃ/	‘inside’	F	/siz/	‘you (formal)’	F
/ili/	‘Ili (place name)’	B	/til/	‘tongue’	B
/ilim/	‘knowledge’	F	/tilsim/	‘magic’	B
/ij/	‘work’	B	/tip/	‘type’	B
/it/	‘dog’	B	/tiz/	‘knee’	B
/dʒin/	‘jinn’	B	/jil/	‘year’	B
/lim/	‘joist’	B	/jip/	‘thread’	B
/miŋ/	‘thousand’	B	/zil/	‘bell’	F
/mis/	‘copper’	F/B			

Table 1: Neutral roots used in the study. The ‘Expected Harmony’ column indicates the predicted harmonic value given frequencies from two large newspaper corpora described in Mayer (2021).

The target words were elicited in both unsuffixed and suffixed forms in the following carrier phrase:

- (12) *Mahinur* _____ *deydu*
 “Mahinur will say _____”

⁹ See also Braver (2019) for an approach that provides similar insights without assuming an exemplar-based framework.

¹⁰ The acoustic measurements and code for the figures and statistical analysis can be found at https://github.com/connormayer/uyghur_neutral_vowels.

An accompanying phrase ‘*orun kélish*’ in parentheses immediately following the target word indicated when it should be produced with the locative suffix /-DA/. Stimuli were presented in one of two random orders. Unaffixed and affixed forms of the same word did not occur adjacent to one another in either order, but whether the affixed form came before or after the unaffixed form in the stimuli list was not controlled.

Data were collected from 23 native speakers of Uyghur living in Almaty, Kazakhstan (18F, 5M, ages 19–62). The stimuli were presented in Cyrillic orthography. Recordings of participants’ responses were made using a Zoom H4n Pro Handy Recorder.¹¹

4.3 Analysis Vowels in both unaffixed and affixed target words were segmented by hand in Praat. In bisyllabic words, measurements were taken from the second vowel. An automated script was used to extract F2 at vowel midpoints. F2 is the most likely measure to reflect a covert contrast between /i/ and /u/, since it is an acoustic correlate of tongue backness. Uyghur has an optional, but pervasive, process of vowel devoicing that occurs before voiceless sounds in coda positions. 116 tokens (39 unaffixed tokens and 77 affixed tokens) where devoicing prevented accurate formant measurements were omitted, resulting in a total of 628 unaffixed tokens and 590 affixed tokens. Roots were coded for whether the speaker attached a front or back suffix in the affixed form.

Statistical analysis was performed in R (R Core Team, 2017) using the `lme4` library (Bates et al., 2015). Significance values were calculated using the `lmerTest` library (Kuznetsova et al., 2017). A linear mixed-effects model was fit to the data with F2 as the dependent variable. The independent variables were suffix backness, speaker gender, and the place of articulation of the consonants preceding and following the final vowel, which have been suggested to be a conditioning factor in /i/ allophony (Hahn, 1991b). The coding for place of articulation is shown in Table 2. A value of ‘n/a’ was used in these fields if vowels occurred word-initially or word-finally. Random intercepts were used for each root and speaker. Because of these intercepts, F2 measures were not normalized within speakers.

Place	Consonants
Labial	p, b, m
Coronal	t, d, s, z, n, r
Palatal	tʃ, ɟʒ, j
Velar	ŋ
Lateral	l

Table 2: Place of articulation assigned to consonants in the statistical models.

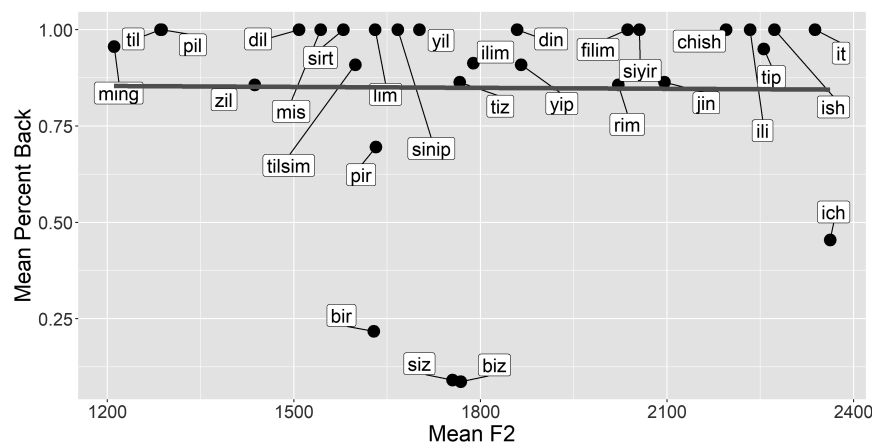


Figure 1: Mean F2 of root-final tokens of /i/ plotted against the proportion of speakers who affixed back forms of suffixes to the root. The line is a simple regression line.

¹¹ Note that these recordings were made in person; the Zoom H4n Pro Handy Recorder has no relationship to the popular video conferencing platform.

4.4 Unaffixed root results The relationship between the F2 of the final root vowel and the proportion of back responses is shown in Fig. 1. There was, unsurprisingly, a significant effect of participant gender on F2: male speakers had lower F2 values than female speakers ($\beta = -332.45$, $SE = 72.41$, $t = -4.591$, $p < 0.001$). There was no significant effect of suffix choice on the F2 of the final vowel in unaffixed forms: vowels in neutral roots that took back suffixes were slightly backer than those that took front suffixes, but this difference was not significant ($\beta = -2.057$, $SE = 46.05$, $t = -0.045$, $p = 0.96$).

Both preceding and following consonant place of articulation had a significant effect on F2. These results are shown graphically in Fig. 2, and the fixed effects relating to consonant place are shown in Table 3. Relative to coronals, a preceding palatal consonant resulted in a significantly higher F2, while a following velar or lateral resulted in a significantly lower F2. In addition, word-initial and word-final tokens of /i/ were both produced with a higher F2. These results are roughly consistent with the impressionistic description of /i/-allophony in Hahn (1991b).

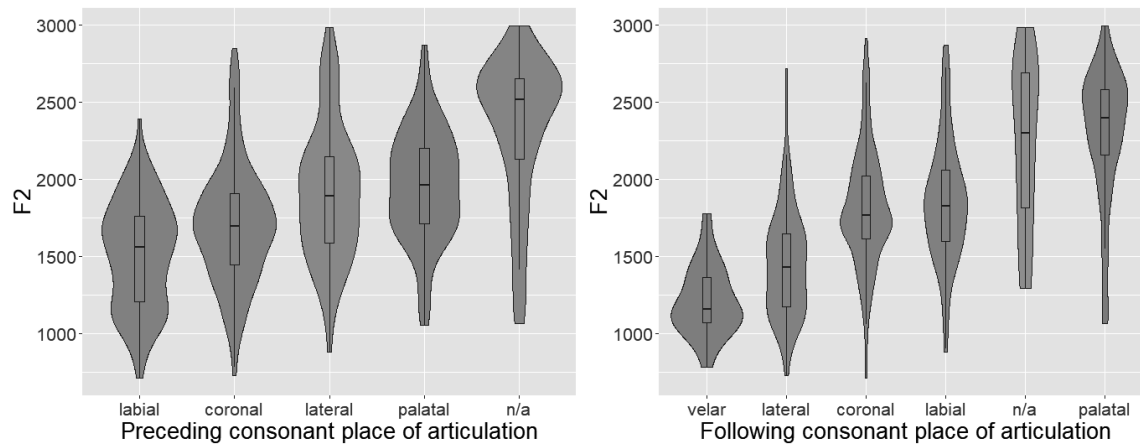


Figure 2: F2 values from final tokens of [i] in neutral roots plotted according to place of articulation of the preceding (left) and following (right) consonant. Boxes indicate the median and upper and lower quartiles.

	Place	Estimate	Std. Error	<i>t</i>	<i>p</i>
Intercept	Coronal	1854.99	85.37	21.73	< 0.001
Preceding	Labial	-137.91	98.39	-1.402	0.17
	Lateral	-11.55	123.31	-0.094	0.93
	Palatal	248.26	95.77	2.592	< 0.05
	n/a	485.87	148.55	3.271	< 0.01
Following	Velar	-431.83	184.19	-2.344	< 0.05
	Lateral	-358.40	93.58	-3.83	< 0.01
	Labial	49.30	99.13	0.497	0.63
	Palatal	87.98	142.53	0.617	0.54
	n/a	472.29	217.50	2.171	< 0.05

Table 3: Fixed effects for preceding and following consonant place in unaffixed root tokens.

4.5 Suffixed root results We also investigated the acoustic properties of the final vowel in suffixed tokens of neutral roots to understand the degree of coarticulation between suffix vowels and the final vowel in the root. A similar model was fit to the data from suffixed forms, with participant gender, suffix backness, and place of articulation of the consonants preceding and following the final root vowel as the independent variables, F2 of the final root vowel as the dependent variable, and random intercepts for both speaker and word. The effects of gender and place of articulation of the preceding and following consonants were similar to those for the unaffixed forms. There was no main effect of suffix backness: final vowels in roots with front suffixes affixed had slightly lower F2, but this result was not significant ($\beta = -15.01$, $SE = 50.26$, $t = -0.299$, $p = 0.77$). These results are shown in Fig. 3.

The results of this experimental study suggest that the tendency for a root to take front or back suffixes

does not correlate with the phonetic backness of its final vowel. This mirrors the results for Hungarian found in Blaho & Szeredi (2013), and also corroborates the results for Uyghur in McCollum (2021). As well, the presence of a harmonizing suffix does not exert a significant coarticulatory effect on the realization of root-final neutral vowels, suggesting that acoustic evidence from suffixed forms may not be sufficient to support a covert contrast analysis.

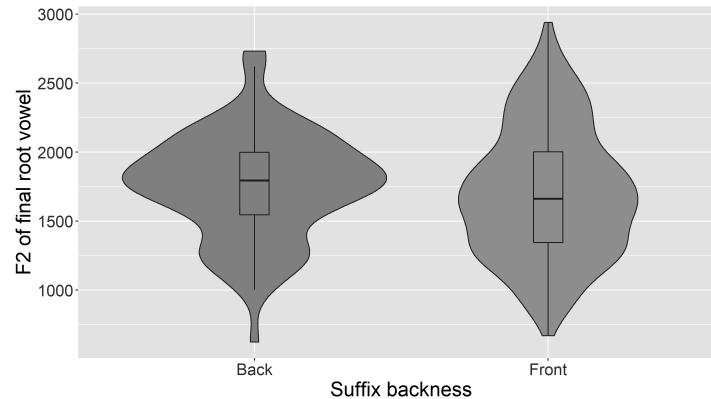


Figure 3: F2 values measured from final tokens of /i/ in neutral roots with front and back suffixes attached.

It is possible that, as claimed by Benus & Gafos (2007) for Hungarian, a covert contrast between /i/ and /u/ is indistinguishable acoustically but present articulatorily. This discrepancy between tongue position and acoustic output can occur in so-called *quantal regions*, where differences in tongue position result in comparatively small differences in acoustic output (Stevens, 1972, 1989). It is impossible to rule out the possibility of such differences based on an acoustic study alone, though the wide range of variation in F2 conditioned by surrounding consonants suggests that this is not a case of quantity masking acoustic variation. Further, McCollum (2021) identifies significant differences in F2 between neutral vowels in harmonizing suffixes that are preceded by front vowels and those preceded by back vowels. These differences would be unexpected under a quantal account of the lack of variation in root vowels.

5 An analysis using lexical diacritics

So far we have presented an argument against a covert contrast analysis of neutral roots in Uyghur based on a lack of phonological contrast and experimental results that fail to find an acoustic difference between vowels in roots that take front suffixes and roots that take back suffixes. In this final section, we present an alternative analysis that treats front harmonizing neutral roots as *lexical exceptions* to the general tendency for such roots to take back suffixes. This analysis is not only compatible with the observations presented so far, but also situates neutral roots more cohesively into the harmony system overall and accounts for the diachronic tendency for only the most frequent roots to have continued to take front suffixes.

Diacritics that determine the idiosyncratic behavior of specific roots are commonly employed in phonological analyses to account for morphological behavior that is not predictable from phonological properties, and for representing exceptions to general phonological patterns (e.g., Kraska-Szlenk, 1997; Fukazawa, 1999; Ito & Mester, 1999; Pater, 2010; Moore-Cantwell & Pater, 2016). Such an analysis applied here suggests that speakers assign neutral roots to one of two morphological classes based on the backness of suffixes they take: a default class of those that take back suffixes, which contains the majority of these roots, and an exceptional class of those that take front suffixes. We can capture the behavior of these two classes using the following constraints:

(13) *FRONTSUFFIX: Assess one violation for each front suffix.

(14) HARMONIZEFRONT_{*i*}: Assess one violation if a root bearing the index *i* takes a back suffix.

The *FRONTSUFFIX constraint enforces a general bias towards back suffixes,¹² while the HARMONIZEFRONT_{*i*}

¹² See Mayer (2021) for discussion of how this bias integrates with the harmony system as a whole.

constraint allows exceptions to this tendency for roots indexed with *i*. A simple pair of tableaux illustrating the application of these constraints are shown in Tables 4 and 5.

/sir-DA/	HARMONIZEFRONT _{<i>i</i>}	*FRONTSUFFIX
☞ a. sir-da		
b. sir-dæ		*!

Table 4: Tableau for /sir-DA/ ‘secret-LOC’. The root /sir/ lacks the index *i*, and so fails to violate the indexed HARMONIZEFRONT constraint in its back-suffixed candidate.

/biz _{<i>i</i>} -DA/	HARMONIZEFRONT _{<i>i</i>}	*FRONTSUFFIX
a. biz-da	*!	
☞ b. biz-dæ		*

Table 5: Tableau for /biz-DA/ ‘us-LOC’. The root /biz/ is indexed to the HARMONIZEFRONT constraint, and so violates it in its back-suffixed candidate.

Although the tableaux above suggest that neutral roots should categorically take front or back suffixes, it is straightforward to predict different proportions of front suffix tokens for different roots using a weighted stochastic variant of Optimality Theory, such as Maximum Entropy OT (Goldwater & Johnson, 2003), and varying the weights of instances of HARMONIZEFRONT that are indexed to specific roots.

There is independent evidence that constraints governing exceptional behavior are necessary for a complete analysis of the Uyghur harmony system. Note that these exceptions are frequently loanwords. As well, many of the cases here do not categorically violate the phonological generalizations presented earlier, but show much greater variability in suffix choice than is typical for roots with similar structures.

First, although roots with no harmonizing vowels and a velar consonant typically take front suffixes, as in (5), a number of show a greater propensity for back suffixes, representing exceptions to this general pattern.

(15) *Exceptional front dorsal roots that can take back suffixes*

ingliz- lar /*-lær	‘English person-PL’
etnik- lar /*-lær	‘ethnic group-PL’
rentigen- ƙa /*-gæ	‘x.ray-DAT’
gips- qa /*-kæ	‘plaster-DAT’

Second, while roots that contain a harmonizing vowel followed by a conflicting harmonizing dorsal typically take suffixes that agree with the vowel, as in (7), a small class of roots containing uvular consonants violates this generalization.

(16) *Exceptional roots with conflicting front vowels and uvulars where the uvular takes precedence*

tæstiq- qa /*-kæ	‘approval-DAT’
tæʃwiq- lar /*-lær	‘publicity-PL’
tætqiq- lar /*-lær	‘research-PL’

Third, a small number of forms optionally violate harmony with the final harmonizing vowel.

(17) *Optional harmony exceptions*

sowet-lær/-lar	‘Soviet-PL’
dejiz sahil-i-gæ/-ƙa	‘ocean shore-3.POS-DAT’ (cf. [sahil-ƙa] ‘shore’)

Finally, Mayer (2021: Ch. 3) investigates an opaque interaction between backness harmony and an independent process of vowel reduction that reduces the harmonizing vowels /æ a/ to the transparent vowel [i] in certain contexts. A corpus study reveals that rates of opaque harmony are positively correlated with root frequency, a relationship that is not predicted by theories that analyze opacity as an ordering relationship between two phonological processes. Because frequency is known to be an important driver of phonological

exceptionality (Bybee, 1985; Morgan & Levy, 2016; Moore-Cantwell, 2018), Mayer (2021) argues that this opaque behavior is best analyzed as a parallel interaction between general phonological constraints that mandate surface harmony and lexically-indexed constraints that specify the harmonic class of a root. Neutral roots show a similar connection between root frequency and exceptional behavior, in that less frequent roots that used to take front suffixes have over time come to take the default back forms.

These cases suggest that lexical exceptionality is necessary to handle a number of corners of the harmony system where harmonizing behavior does not align with phonological generalizations. In addition to unifying the treatment of neutral roots with these other areas of exceptionality, explicit learning procedures for phonological exceptions exist in the literature (e.g., Moore-Cantwell, 2018), while the process for learning a covert contrast is less well-defined.

6 Conclusion

In this paper, we have argued that an analysis of neutral roots in Uyghur using lexically-indexed constraints that drive exceptional harmonizing behavior of a small subset of these roots is preferable to one that assumes a covert phonemic contrast. A covert contrast analysis requires that learners intuit the existence of a phonemic category that has no clear phonetic correlates and no contrastive role, while an analysis using lexically-indexed constraints requires only that they learn the idiosyncratic harmonizing behavior of certain roots. In addition, this analysis unifies the treatment of harmonizing roots with other areas of exceptionality in the backness harmony system, and better accounts for the observation that frequent roots have been the most likely to maintain their exceptional harmonic behavior over time.

More generally, multiple phonological analyses can often account for the same surface patterns in the data. Although covert contrast analyses often fit data well because they recapitulate the diachronic processes that led to the current system, we cannot assume that speakers' synchronic grammars develop along the same path. We can only determine which models best align with human cognition by bringing additional data to bear on their evaluation, and by taking seriously the problem of learnability. This paper represents a modest attempt to apply these principles.

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