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ARTICLE

Variation in articulatory conflict resolution: Vowel allophony and consonant place adaptation in Chanka Quechua

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Abstract

Cross-linguistically, vowel lowering/retraction are common strategies for resolving articulatory conflicts between high vowels and back consonants. Allophonic lowering of vowels /i/ and /u/ adjacent to uvulars has also been documented for several Southern Quechua dialects. For the Chanka dialect (Andahuaylas, Peru), traditional descriptions note similar allophony, but no studies have confirmed it. Unlike other Southern Quechua dialects, Chanka has only two dorsals, which contrast for both manner and place. Thus, Chanka may apply resolution processes differently, for reasons of production and/or perception.

The current investigation considers to what extent articulatory conflict resolution between high vowels and the uvular consonant occurs in Chanka. Acoustic data from a controlled experiment include 3,827 Chanka vowels from 22 speakers, balanced for sex and location of residence. Despite an overall uvular effect found, intra- and interspeaker variation shows three different allophony patterns: categorical, null, and variable. A sex-based difference in patterns is also found for rural speakers, which hints at influence from Spanish on this process in Quechua given differing Spanish proficiencies. Results seem to indicate that consonant place adaptation may exist as an additional, innovative Chanka strategy, also with three variable patterns: stable uvular, stable velar, and homorganic with vowel. This flexibility in vowel and consonant place may partially relate to Chanka's small phoneme inventory, which allows for a broader range of realizations without creating mergers. Speakers thus alternate between vowel lowering and consonant movement as solutions: sometimes the vowel place accommodates to the fricative like in many languages, and at other times the fricative follows the vowel.

Keywords: Chanka Quechua; fricative assimilation; articulatory conflict resolution; acoustic production; vowel allophony

1. Introduction

Articulatory conflicts exist in all spoken languages, and the conflict between high vowels and post-velar consonants is common. In these conflicts, adjacent phonemes have opposing tongue target positions and thus, production difficulties are expected. Numerous cross-linguistic strategies to resolve these conflicts have been documented (Gick & Wilson 2006). One strategy involves vowel allophony – adapting the vowel articulation by lowering, retraction, or both – such as producing [teqe] instead of /tiqi/ 'tie' in Quechua. This process has been described for Southern Quechua in several grammars, including for Chanka, the dialect of study in this paper (Parker 1969; Cerrón-Palomino 1987).[1] However, only a few studies have confirmed it acoustically, and only in some dialects (e.g., Molina-Vital 2011 for Cuzco-Collao; Holliday & Martin 2018 for Cochabamba). To this point, no studies have examined this phenomenon in Chanka Quechua. Chanka is a Southern Peruvian dialect with a unique phonology, particularly in terms of its dorsal consonant characteristics and contrasts. Even if the descriptions were accurate when written in the 1960s and 70s, the language may have changed in the decades since, especially given its increased and sustained contact with Spanish.

This paper reports on an acoustic production experiment that investigates uvular-high vowel articulatory conflict resolution in Chanka Quechua, as spoken in Andahuaylas, Peru. The goal of this experiment was twofold: (1) acoustically document the widely accepted but understudied phenomenon of Quechua vowel allophony and (2) situate the phenomenon more broadly among documented instances of cross-linguistic articulatory conflict resolution, particularly in the realm of postvelar-consonant/high-vowel conflicts. In this sense, a possible additional resolution strategy of consonant place adaptation was identified and could be further investigated in future research.

The nature of Chanka's dorsal consonant phonology provides an opportunity to evaluate each of these aspects. First, like other Southern Quechua dialects, Chanka has a uvular-velar consonant phoneme contrast. However, the Chanka uvular is described as a fricative /χ/, rather than the stop /q/ found in other dialects. Furthermore, the Chanka dorsal contrast differs from that of other dialects both in number and in type: there are only two dorsal phonemes, /k/ and /χ/, unique in both place and manner (velar stop vs. uvular fricative). In fact, this single contrast is unique even for most other languages with dorsals. Other languages that have a uvular fricative /χ/ in their inventory like Arabic, Semitic languages, Nuu-chah-nulth (formerly Nootka), and Chilcotin generally also have at least a uvular stop /q/, if not additional uvular and/or pharyngeal consonants.

In this experiment, we find two variable strategies for resolving the conflict between the uvular fricative and high vowels in Chanka: vowel allophony and consonant place accommodation. The latter emerged as an innovative strategy not previously documented for Southern Quechua. Each strategy manifests variability with three patterns. For vowel allophony, patterns include: (i) categorical, in which mid vowels are produced adjacent to a uvular consonant like in [teχe] 'tie' while high vowels are produced near a velar as in [piki] 'flea'; (ii) null, in which higher vowels[2] are produced in all contexts, both in [tiχi] 'tie' and in [piki] 'flea'; and (iii) variable, in which high and mid vowels can be produced in all contexts, such that [tiχi] ~ [teχe] 'tie' and [piki] ~ [peke] 'flea' vary. For consonant place accommodation, hypothesized patterns include: (i) stable uvular, in which the fricative seems to be mostly realized with a uvular place like in [teχe] ~ [tiχi] 'tie'; (ii) stable velar, in which the fricative usually seems to have a velar place like in [texe] ~ [tixi] 'tie'; and (iii) homorganic, in which the fricative seems to adapt to the vowel place, potentially creating [teχe] 'tie' and [tixi] 'tie'. These resolution strategies combine in complementary ways for production and

[1] The Chanka Quechua dialect is spoken in Ayacucho, Huancavelica, and western Apurímac, areas geographically adjacent to Cuzco, Peru. Related to Cuzco and Cochabamba Quechua, the Chanka variety is classified as a branch of Quechua IIC (Torero 1964; Adelaar with Muysken 2004: 193) or Southern Quechua (Mannheim 1991: 113).

[2] This paper uses the /i/ phoneme to represent a high, fronted vowel articulation, and /u/ to represent a high, backed articulation. Certainly, some authors have argued for a more lax or mid-high articulation of /i/ adjacent to a uvular. The precise F1 and F2 measurements listed later in this paper should be used as more exact representations of vowel quality.

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perception reasons. The discussion in this paper relates the variability in strategies to the lower number and more distinctive nature of Chanka dorsal contrasts, as well as possible influence from language contact with Spanish.

This paper is divided into five main sections, followed by a conclusion. The remainder of the introduction details documented examples of resolution strategies for the uvular-high vowel conflicts in several languages (§1.1), then describes relevant Southern Quechua and Chanka phonology (§1.2 and §1.3). Section 2 specifies the research questions and hypotheses. Section 3 describes the methodologies for research design (§3.1 and §3.2), data collection (§3.3), and phonetic and statistical analysis (§3.4 and subsections). Section 4 presents the results, with vowel allophony in Section 4.1 and subsections, and consonant place in Section 4.2 and subsections. Section 5 displays how the two strategies are combined in the data (§5.1), then offers linguistic (§5.2) and social (§5.3) explanations for the results.

1.1 Cross-linguistic articulatory conflict resolution strategies

Vowel lowering, laxing, and/or retraction are widely documented strategies for resolving articulatory conflicts between high vowels and retracted consonants in many languages. In categorical vowel allophony, the lowering/retraction accommodation occurs throughout the vowel duration. For example, in English dialects with retracted liquids like Pittsburgh and Utah, the /i/ in *feel* /fil/ laxes to [ɪ], such that /fil/ becomes [fɪl]. Similarly, in Korean, /pʰil/ is pronounced [pʰɪl] (Gick & Wilson 2006). In Ayt Seghrouchen Tamazight Berber, /iχf/ 'head' is pronounced [ɪχf], with a laxed vowel, while /ilf/ 'elephant' is [ilf] (Rose 1996: 86).

Alternatively, other languages utilize a type of gradient lowering instead of categorical allophony. In a gradient transition, the high vowel is maintained throughout most of the duration around the midpoint, but a predictable, defined transition appears between the vowel and the consonant, often in the form of an excrescent schwa. This schwa is ultimately the result of the tongue temporarily passing through an intermediate position between opposing tongue root targets. Beijing Chinese applies the excrescent schwa strategy for the transition from a high vowel to the postvocalic *–r* (pharyngeal retroflex) diminutive suffix, such that /pi-ɻ/ 'skin-DIM' becomes [piᵊɻ]. Many dialects of English (besides Pittsburgh and Utah) employ this strategy for the conflict between a high front vowel and dark liquid, such that *feel* /fil/ becomes [fiᵊl], with two distinct vowel articulations (Gick & Wilson 2006). This strategy maintains vowel and consonant targets at the midpoint, with the transition easing the conflict with the consonant.

These accommodation processes are systematic and motivated by dialect-specific phonological rules, rather than utilized solely to increase ease of production. Thus, languages differ in their resolution strategies – whether lowering/retraction occurs before or after the retracted consonant (or both), and whether is categorical or gradient (the entire vowel duration or only the vowel portion adjacent to the consonant). The language-specific nature of these processes is reflected in two western North American languages, which have identical articulatory conflicts between uvular stops and vowels but apply inverse strategies for their resolution. Specifically, Nuu-chah-nulth (formerly Nootka) and Chilcotin use the excrescent schwa transition and vowel allophony strategies in opposite ways (Gick & Wilson 2006). Nuu-chah-nulth inserts an excrescent schwa when the vowel occurs before the uvular consonant and lowers vowels that occur after it – such that /siqiːɬ/ 'to cook' becomes [sɪᵊqeːɬ] rather than ∗[seqᵊiːɬ]. However, Chilcotin lowers vowels before the consonant and inserts schwa after it, such that /niqin/ 'we paddled' becomes [neqᵊin] rather than ∗[niᵊqen]. Thus, the strategies are language- and dialect-dependent.

Arabic offers additional evidence of the dialect-specific nature of vowel allophony. In Baghdadi Gilit Arabic (Bedouin origin), /i/, /u/, and /a/ exhibit retraction and rounding (significantly lower onset F2) adjacent to uvulars and pharyngeals. However, in Muslawi

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Qeltu (sedentary origin), an /a/ next to a uvular exhibits even greater lowering (significantly higher onset F1). A /u/ is fronted, such that the pronunciation of /buqa/ 'he stayed' is [bˤʊqɑ] in Baghdadi Gilit and [bʌqa] in Muslawi Qeltu (Jasim 2020: 72). More drastic high vowel lowering (past mid vowels) near post-velars is also widely attested in other Arabic dialects and other Semitic languages.[3] In these languages, high vowels can lower all the way to [a]. For instance, in Tiberian Hebrew, schwas usually lower following gutturals, and all vowel phonemes tend to lower preceding tautosyllabic root-final gutturals (McCarthy 1994: 208). In Modern Hebrew, a prefix surfaces as /la-/ next to uvulars and other gutturals, like in [la-χʃob] 'think', and /li-/ elsewhere, like in [li-xtov] 'write' (Rose 1996 : 100, citing data from Sandler 1994).

Furthermore, the vowel strategies vary depending on the uvular mode of articulation in various languages. While Nuu-chah-nulth requires excrescent schwa insertion before a uvular stop, this transition is not required preceding a uvular fricative (Wilson 2007). Similarly, around one-fifth of Arabic verbs with gutturals do not require lowering (though half of them allow it as a variant pronunciation). The guttural lowering effect can also be outweighed by the raising effect of adjacent /w/ or /j/. Lowering also occurs less frequently near uvulars than near gutturals in Arabic (McCarthy 1994). The lack of lowering near Arabic uvulars, compared to other consonants, indicates that lowering could be variable for the Chanka uvular. Since Chanka's uvular is also a fricative, lack of vowel allophony in this context would also be analogous to lack of schwa insertion in Nuu-chah-nulth.

In addition to vowel lowering strategies, consonant place accommodation to the vowel occurs in many languages, though it has yet to be documented for Quechua. In this type of process, often palatalization, a consonant segment (generally labial, dental, or velar) adopts a palatal articulation to become homorganic to an adjacent front vowel, palatal semivowel, or palatalized consonant (Bhat 1978). In cases of primary (Keating 1993: 6) or full palatalization (Bateman 2007), the consonant place changes completely, either by tongue-fronting, tongue-raising, spirantization, or a combination of these (Bhat 1978). It commonly occurs for dorsals and coronals (Bateman 2007). For example, in Korean, /s/ palatalizes to [ʃ] before /i/, such that /osɨl/ 'cloth (ACC)' maintains the coronal and is pronounced [osɨl], but /osi/ 'cloth (NOM)' is [oʃi] (Iverson 1993). Similarly, in Dutch, /s/ becomes [ʃ] before /j/, such that /poes/ 'cat' is pronounced [poes] and /poesje/ 'kitten' is [poeʃe] (Booij 1995).

This type of palatalization occurs as described in many languages despite leading to contrast neutralization due to mergers with existing palatal phonemes. For instance, in Somali, when the causative verbal affix *-i* is added to roots ending in uvular stops, like in *dàaq* 'graze', the stop becomes a palatal glide, as in *dáaji* 'put to graze' (Saeed 1999: 32) – despite Somali having a /j/ phoneme (Saeed 1999: 11). Thus, palatalization seems like it could be an even more available strategy for uvular adaptation in Chanka, where no merger would occur. While palatalization seems to be disfavored for uvular consonants (Hall 2000) – Somali is the only known language to fully palatalize the uvular stop – given that they are also dorsals like velars, some fronting of the uvular to accommodate vowels also seems possible. The fricative manner of the uvular in Chanka and the large contact surface for dorsal consonants may also allow more place flexibility. Since its dorsal nature actually implies a large contact surface between the tongue and the velar or uvular, it may be easier for the initial consonant contact to match the vowel place, becoming more velar [x] or palatal [ç].

[3] Emphasis spread is another strategy used in most dialects of Arabic to avoid conflicts with a coronal consonant with a pharyngeal or uvular coarticulation. While related to vowel lowering in Arabic, the process involving a coarticulation is distinct from Chanka, given the different features of the Chanka uvular phoneme.

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1.2 Relevant Southern Quechua phonology

Most Quechua dialects have at least one uvular phoneme, which presents articulatory conflicts with the high vowels /i/ and /u/. Impressionistic descriptions of Southern Quechua identify vowel allophony as the method used to resolve this conflict.[4] While traditionally called lowering in these descriptions, this allophony actually involves both F1 and F2, especially for /i/. Table 1 shows approximate expected and unexpected allophones based on the descriptions.

In descriptions, as shown in Table 1, the allophone [i] is said to appear in non-uvular contexts, as in (1b), with [e] as in (1d), corresponding to a higher F1 and lower F2, appearing before and after a uvular consonant. Similarly, [u] appears in non-uvular contexts like (1a), while a vowel similar to [o] in (1c), with a higher F1, appears near a uvular (Parker 1969; Soto Ruiz 1976; Cerrón-Palomino 1987; Mannheim 1991; Quintero Bendezú 1996; Adelaar with Muysken 2004; Pérez Silva, Acurio Palma, & Bendezú Araujo 2008; Zariquiey & Córdova 2008).

Acoustic studies have confirmed vowel allophony in the Southern Quechua dialects spoken in Cochabamba (Gallagher 2016; Holliday & Martin 2018) and Cuzco (Pérez Silva, Acurio Palma, & Bendezú Araujo 2008; Molina-Vital 2011), where it facilitates production and perception of their large dorsal stop inventories (Gallagher 2016). As shown in the minimal pairs in Table 2, these varieties distinguish six dorsal onset stops, which contrast for place (velar or uvular) and laryngeal features (plain, ejective, or aspirated): /k/, /k'/, /kʰ/, /q/, /q'/, /qʰ/ (Cerrón-Palomino 1987; Mannheim 1991).

Vowel allophony certainly facilitates the production of uvular stops in Southern Quechua (Cerrón-Palomino 1987: 255). However, this process is more than just coarticulatory accommodation of the vowels during the transition to the uvular consonant.

Table 1. Described forms for Chanka Quechua allophonic vowel lowering

		Underlying form	Expected form	Unexpected form	Gloss
	(1a)	/tukun/	[tukun]	[tokon]	'he/she finishes'
(Velar-adjacent) Elsewhere	(1b)	/siki/	[siki]	[seke]	'bottom'
	(1c)	/takin/	[takin]	[taken]	'he/she sings'
Uvular-adjacent	(1d)	/tuχun/	[toχon]	[tuχun]	'he/she makes a hole'
	(1e)	/siχi/	[seχe]	[siχi]	'drawing'
	(1f)	/taχin/	[taχen]	[taχin]	'he/she gathers'

Table 2. Cuzco Quechua minimal pairs: dorsal stop onsets

		Place			
		Velar		Uvular	
Laryngeal features	**Plain**	/kata/	'father-in-law'	/qata/	'brother-in-law'
	Aspirated	/kʰapaχ/	'he who burps'	/qʰapaχ/	'powerful'
	Ejective	/k'ajna/	'in this way'	/q'ajna/	'before'

[4] A couple of authors argue for a five-vowel system /a/, /e/, /i/, /o/, /u/ (e.g., Weber 1994), but most note that /e/ and /o/ are found in Spanish loan words, and are often replaced with /i/ and /u/ by monolingual speakers without contact with Spanish (Parker 1969: 18).

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Instead, it reflects a phonological resolution strategy: high vowels are said to lower categorically across their duration; and lowering or backing can spread across 'transparent' sonorants /n, ɾ, l, ʎ/ and morpheme boundaries (Cerrón-Palomino 1987: 255).[5] Vowel allophony has also been found to be a perceptual cue to the velar-uvular place distinction in Cochabamba (Gallagher 2016). The fact that this phenomenon serves perception as well as production purposes in other Quechua dialects raises the possibility that the process may occur differently in Chanka, given its different phonology, as described in the following subsection.

1.3 Relevant Chanka Quechua phonology

Vowel lowering has also been described for Chanka Quechua (Parker 1969; Cerrón-Palomino 1987), another Southern Quechua dialect, but no known acoustic study has confirmed it. Chanka has 'striking differences in phonology,' including fewer consonant distinctions (Mannheim 1991: 4; see also Cerrón-Palomino 1994). At the same time, Chanka has the same three vowel phonemes as other Southern dialects. Table 3 presents the smaller Chanka consonant inventory, with dorsals shaded.

Two differences in consonant phoneme characteristics are particularly relevant to the current study. First, the uvular phoneme is a fricative in all contexts rather than the stop found in other dialects,[6] as shown in the examples in Table 4. Second, Chanka has only two dorsal contrasts in total: the uvular fricative and the velar stop. They do not contrast for laryngeal features (plain, ejective, aspirated) as in other dialects (Parker 1969; Soto Ruiz 1976; Cerrón-Palomino 1987, 1994; Mannheim 1991; Adelaar with Muysken 2004; Zariquiey

Table 3. Chanka Quechua consonant phoneme inventory

	Labial	Dental	Palatal	Velar	Uvular	Glottal
Stop	p	t		k		
Affricate			tʃ			
Fricative		s			χ	h
Nasal	m	n	ɲ			
Liquid		l ɾ	ʎ			
Glide	w		j			

Table 4. Uvular phoneme correspondences between Cuzco and Chanka Quechua

	Cuzco	Chanka	Gloss
Plain	/qasa/	/χasa/	'frost'
Ejective	/q'asa/	/χasa/	'cliff'
Aspirated	/qʰapax/	/χapaχ/	'powerful'

[5] This process differs from vowel harmony in that vowel retraction is triggered by a nearby uvular consonant rather than the height of nearby vowels.

[6] Descriptions list the place to be uvular given the historical parallel to the uvular stop phoneme /q/ found in other Southern dialects. However, this place has not been acoustically measured.

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Table 5. Chanka dorsal consonant minimal pairs

Velar stop		Uvular fricative	
/aka/	'excrement'	/aχa/	'fermented corn drink'
/kapaχ/	'he who burps'	/χapaχ/	'powerful'
/kajna/	'in this way'	/χajna/	'before'
/siki/	'bottom'	/siχi/	'drawing'

& Córdova 2008). Minimal pairs showing the contrast between the velar stop (/k/) and uvular fricative (/χ/) are presented in Table 5.

2. Research questions

Given the limited, impressionistic descriptions of Chanka Quechua, phonetic analyses of vowel midpoints and transitions (to estimate fricative place) were conducted to investigate strategies used to resolve articulatory conflicts between high vowels and the uvular consonant. Specifically, this study sought answers to the following two questions:

1. Do Chanka speakers exhibit the described vowel allophony adjacent to a uvular phoneme, as compared to a velar context?
2. Do speakers use fricative place adaptation (such as, uvular fronting) as a strategy to resolve the conflict between the uvular fricative consonant and high vowels?

Since the vowel and consonant accommodation strategies documented for other languages are dialect-specific, Chanka may also have its own unique processes, especially given Chanka's small and constrastive dorsal inventory. As for consonant place, fronting of the uvular seems quite plausible, despite not having been documented in descriptions. The uvular stop /q/ in Cochabamba Quechua, another Southern dialect, has also recently been described with a variable velar articulation (Pierrard 2018, 2020), albeit usually voiced to follow a pattern of intervocalic voicing documented for the dialect (Gallagher 2022). Permanent fronting to a velar place occurred several centuries ago for the historically uvular phoneme in Ecuadorean Kichwa varieties, also related to Southern Quechua, which now have no vowel lowering and no uvular consonants (Gualapuro Gualapuro 2017). In fact, Kichwa allowed this fronting despite creation of a velar-uvular stop merger; thus, such an adaptation may be even more probable in Chanka, where mode distinction would remain. Consonant fronting to a palatal fricative, like in Somali, is also possible (Saeed 1999).

Contact with Spanish may also influence both processes for Quechua-Spanish bilingual speakers in an experimental setting. In Spanish, /i/, /e/, /o/, and /u/ are distinct phonemes rather than allophones, such that /pila/ 'battery' and /pela/ 'he peels' are minimal pairs based on vowel height. Bilingual speakers who distinguish high and mid vowels thus have two additional potential outcomes for vowel allophony in Quechua. The meaningful high-mid distinction may influence Chanka speakers to identify mid vowels as a separate category and maintain categorical lowering. In Cuzco, Molina-Vital (2011) found that Spanish speakers lower categorically in Quechua, which he attributed to their ability to distinguish high and mid vowels. However, a common ideology propagated through standardization is that Cuzco-Collao Quechua has a five-vowel system (with categorical lowering near uvular stops), which contrasts with the three-vowel system of Ayacucho-Chanka. Bilingual Chanka speakers interpret this to mean that their dialect has only the three vowels equivalent to Spanish /a/, /i/, /u/; and thus they may avoid mid vowel allophones altogether – maintaining a low F1 value for both high vowels in all contexts. Controlled production may have led them to use more careful speech, in which their ideologies could have affected their pronunciation.

As for consonant place, fronting of the Chanka dorsal fricative would parallel the velar place of the Peruvian Spanish dorsal fricative <j> [x]. As in Kichwa, such a change in the place of articulation in the consonant could minimize vowel lowering since it eliminates the uvular trigger. A lack of vowel lowering on its own would also further encourage movement of the fricative place, as it would make producing a uvular more difficult. For example, the fricative consonant would be fronted adjacent to /i/, to align with the high, front place of the vowel, rather than the vowel lowering or backing to the uvular articulation.

3. Methodology

To address the research questions, the author conducted a controlled production experiment with Chanka Quechua speakers in Andahuaylas, Peru. The author was a native English speaker with native-like Spanish and intermediate Quechua fluency. Participants were compensated 30 Peruvian Nuevos Soles (∼ 9 US dollars) for approximately 15 minutes of their time. The following subsections will describe the participants (§3.1), stimuli (§3.2), data collection (§3.3), and data analysis (§3.4).

3.1 Participants

Recordings from 22 adult speakers (ages 22–59) were analyzed: ten urban (six female, four male) and twelve rural (six female, six male).[7] Most participants were born in their current location of residence or had lived there for most of their lives. The participant sample was designed to test for the social effects of speaker sex and location of residence (urban/rural), with the latter also a proxy for level of Spanish proficiency. Urbanites were natively bilingual in Spanish and Quechua, whereas rural speakers had low to no Spanish proficiency. Rural males had at least primary education and receptive understanding in Spanish but did not speak it fluently. Rural females generally had no education and very limited Spanish knowledge.

Rural speakers were thus expected to have categorical vowel allophony and a true uvular fricative, following traditional descriptions. For urban speakers, several possible outcomes were possible, given their bilingual Spanish proficiency. First of all, it was hypothesized that urban participants would maintain high vowels everywhere due to local dialect pride. Most urban participants were schoolteachers who had metalinguistic awareness that Chanka's three vowel phonemes and lack of lowering were features that distinguished it from neighboring Cuzco Quechua. Additionally, it seemed possible that the same participants would have a velar fricative. Lack of lowering would also be more feasible articulatorily if the place of the fricative for urban participants was also shifting from uvular to velar, to match the Spanish fricative <j>.

3.2 Production task

The experiment stimuli were real Chanka words produced in carrier phrases. Real words were used since the goal was natural pronunciation. Target words were based on roots with a final VCV sequence, as seen in the examples shown in Table 6. The list of words contained

[7] Recordings from three additional speakers were not included in the analysis due to their being older than 70 (two speakers) or from a different dialect region (one speaker).

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Table 6. Stimuli examples (key **VCV** sequence in **bold**; stressed syllable preceded by ˈ)

			/i/		/u/		/a/
Uvular	V1 stressed	a.	/ˈsi.χi/	e.	/ˈtu.χu/	i.	/ˈχa.χa/
	V1 unstressed	b.	/si.ˈχi.ta/	f.	/tu.ˈχu.ta/	j.	/χa.ˈχa.ta/
Velar	V1 stressed	c.	/ˈʎi.kin/	g.	/ˈtu.kun/	k.	/ˈna.kan/
	V1 unstressed	d.	/ʎi.ˈki.ni/	h.	/tu.ˈku.ni/	l.	/na.ˈka.ni/

Table 7. List of carrier phrases

Quechua	English
a. *Wakpi* ___noun.NOM___ *kachkan.*	a. There is a ___*noun.*NOM___.
b. *Wakpi* ___noun.ACC___ *rikuchkani.*	b. There I am seeing a ___*noun.*ACC___.
c. *Ñuqa allinta* ___verb.1SG___ *kaypi.*	c. I ___*verb.1*SG___ well here.
d. *Pay allinta* ___verb.3SG___ *chaypi.*	d. He ___*verb.3*SG___ well there.
e. /ʎuχi/ *makiwan hapini.*	e. I grasp it with my *left* hand.
f. *Wasipa* /ʎuχinpi/ *suyachkani.*	f. I am waiting to the *left* of the house.

all three phonemic Chanka vowels (/a/, /i/, or /u/) in two key dorsal consonant contexts (/k/ or /χ/). Words with high vowels /i/ and /u/, for which vowel allophony has been described, were used to test for lowering and retraction. These words as well as those with the low vowel /a/ were used to compare the places of articulation of the dorsal consonants. The /a/ vowel was included since it has been described as maintaining a similar position in both consonant contexts. Only the vowel-consonant transition was expected to differ depending on consonant place.

Two morphological forms of each word were elicited, such that both vowels in each VCV sequence were pronounced stressed (penultimate) and unstressed (elsewhere). As shown in Table 6, noun roots were elicited in nominative case with no suffix for pre-consonantal stress like in (6a,e,i) and in accusative case with a one-syllable suffix -*ta* for post-consonantal stress like in (6b,f,j). Verb roots were pronounced in 1st person singular with a one-syllable suffix –*ni* for post-consonantal stress as in (6d,h,l) and in 3rd person singular with a one-phoneme suffix –*n* for pre-consonantal stress as in (6c,g,k) (this suffix added no extra syllable, thus stress remained on the penultimate vowel). The complete set of stimuli words and derivations are listed in Appendix A.

The six carrier phrases that allowed for logical insertion of the target word stimuli appear in Table 7 above. The only adjectival target word, /ʎuχi/ 'left', and its derivation were elicited in unique carrier phrases, seen in (7e,f), since they did not logically fit into the other carrier phrases.

3.3 Data collection

Data was recorded by the author in homes and offices with minimal background noise using an Audio Technica 831b lapel microphone and Marantz PMD560 recorder. Instructions were given in Spanish or Quechua, depending on the language in which participants usually communicated with the researcher. Where possible, the researcher gave limited example phrases, stating only the first full carrier phrase for the participant to repeat exactly. Then

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Table 8. Sample trial

Spanish/Quechua	English
R: Repite esta frase: *Wakpi piki kachkan.*	**R:** Repeat this phrase: *Wakpi piki kachkan.*
P: *Wakpi piki kachkan.*	**P:** *Wakpi piki kachkan.*
R: Muy bien. Ahora, en vez de *piki*, di *maki*. *Wakpi maki kachkan.*	**R:** Very good. Now, instead of *piki*, say *maki*. *Wakpi maki kachkan.*
P: *Wakpi maki kachkan.*	**P:** *Wakpi maki kachkan.*
R: Bien. Ahora, repite la misma frase, pero en vez de *maki,* di *chuku*.	**R:** Good. Now, repeat the same phrase, but instead of *maki,* say *chuku*.
P: *Wakpi chuku kachkan.*	**P:** *Wakpi chuku kachkan.*
R: Ahora, *waka*.	**R:** Now, *waka*.
P: *Wakpi waka kachkan.*	**P:** *Wakpi waka kachkan.*

Table 9. Sample phrase switch

Spanish/Quechua	English
R: Muy bien. Ahora, la frase va a cambiar pero vas a seguir repitiendo las palabras que te digo. Por ejemplo, dices *Wakpi pikita rikuchkani*.	**R:** Very good. Now, the phrase is going to change but you are going to continue repeating the words that I tell you. For example, you say *Wakpi pikita rikuchkani*.
P: *Wakpi pikita rikuchkani.*	**P:** *Wakpi pikita rikuchkani.*
R: Y ahora, la misma frase, pero en vez de *pikita* dices *makita*. *Wakpi makita rikuchkani.*	**R:** And now, the same phrase, but instead of *pikita* you say *makita*. *Wakpi makita rikuchkani.*
P: *Wakpi makita rikuchkani.*	**P:** *Wakpi makita rikuchkani.*
R: Bien. Ahora, *wakata*.	**R:** Good. Now, *wakata*.
P: *Wakpi wakata rikuchkani.*	**P:** *Wakpi wakata rikuchkani.*

she stated only a new target word for the participant to insert in the same case or conjugation, though she often also gave the second target word in the full carrier phrase for illustrative purposes. Following this, most participants could repeat the carrier phrase and insert each new stimuli. Table 8 exemplifies the start of the experiment.

After the participant stated all of the words logically related to one carrier phrase, the researcher informed him or her that the repetition task would continue with a new phrase. Each phrase change interaction was similar to the following in Table 9.

The researcher's level of involvement increased when participants did not understand these instructions, likely due to less formal education experience. As shown in the previous examples, when the participant understood the task based on these instructions and two practice phrases, the researcher stated the six relevant carrier phrases only once or twice and then each new target word, which the subject inserted into the relevant carrier phrase (except for phrases e and f in Table 7, which the researcher stated completely once, and the participant repeated two or three times). However, some participants did not understand the replacement task even with practice trials. In those cases, the researcher stated the full carrier phrase each time, changing the target word, for the participant to repeat.

These procedures were selected due to the limited experience that Chanka speakers have with following instructions for abstract linguistic manipulation tasks. Most of the participants had less than a primary education and did not understand the construction of the abstract experimental phrases, and it was especially difficult for them to alter them by replacing one word as requested. Similarly, they had little experience with printed (2D) images or drawings, which made vocabulary elicitation through pictures unsuccessful as

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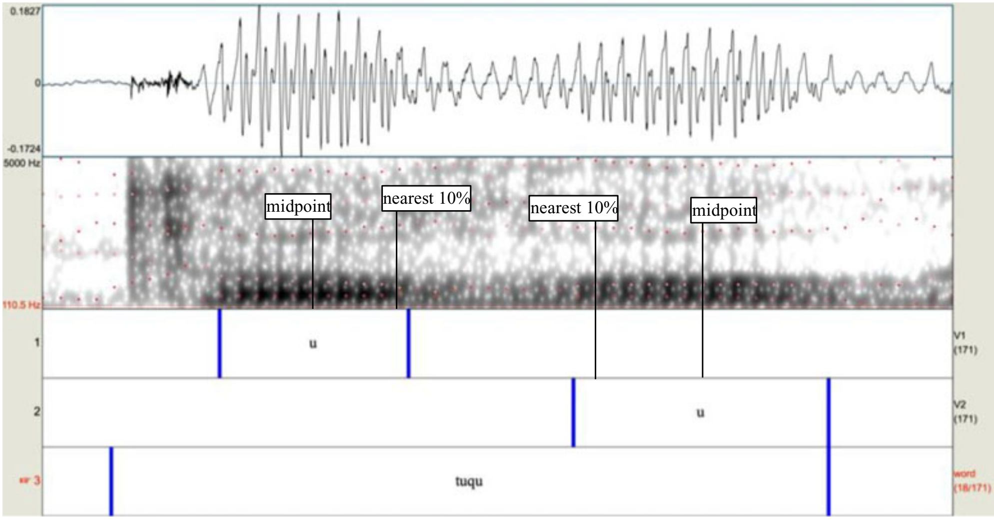

Figure 1. Example of vowel measurement methodology adjacent to the fricative (/χ/).

well. Instead, much of participants' educational and social practices center around oral repetition, hence why rote repetition was successful in eliciting data in this scenario.

Both experimental procedures (full and partial repetition) led to natural pronunciations, for two reasons. First, Quechua speakers, especially monolinguals (the participant subset who heard and repeated entire phrases), had not been exposed to non-native Quechua speech prior to the experiment, and nativized pronunciation instead of imitating the researcher's non-native accent. These speakers also had a very strong Quechua accent in any Spanish interactions (in terms of fewer vowel distinctions, more unstressed vowel reduction, stress-timed instead of syllable-timed, word order) which further highlights the dominance of Quechua phonology in their linguistic competence. Second, given the cognitive requirement of producing the carrier phrase, all with words familiar to participants, participants focused on correct repetition of the vocabulary rather than the interviewer's non-native pronunciation.

3.4 Phonetic analysis and statistical modeling procedures

Acoustic analyses were performed to answer each research question. Target words and vowels were segmented in Praat (Boersma & Weenink 2016), and vowel F1 and F2 measurements were taken using a script at the midpoint and the onset or offset. For segmentation, the beginning of a vowel was defined as the point where the F1 and F2 formants became clear following a preceding stop or fricative (after the burst of a preceding stop or after frication stopped), and the end was where the formants stopped and the regular waveform ended. The midpoint was halfway between those points, or at 50% vowel duration. The onset and offset measurements were taken at the nearest 10% to the key consonant. For vowels preceding /k/ or /χ/, the offset was at 90% of duration. For vowels following the key consonant, the onset was at 10% of duration.

Figure 1 shows examples of delineation of target vowel segments for the word /tuχu/ 'hole', with midpoints and nearest 10% values marked. Section 3.4.1 will describe the statistical methods used to assess vowel allophony, and Section 3.4.2 will describe the methods for consonant place.

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Table 10. Factors considered for F1 and F2 at midpoint

Type	Variable	Levels
Fixed effects	vowel	/i/, /u/
	context	/k/, /χ/
	vowel position	before, after
	stress	yes, no
	sex	male, female
	location	urban, rural
Random effect	speaker	

3.4.1 Statistical modeling for vowel allophony

Vowel allophony was evaluated in two separate models for F1 and F2, using the midpoint values as the dependent variables. Midpoint values provide the best estimate for the vowel target without coarticulatory influence from surrounding consonants.

Parameter estimates chosen by maximum likelihood were used to fit separate linear mixed-effects models for F1 and F2 using the lme4 package (Bates et al. 2015) in the statistical program R (R Core Team 2021). As shown in Models 1 and 2, each model included relevant linguistic and social factors, with the same fixed and random effects and interactions, detailed in Table 10. Fixed effects were vowel category, consonant context, vowel position relative to the key consonant, stress, speaker sex, and speaker location. Only high vowel categories (/i/ and /u/) were ultimately included in the analysis, as they are the main target for vowel allophony near uvulars, according to Quechua descriptions and relevant literature on other languages.

The models also included interactions between the fixed effects. As F1 and F2 were expected to be unique for each vowel phoneme, an interaction with consonant context was added to account for possible vowel-specific effects of the consonant. Additional two-way interactions were those between linguistic factors (vowel position and stress) and social factors (sex and location). The interaction between stress and vowel position was included given that stress is almost always penultimate in Quechua, and unstressed vowels following the key consonant in nouns would thus usually be word-final (though not phrase-final). The interaction between sex and location was included due to the fact that female and rural speakers tend to have lower Spanish proficiency, such that rural females have the lowest, rural males slightly more, and urbanites of both sexes the most Spanish (usually bilingual). Finally, speaker was included as a random effect to account for interspeaker variation.[8] For F2, by-speaker slopes were also added for the interaction of vowel and context.

Model 1. Mixed effects model of F1 for vowel allophony

$$\textbf{F1 at midpoint} \sim \textbf{1} + \textbf{vowel} * \textbf{context} * \textbf{sex} * \textbf{location} + \textbf{vowel} * \textbf{context} * \textbf{V\_position} * \textbf{stress} + \textbf{(1 | speaker)}$$

[8] The same models, with the addition of 'word' as a random effect, were run first. However, the models did not converge, likely due to the fact that each word had two unique vowels that were included in the analysis. Thus, 'word' was removed from the model.

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Model 2. Mixed effects model of F2 for vowel allophony

$$\textbf{F2 at midpoint} \sim \textbf{1} + \textbf{vowel} * \textbf{context} * \textbf{sex} * \textbf{location} + \textbf{vowel} * \textbf{context} * \textbf{V\_position} * \textbf{stress} + \textbf{(1} + \textbf{vowel} * \textbf{context} \mid \textbf{speaker)}$$

These models were the best fit models (lowest AIC) when compared to models that spelled out interactions individually or to those that included fewer interactions between fixed effects.[9] Model fit was further confirmed by dropping one factor at a time (using *drop1()*) and comparing the resulting nested model via a likelihood ratio test with a confidence level of 0.95 in the lsmeans package (Lenth 2016). All factors and interactions remained in each model as shown, although for F1 no individual factors and only some interactions emerged as significant. For all significant interactions, the *contrast()* function (pairwise method) in lsmeans was used to estimate their effects.

3.4.2 Statistical modeling for consonant place

The fricative place of articulation was estimated by comparing the magnitude of the adjacent vowel transition with the transitions to/from the velar stop. Transitions were quantified as the trajectory length between the vowel midpoint and the onset or offset (nearest 10% to the key consonant, as previously described). Trajectory length is a measure that encompasses the F1 and F2 differences between two relevant points by calculating the Euclidean distance (ED) between them (Fox & Jacewicz 2009; Jacewicz, Fox, & Salmons 2011). The Euclidean distance (ED) is calculated using the following formula:

$$\text{ED} = \sqrt{((F1_{50\%} - F1_{10\%})^2 + (F2_{50\%} - F2_{10\%})^2)}$$

The estimates of vowel transitions were modeled using logistic regression in R, with Euclidean distance as the dependent variable. The full model (Model 3) included the same independent factors and interactions used for vowel allophony in Models 1 and 2. By-speaker slopes were not included in the model, as they led to a singular fit or nonconvergence, similar for F1 at midpoint (Model 1).[10] For Model 3, the 'vowel' variable included all three vowel phonemes: /a/, /i/, and /u/. Table 11 details all fixed and random effects and their levels. The statistical analysis was used to identify the factors that significantly affected vowel-consonant transitions, as a proxy for identifying factors that affected consonant place. Ultimately, transitions to/from the fricative (underlying uvular) were compared to transitions to/from the velar stop. If consonant context were to emerge as a significant effect leading to distinct transitions, then the dorsal stop (known to be velar) and fricative likely maintained distinct places of articulation. If transitions were similar, not significantly affected by consonant context, then the fricative likely had a place close to velar.

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[9] For F1 and F2, four models each were compared to evaluate the inclusion of by-speaker slopes: one with no by-speaker slopes, one with by-speaker slopes for the two-way interaction between vowel and context (the main research question), one with by-speaker slopes for the four-way interaction between vowel, context, vowel position, and stress, and one with by-speaker slopes for the four-way interaction between vowel, context, location, and speaker sex. For F1 models, any by-speaker slope led to a singular fit. For F2 models, the by-speaker slopes with four-way interactions led to a singular fit.

[10] For transitions, four models were compared to evaluate the inclusion of by-speaker slopes: one with no by-speaker slopes, one with by-speaker slopes for the two-way interaction between vowel and context (the main research question), one with by-speaker slopes for the four-way interaction between vowel, context, vowel position, and stress, and one with by-speaker slopes for the four-way interaction between vowel, context, location, and speaker sex. Any by-speaker slope led to a singular fit.

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Table 11. Factors considered for transitions (ED) between midpoint and nearest 10%

Type	Variable	Levels
Fixed effects	vowel	/a/, /i/, /u/
	context	/k/, /χ/
	vowel position	before, after
	stress	yes, no
	sex	male, female
	location	urban, rural
Random effects	speaker	

In addition to the statistical analysis, a preliminary visual analysis of average transition plots compared the transition size and direction between the velar stop and uvular fricative for /a/ and /i/ vowels. The transition arrows on the plots represent the trajectory length (ED), or F1 and F2 differences, between the midpoint and onset/offset, as described above. With the understanding that formant movements are unique for each place of articulation (Ladefoged and Disner 2012), if transitions between each consonant and a specific vowel appeared similar, then the fricative likely matched the velar place of the stop. If they appeared distinct with regards to size and/or direction, then the fricative place likely differed from velar. Assuming a place distinction was maintained for the two dorsal consonants, the clearest difference in transition size depending on consonant context was expected for /a/. For instance, given that /a/ would be homorganic with a uvular, a minimal transition was expected adjacent to this consonant when a true uvular, with a large transition up to the velar. Further investigations should include additional measures to confirm these visual hypotheses.

Model 3. Mixed effects model for vowel transitions

$$\begin{aligned}\textbf{F1/F2 Euclidean distance (midpoint – nearest 10\%)} \sim \\ \mathbf{1 + vowel * context * sex * location} \\ \mathbf{+ vowel * context * V\_position * stress} \\ \mathbf{+ (1 \mid speaker)}\end{aligned}$$

4. Results

Variation in both vowel allophony and fricative place were found. The following sections provide detailed description and graphic representation of results. A total of 3,827 vowel tokens were analyzed for both questions. Section 4.1 will detail vowel allophony, and Section 4.2 will present the fricative place of articulation.

4.1 Vowel allophony results

This section details the relevant regression results for vowel midpoints, used to determine allophony. Certainly, various linguistic factors affect F1 and F2. These factors are included in the model to increase the accuracy of estimates for the context-related coefficients, but they will be left aside for this paper. The results described in detail in this section will be

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the significant factors related to consonant context, in order to respond to the first research question about the effect of the uvular context on vowel F1 and F2. Complete results of the logistic regression models for vowel midpoints are listed in tables in Appendix B (F1) and Appendix C (F2).

Visually, the difference between average midpoints and the range of possible pronunciations in each consonant context can be observed on vowel plots of F1–F2 that include standard deviation ovals. These plots will be used throughout subsections of 4.1. When plotted, average midpoints represent the average F1–F2 target for the vowel in the respective consonant context, and the standard deviations represent F1–F2 values that may occur statistically given the actual pronunciations of the stimuli values. When average midpoints and standard deviations are distinct for each consonant context, it is an indication that allophony likely exists. Conversely, when average midpoints and standard deviations are close to the same for a specific vowel category in distinct consonant contexts, allophony does not exist. Finally, when average midpoints differ but standard deviations overlap for a specific vowel category in distinct consonant contexts, allophony is variable. Certainly, while these production results provide insight into vowel acoustics, a perception study would be beneficial in confirming them.

4.1.1 Vowel allophony logistic regression results

Overall, vowel allophony exists: a uvular context significantly raises the F1 and lowers the F2 of high vowels at the midpoint ($p < .001$, F1 $\beta = 34.68$ Hz, F2 $\beta = -156.2$ Hz). At the same time, the size of the uvular effect is vowel-specific, as /i/ and /u/ exhibit different patterns. This is confirmed with the significant interaction between vowel and context found for F1 ($\beta = -29.5$ Hz, $p < .01$). As measured by pairwise comparison, the uvular significantly lowers and retracts the vowel articulation for /i/ (F1 difference: $\beta = 38.0$ Hz, $p < .0001$, $SE = 3.08$; F2 difference: $\beta = -149.7$ Hz, $p < .0001$, $SE = 20.4$), and lowers without retracting the /u/ articulation (F1 difference: $\beta = 24.2$ Hz, $p < .0001$, $SE = 2.64$; F2 difference, not significant: $p > .5$). Figure 2[11] plots average population midpoints and overlapping standard deviations for both vowels in each context.

As described, F2 differences were significantly greater than for F1 for all factors and interactions. In addition to the aforemented significant effects of consonant context, the fixed factors significantly affecting F1 included vowel category and stress, with speaker sex approaching significance; the factors significantly affecting F2 also included vowel category, vowel position, speaker sex, and location of residence. Some of these factors also participated in significant interactions, such that their actual effect was intertwined with the factor(s) of interaction.

The size of the effect of the uvular consonant on F1 and F2 depends on each vowel, and whether the vowel precedes or follows the uvular. This is because vowel, consonant context, and vowel position show a significant three-way interaction for both F1 ($\beta = 33.27$ Hz, $p < .01$, $SE = 11.08$) and F2 ($\beta = 221.68$ Hz, $p < .0001$, $SE = 42.89$). At the same time, the uvular effect of increasing F1 and decreasing F2 generally remains regardless of vowel position. F1 increases before and after a uvular are always significant ($p < .0001$), while F2 decreases are significant for both /i/ and /u/ following a uvular, as well as for /i/ preceding a uvular ($p < .0005$). F1 of /i/ increases by 35.1 Hz preceding and 40.8 Hz following a uvular ($p < .0001$); F2 of /i/ decreases by 186.9 Hz preceding a uvular ($p < .0001$) and 112.5 Hz following one ($p < .0001$). F1 of /u/ increases by 31.4 Hz preceding and 17.0 Hz following a uvular ($p < .0001$);

[11] As this study is concerned with production differences, vowel normalization was not used for analysis. Vowel normalization techniques did not accurately reflect Quechua vowel categories, given the small inventory. However, the random effects of speaker included in the models help to control for the individual variation found in this study.

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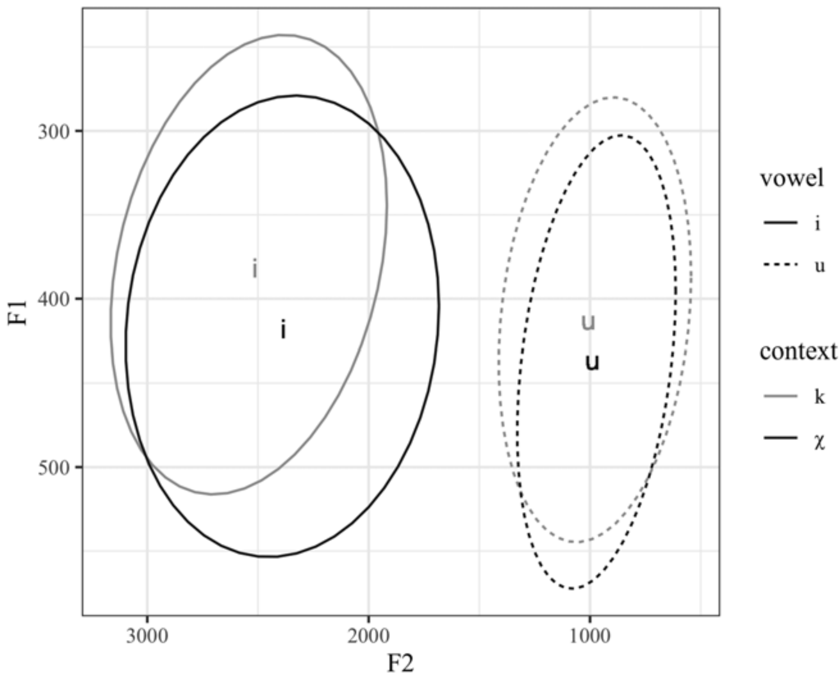

Figure 2. Average high vowel midpoints by consonant context (population-level).

F2 of /u/ decreases by 76.1 Hz following a uvular ($p < .001$), with no significant finding for a change in F2 of /u/ preceding a uvular ($p < .11$). Despite the significant interaction, the uvular consonant context maintains an overall effect on F1 and F2 at midpoint, to varying degrees depending on the vowel and its position.

In addition to linguistic factors, the social factors of speaker sex and location of residence affected vowel allophony related to the uvular. Interactions between these factors specify the size of the effect of the uvular consonant on F1 and F2 for the four relevant social groups: rural females, rural males, urban females, and urban males. The size of the effect of consonant context on vowel backing differs depending on the group, and this also differs depending on the vowel for F2.

For F2, the four-way interaction between vowel category, consonant context, speaker sex, and location is significant ($\beta = 186.93$ Hz, $p < .05$, $SE = 78.47$); for F1, the three-way interaction between consonant context, sex, and location approaches significance ($\beta = -20.76$ Hz, $p < .086$, $SE = 12.06$).[12] In the pairwise comparison for F1, the effect of consonant context is significant for F1 for all social groups ($p < .0001$ in each case); it simply varies in size. F1 next to a uvular versus a velar increases an estimated 36.1 Hz for rural males ($SE = 3.85$), 19.1 Hz for rural females ($SE = 3.72$), 36.1 Hz for urban males ($SE = 4.64$), and 21.1 Hz for urban females ($SE = 3.77$). For F2, the effect of consonant context depends on the vowel. The effect on F2 of /i/ is significant for all four social groups ($p < .05$ in each case). F2 of /u/, however, does not change significantly for any group ($p > .75$). For /i/, F2 next to a uvular lowers an estimated 116.62 Hz for rural males ($SE = 38.5$), 169.78 Hz for rural females ($SE = 38.1$), 194.87 Hz for urban males ($SE = 46.9$), and 117.47 Hz for urban

[12] This three-way interaction was also significant for F2 (vowel:sex:location $\beta = -111.86$ Hz, $p < .05$, $SE = 47.93$; context:sex:location $\beta = -117.71$ Hz, $p < .05$, $SE = 49.52$).

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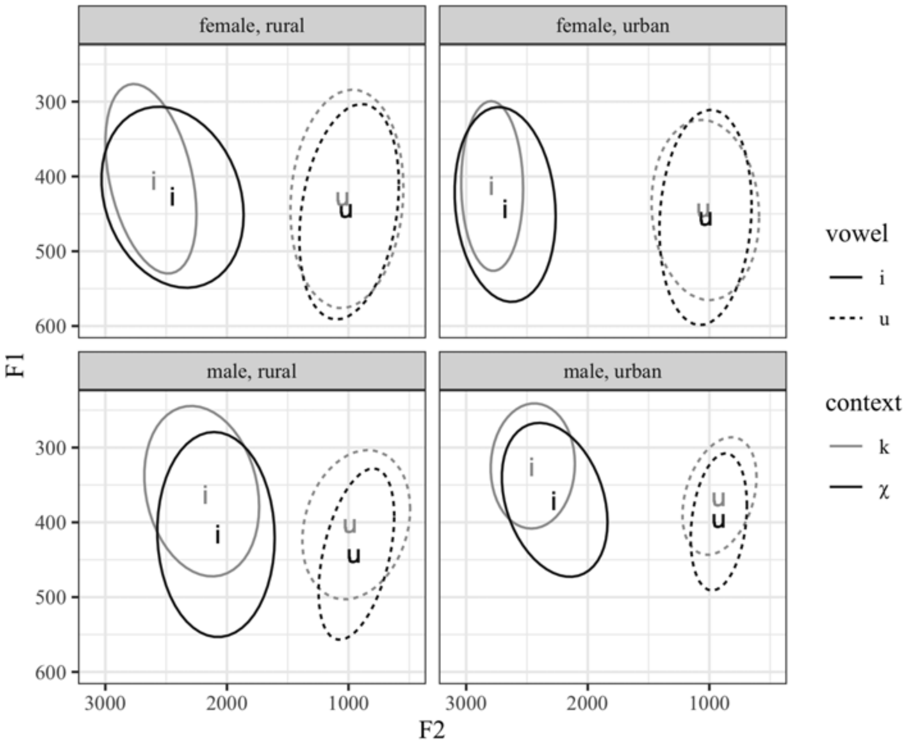

Figure 3. Context-related average high vowel midpoints by sex and location.

females (SE = 38.2). Figure 3 plots the data by sex and location to exemplify these different effects.

In summary, a uvular consonant context raises F1 and lowers F2 of high vowels overall. While the size of this effect differs depends on the linguistic factors of vowel position and stress, the effect remains generally significant regardless of these factors. As for social factors, all locations and sexes show significant effects of the uvular on F1 (height) for both vowels and F2 (retraction) of /i/. However, these effects occur to different degrees for each social group, as demonstrated by the aforementioned interactions. The following section will describe the allophony patterns found, and the groups that exhibit them.

4.1.2 Variation in vowel allophony

The regression results demonstrate trends in the variability of vowel allophony. While consonant context affects high vowel F1 and F2 overall, some but not all uvular-adjacent tokens of each vowel have higher F1 and lower F2 than all velar-adjacent ones. On an individual level, speakers exhibit three different allophony patterns: categorical, null, and variable. Moreover, patterns are specific to the vowel category and position relative to the consonant: they differ for /i/ and /u/, and before and after the key consonant. This section will present the three vowel patterns found. To control for the significant interactions with consonant context and vowel position, the following discussion of individual variation will focus on /i/ in preceding position only, as this instance showed the largest effect of consonant context.

4.1.2.1 Categorical vowel allophony pattern. In the categorical pattern, all high front vowels before a uvular have a higher F1 and lower F2 than those before a velar, and the standard

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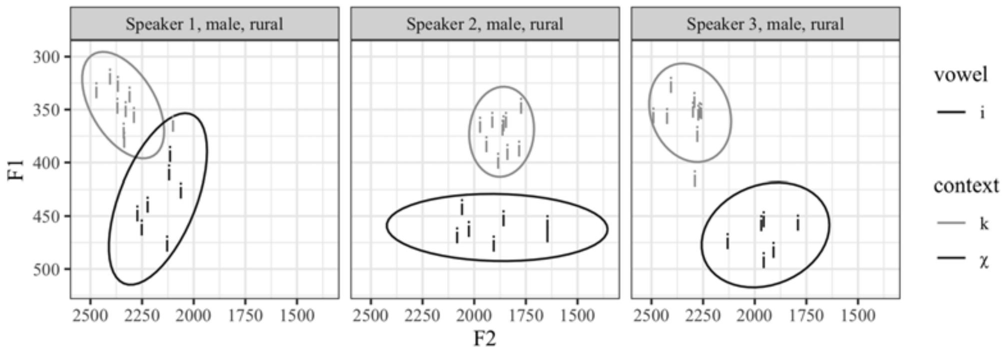

Figure 4. Categorical vowel allophony pattern in selected individual speakers (preceding /i/).

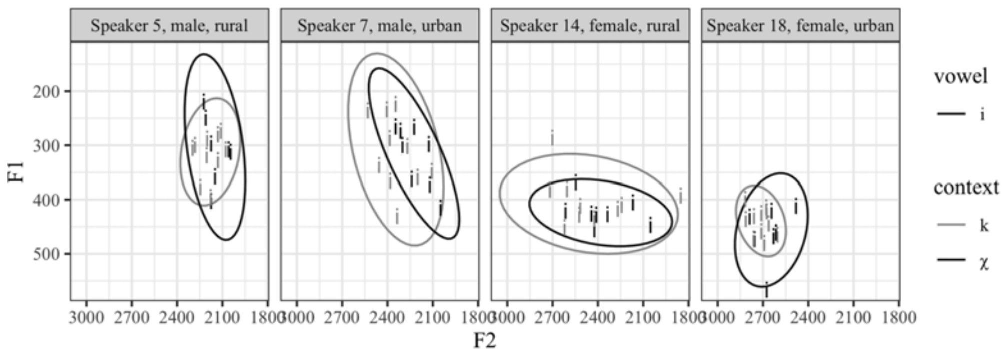

Figure 5. Null vowel allophony pattern in selected individual speakers (preceding /i/).

deviations generally do not overlap. This pattern appeared for three rural males, only for /i/ in preceding position. Their /i/ vowels in preceding position are plotted in Figure 4.

4.1.2.2 Null vowel allophony pattern. In the null pattern, F1 and F2 values of high front vowels do not differ between uvular and velar contexts. In other words, midpoint averages for each context are similar, and F1–F2 standard deviation ovals almost completely overlap, as seen in the selected individual plots in Figure 5. The null pattern appeared variably. Three speakers exhibited the null pattern for /i/ in both positions, five speakers only in preceding, and three only in following. Of those who had null allophony in both positions, all three were female. Those with null vowel allophony only in one position represent both sexes and places of residence.

4.1.2.3 Variable vowel allophony pattern. Finally, in the variable pattern, average F1 is often higher and F2 lower next to a uvular (average midpoints are different), but there is some overlap with the velar context (standard deviations partially overlap). As seen in selected individual plots of the variable pattern (Figure 6), most but not all uvular-adjacent tokens have higher F1 and lower F2 than some velar-adjacent ones. Variable allophony was the most common pattern, though the degree of overlap varies by speaker. Nine speakers exhibit the variable pattern for /i/ in both positions, two speakers only in preceding, and five only in following, with no apparent correlation based on social category.

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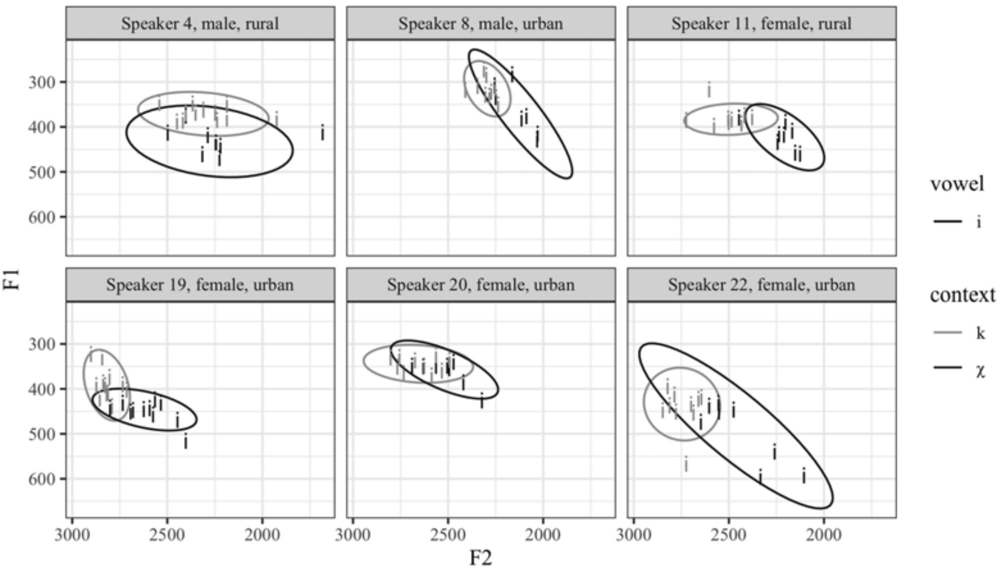

Figure 6. Variable vowel allophony pattern in selected individual speakers (preceding /i/).

4.1.3 Summary of variation in vowel allophony

While consonant context significantly affects F1 and F2 of high vowels overall, with varying effects for each vowel category, it is clear that individual Chanka speakers actually exhibit variability. The significant interaction between sex and consonant context reflects the finding that only males lower (and retract, in the case of /i/) categorically preceding a uvular, and only females exhibit the null pattern and never lower or retract in any position. The rest are variable: eleven speakers do not lower or retract in preceding or following position but partially lower and/or retract in the other position, and the remaining speakers lower and/or retract variably in both positions.

Table 12 summarizes the inter- and intraspeaker variability for /i/, preceding and following the key consonants. Each row includes one speaker, with a '+' under the appropriate vowel position if the vowel allophony pattern was categorical, '–' if the pattern was null, and '±' if the pattern was variable. As described, the only + appear for rural males, and more – appear for females than for males. However, most speakers show ±.

To condense Table 12, Table 13 shows how common each pattern was for each social group for /i/ in preceding position. Only rural males had categorical allophony, mostly females (more rural than urban) had null, and all groups had more than one speaker with variable allophony. The differences between social groups can be seen in the graph in Figure 7.

4.2 Consonant place results

This section details the regression results for vowel transitions, which were measured as the trajectory (Euclidean distance) from the key consonant to the vowel midpoint and used to estimate fricative place (described as uvular [χ] but possibly velar [x] or palatal [ç]). Ultimately, transitions to/from the fricative are compared to transitions to/from the velar stop; for this reason, results show whether the fricative is velar (similar to the transitions) or non-velar (distinct from the velar stop transitions).

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Table 12. Individual speaker vowel patterns for /i/, in both positions

Speaker	**Location** (Rural/Urban)	**Sex** (Male/Female)	Preceding position	Following position
1	R	M	+	±
2	R	M	+	±
3	R	M	+	–
4	R	M	±	–
5	R	M	–	±
6	R	M	±	±
7	U	M	–	±
8	U	M	±	±
9	U	M	±	±
10	U	M	±	±
11	R	F	±	±
12	R	F	±	±
13	R	F	–	±
14	R	F	–	±
15	R	F	–	±
16	R	F	–	–
17	U	F	–	–
18	U	F	–	–
19	U	F	±	–
20	U	F	±	±
21	U	F	±	±
22	U	F	±	±

Table 13. Number of speakers with each vowel allophony pattern by social group

	Categorical	Variable	Null
Rural males	3	2	1
Urban males	0	3	1
Rural females	0	2	4
Urban females	0	4	2
TOTAL	**3**	**11**	**8**

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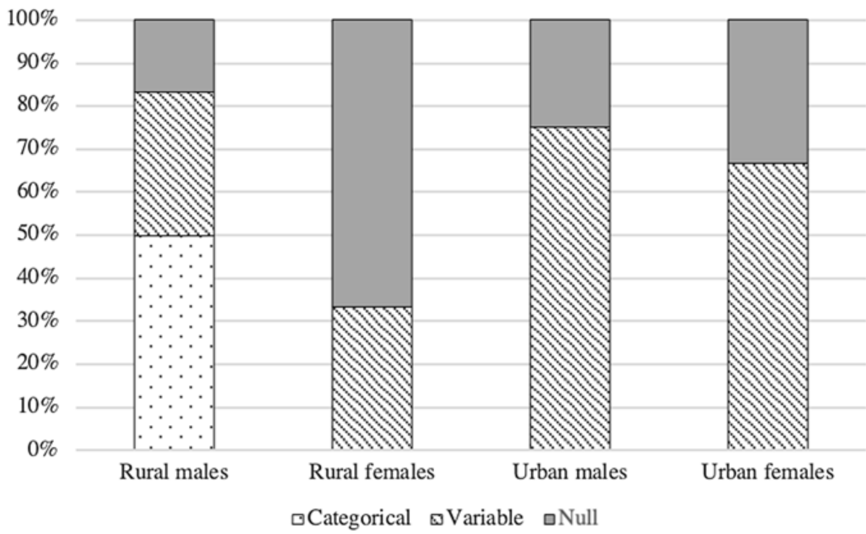

Figure 7. Distribution of vowel allophony patterns by social group.

As with vowel allophony, the results described in detail in this section will be the significant factors related to consonant context, in order to respond to the second research question about the effect of the consonant context on vowel transitions. Complete results of the logistic regression models for vowel transitions are listed in Appendix D.

Visually, the transition from the vowel to the consonant can be observed on vowel plots of F1–F2 that include arrows from the midpoint to the nearest 10% values. These plots will be used throughout Section 4.2. In the plots, the arrows represent the Euclidean distance between the midpoint F1 and F2 and the nearest 10% F1 and F2 measurements and show distance and direction changes. Transition arrows of similar length and direction in fricative and velar stop contexts for the same vowel indicate a similar place of articulation (velar) for both consonants, whereas diverging arrows indicate distinct places of articulation of the consonants (thus, a non-velar fricative). Additionally, a short transition to/from any vowel likely indicates that the adjacent consonant is close to homorganic with the place of articulation of the vowel since minimal tongue movement is needed to reach the place of articulation. For example, a short transition arrow to/from /i/ could indicate that the adjacent consonant had a more fronted place closer to the vowel articulation, such as palatal [ç]. A short transition to/from /a/ could indicate that the adjacent consonant had a lower and more central articulation, such as pharyngeal, whereas a longer transition from /a/ could indicate a higher articulation, such as velar [x]. These preliminary results can be confirmed with more precise measurement methods in the future, such as fricative center of gravity.

4.2.1 Consonant place logistic regression results

Overall, the fricative appears to have a place distinct from the velar stop most of the time, as consonant context significantly affects vowel transitions ($\beta = 36.6$ Hz, SE = 18.2, $p < .05$). However, this turns out to be a vowel-specific effect when evaluated with a pairwise comparison of the vowel-context interaction. Only transitions to and from /a/ are significantly 23.1 Hz smaller in the uvular context (SE = 7.23, $p < .01$) – meaning that fricative is likely usually non-velar. Transitions to and from /i/ and /u/ are not context-dependent according to this model, and thus the fricative near these vowels may be closer in place to the velar stop (for /i/: $\beta = -14.4$ Hz, SE = 9.1, $p = .3$; for /u/: $\beta = 8.7$ Hz, SE = 7.81, $p = .6$).

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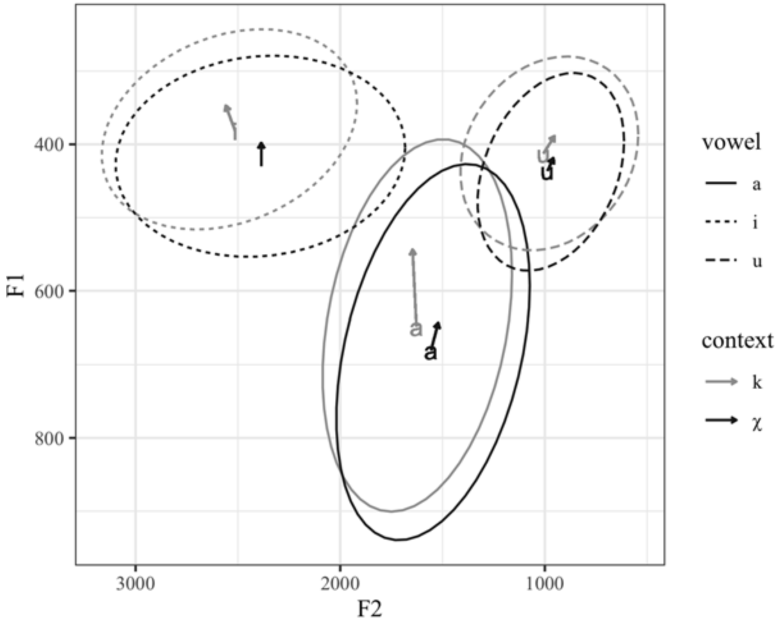

Figure 8. Average vowel transitions by consonant context (population-level).

The previous figure offers a visual representation of these findings. Figure 8 shows population-level average midpoint (marked by vowel letters) and nearest 10% to consonant measurements (arrow tips) for all three vowels. As reflected in the regression results, the fricative and the velar stop have distinct transitions, which hints at distinct places of articulation. The arrow is generally longer for all three vowels next to the velar stop, which indicates that the difference between the midpoint and nearest 10% F1 and F2 measurements is larger for velar stop than for uvular fricative contexts. This is clearest for /a/, reflecting the vowel-specific nature of the context effect. A very small uvular context arrow appears next to /a/, as F1 and F2 values next to the uvular remained constant throughout the vowel. For /i/, the length of the transition arrows is similar, but they point in slightly different directions, which could indicate that the average fricative is close to but not quite velar. For /u/, differences in arrows are observable but to a lesser extent, thus analysis of this vowel's transitions will be left aside for this paper.

Ultimately, the effect of consonant context differed depending on the vowel category and vowel position,[13] as the three-way interaction between vowel, context, and position was significant ($\beta = 87.0$ Hz, SE = 30.0, $p < .01$).[14] The pairwise comparison showed that for non-front vowels (/a/ and /u/), transition size was significantly different between consonant contexts only in preceding position, being 71.8 Hz smaller for /a/ before a uvular (SE = 9.5, $p < .001$) and 36.8 Hz smaller for preceding /u/ (SE = 11.4, $p < .05$). Neither vowel had significant context-related transition differences when following the consonant. For /i/, the opposite was found: transition size was significantly 31.0 Hz larger following a uvular

[13] Vowel position on its own was another significant factor in the large model and should be considered in more detail in future studies. Transitions from a preceding vowel to the key consonant were 23.2 Hz larger than transitions from a consonant to a following vowel (SE = 4.6, $p < .001$).

[14] Two-way interactions between consonant context and vowel category and context and position were also significant. However, the most accurate effect of these interactions can be seen in their three-way interactions of consonant context with vowel category and position, described here.

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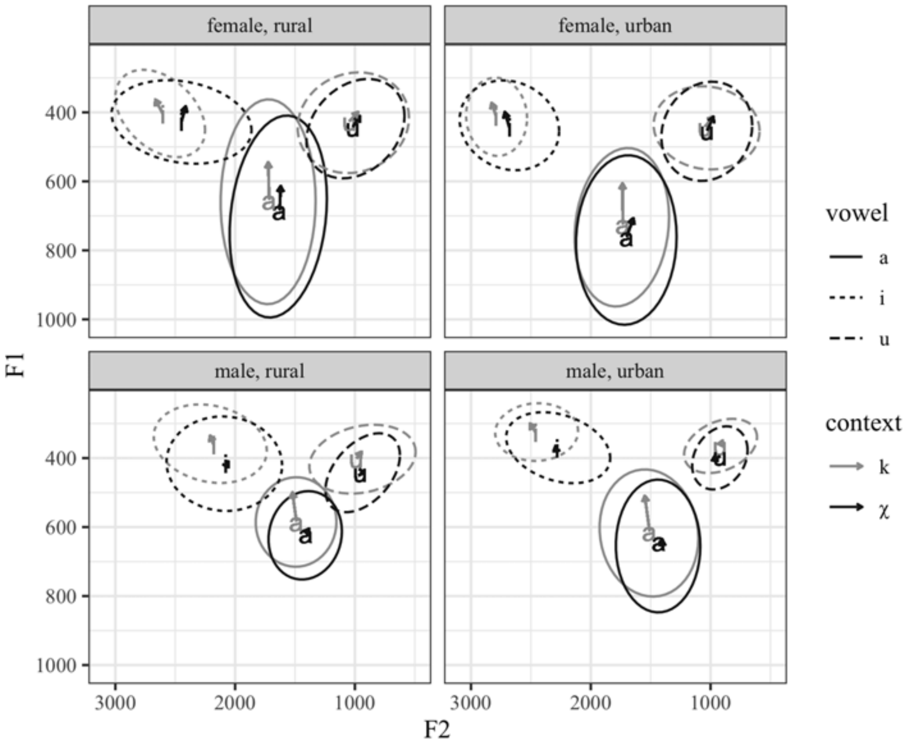

Figure 9. Context-related average vowel transitions by sex and location.

(SE = 11.8, p < .05), but almost no difference in transitions was found for /i/ in preceding position.

As for social factors affecting high vowel transitions, sex was a significant overall factor affecting transition size, with males having an average transition 43.1 Hz larger than that of females (SE = 16.6, p < .05). However, this sex-based difference ended up being dependent on vowel category and location, with a significant interaction between the three factors (β = 78.1 Hz, SE = 31.9, p < .01). Speaker sex ended up being significant only for /a/ transitions (β = −43.4 Hz, SE = 12.4, p < .01), where the interaction between context and sex also approached significance (β = −23.3 Hz, SE = 12.8, p = .067). For males, the difference in transitions between /a/ and an adjacent velar compared to uvular consonant was 33.0 Hz larger (SE = 7.6, p < .001). No significant difference between consonant contexts was found for female transitions for any vowel.

Urban (vs. rural) location led to a significantly smaller transition size for /i/ (β = -63.5 Hz, SE = 24.1, p < .05). For /u/, the interaction between sex and location significantly affected transitions (β = 112.0 Hz, SE = 50.5, p < .05). Urban males had transitions to/from /u/ significantly 107.4 Hz larger than rural males (SE = 36.8, p < .05), but no significant location-based difference was found for females. Urban males also had a context-based difference in transition size for /i/, with transitions to/from the fricative 52.5 Hz larger than to/from the velar stop (SE = 20.6, p < .05). No other social factors emerged as significant in these smaller models of transition differences.

Figure 9 offers a visual representation of the location- and sex-based differences in transitions. Males have distinct transition arrows between all vowels and each consonant context. For them the vowel transition arrow to the fricative is almost null for all vowels, whereas there is some transition in the stop context, particularly for /a/. This seems to

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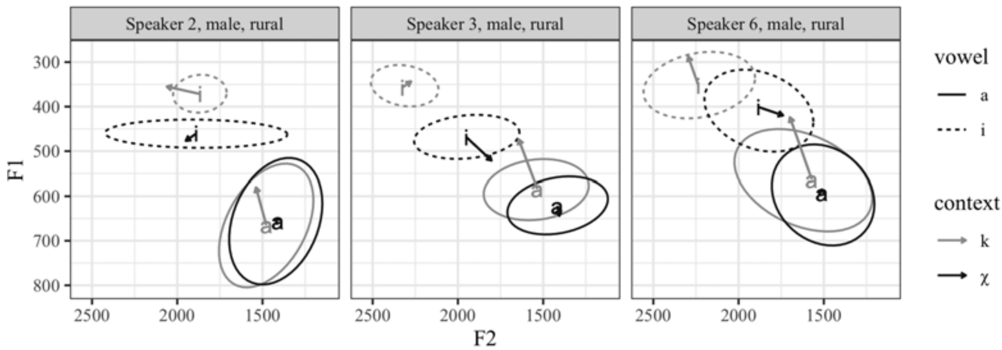

Figure 10. Stable uvular fricative-like pattern in average transitions of preceding /i/ and /a/ for selected speakers.

indicate that the fricative is different in place from the velar stop, potentially homorganic with the vowel. For females, transition arrows are of similar lengths for each vowel and context regardless of location. However, the direction of the fricative arrow differs from the stop arrow to/from /i/ for rural females, whereas the direction of the arrows to/from /a/ differs for urban females. These socially based differences will be further described in the following section.

4.2.2 Variation in fricative place of articulation

Despite apparent population-level trends, the regression results for vowel transitions ultimately reflect interspeaker variability in fricative place. When speakers are considered individually, interspeaker variation in vowel transitions appears to indicate three fricative place patterns, termed here as stable uvular, stable velar, and homorganic. Using visual evidence from the /i/ and /a/ transition plots of selected speakers, the following sections will describe the estimated fricative place patterns. Due to the different effects of vowel position found in the regression models, the figures include only vowels preceding the key consonants. Certainly, these hypotheses should be confirmed by building the regression model using additional data.

4.2.2.1 Stable uvular fricative pattern. Speakers with a denominated 'stable uvular' produce the fricative with a non-velar place that appears to always be uvular, /χ/. This can be observed for the three representative speakers in Figure 10, where average /ik/-/iχ/ and /ak/-/aχ/ transitions differ for each key consonant context in ways that hint at a uvular place regardless of the vowel. For /a/, each speaker's upward transition arrow to the stop /k/ indicates lowered F1 closer to the consonant, while the lack of a transition arrow to the fricative indicates stable F1 and F2 throughout the duration of the vowel, without a transition to the consonant. For /i/, the context-dependent difference in transition arrows, with a stable or rising F1 as the vowel approaches the uvular, also indicates a different place of articulation for the consonants here. Since the stop is velar /k/, the difference in transitions indicates that the fricative is likely uvular /χ/ in both cases. This stable uvular pattern was exhibited by four rural speakers: three males, one female.

4.2.2.2 Stable velar fricative pattern. Speakers with a 'stable velar' fricative appear to realize a velar /x/ in place of a uvular /χ/ most of the time. This can be observed for the three representative speakers in Figure 11, where average transitions are similar in both consonant contexts, for each vowel (comparing /ik/ with /iχ/ and /ak/ with /aχ/). For /i/, the upward, leftward transition arrows indicate lowered F1 and raised F2 closer to both key consonants. For /a/, the upward transition arrows indicate lowered F1 closer to each consonant. Since

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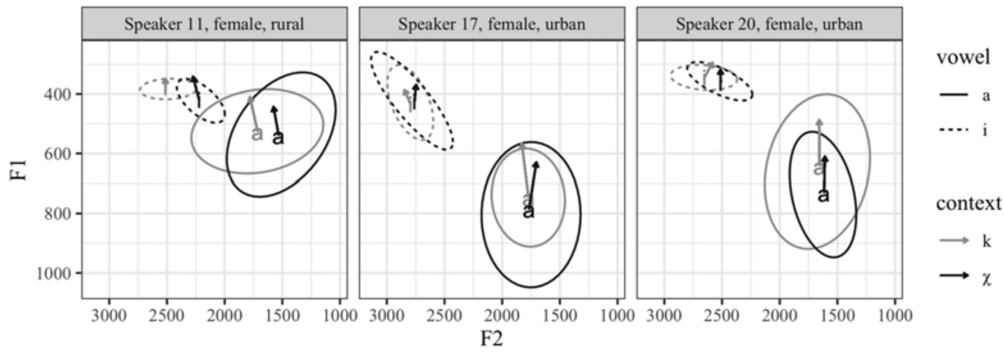

Figure 11. Stable velar fricative-like pattern in average transitions of preceding /i/ and /a/ for selected speakers.

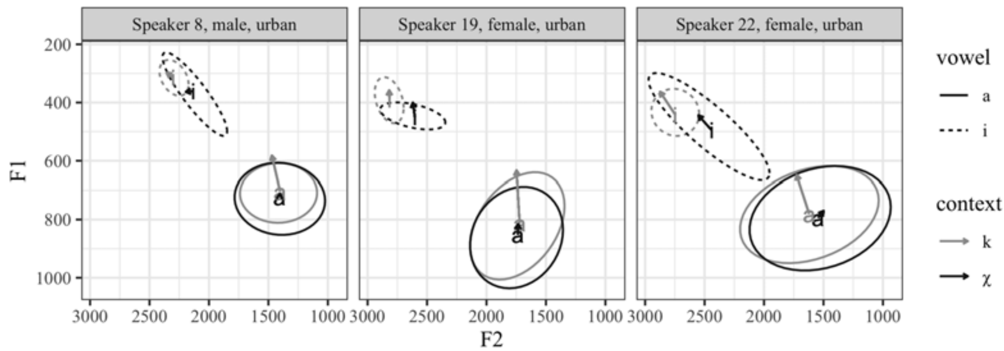

Figure 12. Homorganic fricative-like pattern in average transitions of preceding /i/ and /a/ for selected speakers.

the stop is the velar /k/, the similarity of transitions indicates that the fricative is likely also velar, or /x/, in both cases. This stable velar pattern was exhibited by four females: three urban, one rural.

4.2.2.3 Homorganic fricative pattern. Speakers with a termed 'homorganic' fricative appear to adapt the fricative to the vowel place of articulation (though they may also be adapting the vowel to a dorsal fricative with place variation).

In this way, the fricative place may vary between uvular [χ] near lower vowels such as [a] and [e], and possibly velar [x] or even palatal [ç] place for higher, fronter vowels like [i]. As seen for three representative speakers in Figure 12, each participant's average /ik/-/iχ/ transitions are similar to each other despite distinct consonant contexts, which indicates that the fricative matches the velar place of the stop when adjacent to /i/. In this case, the raised tongue root for a velar fricative would make the consonant homorganic with the high front vowel /i/.

For /a/, however, the transitions between /k/ and /χ/ are generally different from each other: /ak/ has an upward transition arrow, indicating lowered F1 closer to the stop consonant, but /aχ/ has almost no transition, indicating higher F1 even adjacent to the consonant. In this case, the fricative place differs from the velar stop place. It is more likely a true uvular, as the lowered tongue root keeps it homorganic with the low vowel /a/. Given the accommodation-like nature of this phenomenon, the exact fricative place could vary within vowel categories as well. For example, since fricative place depends on vowel height (or vice versa) rather than on vowel category, speakers may have a true uvular fricative with

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Table 14. Number of speakers with each fricative pattern by social group

	Stable uvular	Homorganic	Stable velar
Rural males	3	3	0
Urban males	0	4	0
Rural females	1	4	1
Urban females	0	3	3
TOTAL	**4**	**14**	**4**

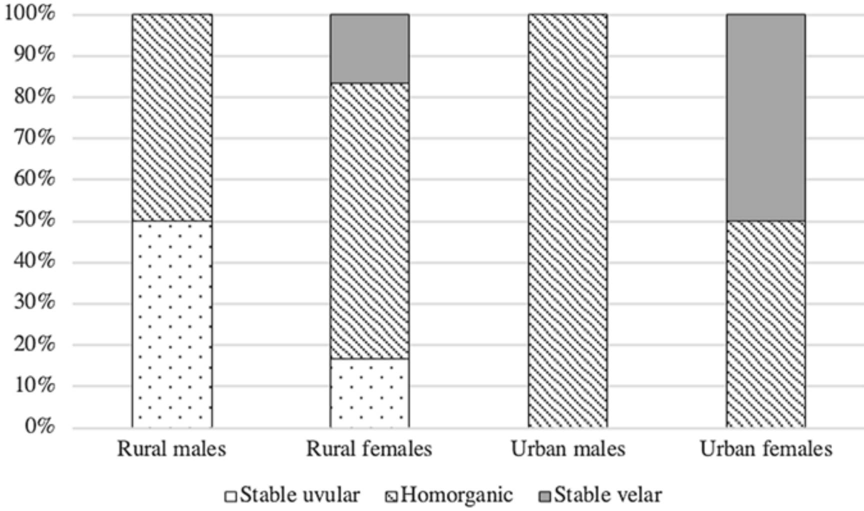

Figure 13. Distribution of fricative place patterns by social group.

lowered /i/, but a velar fricative with high /i/. This homorganic pattern was exhibited by the remaining eleven speakers: three rural males, four urban males, one rural female, and three urban females.

4.2.3 Summary of variation in fricative place patterns

Despite the overall effect of consonant context on vowel transitions found in the regression models, Chanka speakers appear to exhibit variation in the place of articulation of the fricative usually described as uvular. To show the hypothesized inter- and intraspeaker variability for fricative place, Table 14 summarizes how common each pattern was for each social group for /i/. Three rural males and one rural female had a stable uvular, one rural female and three urban females had a stable velar, and the remaining 14 speakers had the homorganic consonant pattern.

The significant effect of sex can be seen in the fact that the stable uvular is used mostly by male speakers (except for one rural female), and the stable velar only by female speakers. In fact, the almost-significant interaction between sex, location, and consonant context reflects the fact that urban males exclusively exhibit the homorganic pattern, and the stable uvular is used almost exclusively by rural males. Overall, the homorganic pattern seems preferred by the majority of participants. The graph in Figure 13 displays the distribution of the fricative place patterns by social group.

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5. Discussion

The variable strategies for resolving the articulatory conflict between high vowels and the uvular fricative in Chanka Quechua both confirm and expand traditional descriptions of the dialect. Confirming descriptions, vowel allophony exists at the population level, with average midpoints for all high vowels being significantly different between velar and uvular contexts. Overall, the uvular fricative's most significant effect on vowel characteristics was on F2, which resulted in backing of the front vowel /i/. This fact in itself expands traditional conceptualization of the allophony in Quechua, where authors often describe 'lowering' rather than 'retraction'.

At the same time, vowel allophony exhibits much more variation than has been described. This relates to the additional resolution strategy found in this study, previously undocumented for Chanka, in which the fricative consonant appears to variably adapt to the vowel place. In tandem, these strategies tend to be applied in complementary ways for plausible linguistic reasons. Furthermore, the results seem to highlight that social factors influence F2 variation the most, given that the F2 allophony model fit improved with the addition of by-speaker slopes. Section 5.1 presents the vowel-allophony/fricative-place pattern combinations found for Chanka, and Section 5.2 discusses the linguistic motivations for them. Finally, the social factors leading to variation in Chanka strategies will be discussed in Section 5.3.

5.1 Combining the conflict resolution strategies

The variability in vowel allophony and fricative place relates to the phonetic traits of the vowels and consonants involved. This section will first present the frequency of each allophony-fricative pattern combination, then discuss linguistic motivations for each one. To this end, Table 15 crosses the vowel allophony patterns previously presented in Table 12 (down the left side) and the fricative place patterns from Table 14 (across the top). Each cell in Table 15 shows an example of realizations allowed under each combination, as well as the total number of speakers that utilize each pattern combination. The pattern combination found in traditional descriptions, categorical allophony with a stable uvular fricative, is represented in the top left cell, and the combination most distant from traditional descriptions, null allophony with a stable velar, in the bottom right, with intermediate realizations in between.

As seen in the top left cell of Table 15, only two speakers (10%) have both of the patterns found in traditional descriptions for /i/ and /χ/. Instead, indicated by the four bottom right

Table 15. Combination of vowel and fricative place patterns: possible realizations of /χi/ and /χa/ and total speakers for each combination

		Fricative place pattern			TOTAL
		uvular (+)	homorganic (±)	velar (−)	
Allophony pattern	**categorical (+)**	1 2 [χe], [χa]	1 [χe], [χa]	0 [xe], [xa]	3
	variable (±)	1 [χe]/[χi], [χa]	7 [χe]/[xi], [χa]	3 [xe]/[xi], [xa]	11
	null (−)	1 [χi], [χa]	6 [xi], [χa]	1 [xi], [xa]	8
TOTAL		4	14	4	

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cells (shaded gray), most speakers (17/22 or 77%) exhibit either variable or null allophony with a homorganic or stable velar consonant. This means that they maintain a high vowel [i] most of the time (including adjacent to the fricative) and only produce a true uvular fricative adjacent to /a/ (in the homorganic pattern), if at all. Thus, the majority of speakers in this study employ pattern combinations that modify the place of the fricative, instead of modifying the place of the vowel as traditionally described. Certainly, the well-known categorical vowel allophony pattern exists in the data, but its variability and rarity indicate that fricative place accommodation is an additional common strategy for resolution of the articulatory conflict between high vowels and the uvular fricative in Chanka. In fact, the lack of speakers employing categorical vowel allophony with a stable velar (top right cell) further indicates that phonemic mid vowels do not appear without a uvular consonant trigger.

While contradictory to descriptions, the use of these alternative strategies would make sense in articulatory terms. A non-uvular consonant place can facilitate greater use of high vowels (a lack of vowel allophony), whether variably (Speakers 11, 20, 21) or categorically (Speaker 17). Similarly, more high vowels (less vowel allophony) can facilitate a non-uvular consonant place. This is because high vowels have fewer features in conflict with a velar consonant, and no conflict if the consonant place is homorganic to the vowel. Similarly, the rural male speaker (Speaker 1) who combines the homorganic consonant pattern with the categorical allophony pattern (top middle cell) does not generate any articulatory conflicts, as the variable fricative place matches that of the vowel. The appearance of this strategy, in any case, further demonstrates that both vowel allophony and consonant place movement can be used in combination to address the articulatory conflict. Further investigations can identify the fricative place more precisely in order to better describe how the strategies can be combined.

5.2 Linguistic motivations for conflict resolution strategies

The articulatory conflict resolution strategies found for Chanka reflect many that have documented cross-linguistically, with adjustments related to speech perception and production. Perceptually, dorsal consonant place movement likely has little impact in Chanka compared to other Quechua dialects. Chanka's historical velar-uvular place contrast, parallel to the velar-uvular stop contrast in other Southern dialects, is additionally cued by the stop-fricative manner difference. In Cuzco, the dorsals in /qusa/ [qosa] 'husband' and /kusa/ [kusa] 'good' differ only for the place feature, and vowel allophony adds an additional useful cue so that the minimal pairs differ for consonant place and vowel quality. In Chanka, however, the dorsals in /χusa/ 'husband' and /kusa/ 'good' already differ in two ways, for place and manner.

The Chanka trend away from categorical vowel allophony and a uvular consonant place parallels the uvular-velar stop alternation in Cochabamba Quechua (Pierrard 2018, 2020), as well as the merger that occurred in Ecuadorean Kichwa dialects in the sixteenth century. In Kichwa, null vowel allophony and fronting of the uvular stop to velar are categorical, and leading to a merger with the velar stop (Gualapuro Gualapuro 2017). Given the additional manner distinction between Chanka dorsals, a permanent change of the fricative to velar or any other place likely faces less resistance, as it does not lead to complete contrast neutralization. In fact, results from this study indicate that manner may even be the most salient feature used by Chanka speakers for distinguishing these phonemes. The dorsal consonant phonemes in Chanka can be easily distinguished based on manner regardless of their precise place or the height of adjacent vowels, which can thus remain high or lower variably without much impact on perception.

Furthermore, Chanka's small fricative inventory of only three phonemes – alveolar /s/, uvular /χ/, and glottal /h/ – allows for fricative place fluidity between

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palatal-velar-postvelar articulations without creating mergers. This velarizing or consonant fronting adaptation process is essentially an analogy of fricative place adaptation strategies applied in other languages, like /s/ palatalization in Dutch and Korean. Given that speakers have been found to consider fricative distinctions that are not phonemic in their language to be more perceptually similar than speakers who have a phonemic distinction (Johnson & Babel 2010), a fluid dorsal fricative is likely not very noticeable for Chanka speakers. Furthermore, the Peruvian Spanish <j> fricative is known to vary in this way, palatalizing near front vowels and velarizing elsewhere (Quilis 2002), which could be influencing Quechua. Uvular fricative movement is not as readily available for languages like Nuu-chah-nulth, which already has nine fricative phonemes, including two velar and four post-velar (Wilson 2007).

In the articulatory sense, the most surprising results in this study come from the two speakers who exhibit a stable uvular consonant with null or variable vowel allophony (bottom two cells of the left column). These speakers do not resolve the articulatory conflict with either of the patterns listed in traditional descriptions; furthermore, they seem to produce conflicting adjacent segments. In the case of the rural female with null allophony, she always produces a high front vowel at the midpoint and a uvular fricative at the transition. The rural male with variable allophony occasionally does the same. While this could indicate that these speakers tolerate the articulatory conflict, it is also possible that they resolve it in an alternative way that cannot be detected by the analytical methods used for this study. For example, they may have the gradient transition documented for Nuu-chah-nulth and Chilcotin. In this case, as found, the midpoint F1 and F2 values would always reflect high (and front, as necessary) vowels (null allophony), and the nearest 10% would always reflect an adjacent uvular consonant. However, if this is a gradient transition, the vowel F1 and F2 would be changing gradually between the midpoint and the nearest 10% measurement, which would lead to less conflict between the vowel and the uvular. To test for this gradient transition, F1 and F2 measurements could be compared at more intermediate points in the vowel duration. Expanding the dataset to additional participants in the future could provide further evidence for this potential gradient strategy. Although only two participants in this study of Chanka showed unexpected apparent tolerance of the conflict, a wider sample of the population would likely show more speakers with similar tendencies. In fact, this pattern mirrors the progressive lowering found by Molina-Vital (2011) for monolingual speakers of Cuzco Quechua. Controlling for Spanish proficiency, speech rate, and style would also evaluate whether any of these patterns were more common in monolinguals and/or careful speech.

The fact that the Chanka uvular has a fricative manner makes such a gradient transition more feasible than it would be for other Southern Quechua dialects that have a stop. The dialect differences reflect the way that Nuu-chah-nulth and other languages apply more defined resolution strategies near uvular stops than near a uvular fricative. Production-wise, a uvular fricative /χ/, with only a partial closure, allows for a longer transition to/from the vowel than a stop /q/, which requires a full closure. Perceptually, these gradient transitions rather than categorical allophony changes would sufficiently cue dorsal consonant place in Chanka.

Certainly, acoustic measurements of speech do not precisely reflect articulation. However, the acoustic results presented in this paper provide an initial picture of the unique ways that Chanka speakers appear to utilize vowel allophony and fricative place in order to resolve the potential articulatory conflict. A future perception study should test consonant distinctiveness, as well as the role of vowel height in consonant perception. Future research should also use additional measures to confirm variation in the fricative place, such as fricative center of gravity and ultrasound measurements. In addition, the research should evaluate whether different vowel transitions are a result of only a place distinction, or are also related to the manner distinction, or even other factors such as labialization, degree of tongue constriction, other changes in tongue position, or interspeaker differences in vowel quality. For instance, evaluation of a possible influence from the manner distinction can be done by comparing the transitions between a stop and a fricative where their place is known to be identical, such as /t/ and /s/.

5.3 Social factors conditioning variation

The categorical allophony pattern was considered the traditional pattern, and locally, rural Quechua monolinguals are considered the most 'traditional.' However, this uncommon pattern was found only for three rural males and no rural females. In fact, rural females often had null allophony. These unexpected results were initially though to be related to Spanish proficiency and education, as rural males generally had some (albeit limited) Spanish knowledge and formal education, whereas females had basically none. Rural males may be utilizing Spanish mid-vowels adjacent to the uvular, especially since they may have associated the controlled repetition task with a school setting, where they used Spanish. Since rural females had little influence from Spanish in their Quechua, their null allophony patterns evidence the wide fluidity of each Quechua vowel category on its own, seemingly without the defined allophonic contexts presented in prior descriptions. At the same time, the effect of Spanish that leads to categorical Quechua vowel allophony in emerging bilinguals (rural males) does not exist for the Spanish-proficient urban bilinguals. Urban speakers of both sexes allow much more fluidity between the high and mid-vowel categories in Quechua, as they generally exhibit the variable allophony pattern. Thus, it is unlikely that Spanish leads to categorical allophony in rural speakers, and more probable that the vowel is lowered for articulatory reasons depending on the fricative place.

Another plausible explanation for the lack of categorical allophony for most speakers comes from the evidence that the fricative place is not always uvular, and thus does not conflict as much with the high vowels. The homorganic pattern was prevalent for both sexes (14 speakers total). Males are more likely to have a uvular-velar place distinction for /a/, pronouncing [ka] and [χa] on average. This reflects the fact that they most often used the homorganic pattern, that three (rural) males were the only ones who maintained a stable uvular, and that no males had a stable velar. Females did not have this significant place distinction, meaning that their average pronunciations were [ka] and [xa]. This again reflects the prevalence of the homorganic pattern, as well as the four females (one rural, three urban) with a stable velar, and the single rural female with a stable uvular. The pervasiveness of the homorganic pattern for both urban and rural speakers also explains why location did not have an overall effect on transitions when all vowels were considered.

The details of the effect of location on the fricative patterns become clearer when only high vowels are observed. Urbanites had a higher percentage of velar or homorganic instead of uvular fricatives given their average smaller transition for /i/. These place articulations coincide with the fact that this group also had less vowel allophony, seemingly preferring to accommodate the consonant place instead. Even so, urban males may have more of an intermediate place between uvular and velar, given that they had a larger transition between /i/ and the fricative than rural males and thus would not have a homorganic consonant. This larger transition is articulatorily necessary given their lack of categorical vowel allophony. For females, no location-based difference was found for consonant place, which makes sense since all but one female had a non-uvular place pattern.

While a lack of allophony and the velar fricative seem linked to Spanish influence, paralleling the five Spanish vowels and velar or homorganic place of Spanish <j>, this does not completely explain the social facts reflected in the data. Certainly, more urbanites than rural speakers produce a velar some (homorganic) or all (stable velar) of the time. At the same time, rural females, with little Spanish proficiency, have less allophony and fewer uvular fricatives than rural males and urbanites. This finding may be explainable based on local social norms that allow for Quechua-internal variation. Chanka rural females tend to travel to the urban center more frequently than males, as local gender roles tend to require women to sell at markets while men work in the fields. The women still interact mostly in Quechua in the city. Thus, rural women potentially have more experience with the urban Quechua patterns that they seem to be using. While the differing patterns seem to come from Spanish contact in certain respects, they are also being shared among Quechua monolinguals. In fact, these two patterns, categorical vowel allophony with a uvular fricative and null allophony with a velar fricative, could be two separate outcomes related to Spanish influence. In the former case, familiarity with the Spanish five-vowel system leads speakers to maintain separate mid vowel categories in the specific uvular context. In the latter, the velar place of the Spanish dorsal fricative leads speakers to replace the Quechua uvular, and thus the articulatory need for allophony. More in-depth comparisons that include speakers' Spanish proficiency and characteristics of their Spanish phonology would shed light on these hypotheses.

6. Conclusion

This paper confirmed that the uvular can trigger vowel lowering and especially retraction in Chanka on a population level, which parallels the allophonic process in other Southern Quechua varieties and articulatory conflict resolution strategies in other languages. However, allophony occurs to a lesser extent, as both vowel allophony and consonant place accommodation are utilized, with three patterns found for each phenomenon. Specifically, Chanka's small phoneme inventory allows for fluidity in place realizations of both vowels and consonants without merging phonemic contrasts. Like for other Southern Quechua varieties, the fact that Chanka has only three vowel categories allows the high vowels to move across a wide range of F1 and F2 space in order to accommodate to the uvular. Moreover, the fact that Chanka has only one retracted and only three total fricative phonemes allows the underlying uvular fricative to move across a wider range of places in order to accommodate to the high front vowel.

Vowel allophony patterns include the traditionally described categorical allophony, null allophony, and an intermediate variable allophony pattern. The consonant accommodation patterns include the traditionally described stable uvular, a potentially Spanish-influenced stable velar, and a variable homorganic pattern. Speakers tend to combine these patterns as expected based on documented cross-linguistic strategies for the resolution of this articulatory conflict, with less categorical vowel allophony corresponding to fewer uvular fricative place articulations. Socially, speakers with typically high Spanish proficiency (urbanites) tend to utilize less categorical allophony and fewer uvulars. However, these patterns do not necessarily play out in the rural realm, as speakers with no Spanish (rural females) are also following the urbanite trends, while intermediate Spanish speakers (rural males) have more categorical allophony and stable uvular fricatives. In this case, the contact that Quechua monolinguals have with urban Quechua speakers may be leading to these similarities in non-traditional usage. Future studies can include individual measures of Spanish proficiency, which would help to disentangle the effect of Spanish on these conflict resolution strategies.

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Appendix A. Stimuli: Carrier phrases and target words, in order of elicitation.

(Stress is on the penultimate vowel of each word.)

Table A1. Noun target words

Wakpi* ________ *kachkan.	***Wakpi* __________ *rikuchkani.***
'Over there is a __________.'	'Over there I am seeing a ________.'
tuχu	tuχuta
tuχu	ruχuta
uχa	muχuta
suχu	uχata
chuku	chukuta
piχa	paχuta
paχu	pikita
siχi	makita
muχu	siχita
piki	piχata
maki	suχuta
aχa	aχata
aka	akata
χaχa	χaχata
chaka	chakata
waka	wakata

Table A2. Adjective target words

ʎuχi makiwan qapiy. 'Grab (it) with the left hand.'	***Wasipa ʎuχinpi suyachkan.*** 'He is waiting to the left of the house.'
ʎuχi	ʎuχinpi

Table A3. Verb target words

Ñuqa allinta* __________ *kaypi.	***Pay allinta* ___________ *chaypi.***
'Here I ___________ well.'	'There he/she _________ well.'
suχuni	suχun
sukuni	tukun
pukuni	pukun
sukini	sukin
pakini	pakin
ukuni	ukun

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Table A3. Continued

Ñuqa allinta* __________ *kaypi.	***Pay allinta* __________ *chaypi.***
'Here I __________ well.'	'There he/she __________ well.'
tiχuni	tiχun
rikuni	rikun
rantikuni	rantikun
mikuni	mikun
taχini	taχin
tuχani	tuχan
siχini	siχin
ʎikini	ʎikin
takini	takin
tuχuni	tuχun
saχini	saχin
tʃaχani	tʃaχan
maχani	maχan
aχani	aχan
waχani	waχan
pakani	pakan
nakani	nakan
takani	takan

Appendix B. Results of best-fit mixed effects model of F1 at midpoint (high vowels)

Table B1. Results of best-fit mixed effects model of F1 at midpoint (high vowels)

	Estimate	Std. error	*df*	*t*-value	Significance
(Intercept)	396.43	16.61	26.00	23.87	.***
vowel (vs. /i/) /u/	17.67	7.12	2284.57	2.48	*
consonant context (vs. /k/) /χ/	34.68	7.34	2281.09	4.73	***
sex (vs. female) male	–46.35	23.04	24.05	–2.01	[.056]
location (vs. rural)					[.834]
urban	4.87	23.04	24.04	0.21	.
vowel position (vs. following) preceding	8.75	5.52	2281.22	1.59	[.113]
stress (vs. unstressed) stressed	17.11	5.52	2281.25	3.10	**
vowel × context (vs. /i/ × /k/) /u/ × /χ/	–29.54	9.70	2281.10	–3.05	**

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Table B1. Continued

	Estimate	Std. error	*df*	*t*-value	Significance
vowel × sex (vs. /i/ × female) /u/ × male	20.63	7.85	2284.61	2.63	**
context × sex (vs. /k/ × female) /χ/ × male	33.12	8.03	2281.11	4.12	***
vowel × location (vs. /i/ × rural) /u/ × urban	13.15	7.81	2284.58	1.69	[.092]
context × location (vs. /k/ × rural) /χ/ × urban	9.24	7.93	2281.08	1.17	[.244]
sex × location (vs. female × rural) male × urban	−39.07	34.59	24.12	−1.13	[.270]
vowel × position (vs. /i/ × following) /u/ × preceding	−3.70	7.97	2281.19	−0.47	[.642]
context × position (vs. /k/ × following) /χ/ × preceding	−18.98	8.30	2281.20	−2.29	*
vowel × stress (vs. /i/ × unstressed) /u/ × stressed	6.50	7.57	2281.19	0.86	[.390]
context × stress (vs. /k/ × unstressed) /χ/ × stressed	−19.65	7.83	2281.06	−2.51	*
vowel position × stress (vs. /k/ × unstressed) /χ/ × stressed	−19.65	7.83	2281.06	−2.51	
context × stress (vs. following × unstressed) preceding × stressed	−7.36	8.26	2281.21	−0.89	[.373]
vowel × context × sex (vs. /i/ × /k/ × female) /u/ × /χ/ × male	−8.17	10.61	2281.10	−0.77	[.441]
vowel × context × location (vs. /i/ × /k/ × rural) /u/ × /χ/ × urban	−14.55	10.50	2281.09	−1.39	[.166]
vowel × sex × location (vs. /i/ × female × rural) /u/ × male × urban	−11.67	11.68	2282.70	−1.00	[.318]
context × sex × location (vs. /k/ × female × rural) /χ/ × male × urban	−20.76	12.06	2281.07	−1.72	[.085]
vowel × context × position (vs. /i/ × /k/ × following) /u/ × /χ/ × preceding	33.27	11.08	2281.17	3.00	**
vowel × context × stress (vs. /i/ × /k/ × unstressed) /u/ × /χ/ × stressed	27.45	10.52	2281.08	2.61	**

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Table B1. Continued

	Estimate	Std. error	*df*	*t*-value	Significance
vowel × position × stress (vs. /i/ × following × unstressed) /u/ × preceding × stressed	–9.61	11.57	2281.21	–0.83	[.406]
context × position × stress (vs. /k/ × following × unstressed) /χ/ × preceding × stressed	26.55	12.06	2281.18	2.20	*
vowel × context × sex × location (vs. /i/ × /k/ × female × rural) /u/ × /χ/ × male × urban	13.49	15.90	2281.07	0.85	[.396]
vowel × context × position × stress (vs. /i/ × /k/ × following × unstressed) /u/ × /χ/ × preceding × stressed	–26.44	15.88	2281.18	–1.66	[.096]

significance codes: *** = <0.001, ** = <0.01, * = <0.05,. = <0.1

Appendix C. Results of best-fit mixed effects model of F2 at midpoint (high vowels)

Table C1. Results of best-fit mixed effects model of F2 at midpoint (high vowels)

	Estimate	Std. error	*df*	*t*-value	Significance
(Intercept)	2626.66	45.05	25.62	58.30	***
vowel (vs. /i/) /u/	–1612.87	66.79	21.40	–24.15	***
consonant context (vs. /k/) /χ/	–156.19	39.01	36.52	–4.00	***
sex (vs. female) male	–413.52	61.20	21.82	–6.76	***
location (vs. rural) urban	198.81	61.18	21.79	3.25	**
vowel position (vs. following) preceding	–72.83	21.31	2222.10	–3.42	***
stress (vs. unstressed) stressed	–30.04	21.33	2224.82	–1.41	[.159]
vowel × context (vs. /i/ × /k/) /u/ × /χ/	45.55	44.69	39.61	1.02	[.314]
vowel × sex (vs. /i/ × female) /u/ × male	403.40	90.37	18.19	4.46	***
context × sex (vs. /k/ × female) /χ/ × male	53.15	49.00	22.74	1.09	[.289]
vowel × location (vs. /i/ × rural) /u/ × urban	–165.78	90.29	18.13	–1.84	[.083]
context × location (vs. /k/ × rural) /χ/ × urban	52.30	48.76	22.29	1.07	[.295]

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Table C1. Continued

	Estimate	Std. error	*df*	*t*-value	Significance
sex × location (vs. female × rural) male × urban	82.07	91.94	21.94	0.89	[.382]
vowel × position(vs. /i/ × following) /u/ × preceding	47.46	30.81	2228.35	1.54	[.124]
context × position(vs. /k/ × following) /χ/ × preceding	–36.94	32.18	2234.59	–1.15	[.251]
vowel × stress (vs. /i/ × unstressed) /u/ × stressed	68.60	29.25	2226.64	2.35	*
context × stress (vs. /k/ × unstressed) /χ/ × stressed	47.17	30.30	2228.04	1.56	[.120]
vowel position × stress (vs. /k/ × unstressed) /χ/ × stressed	53.78	31.91	2222.63	1.69	[.092]
vowel × context × sex (vs. /i/ × /k/ × female) /u/ × /χ/ × male	–93.52	52.79	20.29	–1.77	[.092]
vowel × context × location (vs. /i/ × /k/ × rural) /u/ × /χ/ × urban	–70.41	52.45	19.77	–1.35	[.195]
vowel × sex × location (vs. /i/ × female × rural) /u/ × male × urban	–194.85	134.64	17.84	–1.45	[.165]
vowel × context × position (vs. /i/ × /k/ × following) /u/ × /χ/ × preceding	221.68	42.89	2235.03	5.17	***
vowel × context × stress (vs. /i/ × /k/ × unstressed) /u/ × /χ/ × stressed	52.10	40.67	2228.25	1.28	[.200]
vowel × position × stress (vs. /i/ × following × unstressed) /u/ × preceding × stressed	–100.35	44.75	2229.62	–2.24	*
context × position × stress (vs. /k/ × following × unstressed) /χ/ × preceding × stressed	–74.79	46.72	2233.47	–1.60	[.110]
vowel × context × sex × location (vs. /i/ × /k/ × female × rural) /u/ × /χ/ × male × urban	186.93	78.47	19.86	2.38	*
vowel × context × position × stress (vs. /i/ × /k/ × following × unstressed) /u/ × /χ/ × preceding × stressed	–56.45	61.49	2235.70	–0.92	[.359]

significance codes: *** = <0.001, ** = <0.01, * = <0.05,. = <0.1

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Appendix D. Results of logistic regression for Euclidean distance (all vowels)

Table D1. Results of logistic regression for Euclidean distance (all vowels)

	Estimate	Std. error	*df*	*t*-value	Significance
(Intercept)	122.05	15.27	256.65	8.00	***
vowel (vs. /a/)					
/i/	34.02	20.42	3783.70	1.67	[.096]
/u/	9.66	19.72	3806.82	0.49	[.624]
consonant context (vs. /k/)					
/χ/	36.61	18.18	3805.85	2.01	*
sex (vs. female)					
male	–43.13	16.65	100.46	–2.59	*
location (vs. rural)					
urban	–1.92	16.56	98.25	–0.12	[.908]
vowel position (vs. following)					
preceding	81.88	14.74	3805.00	5.56	***
stress (vs. unstressed)					
stressed	8.17	16.07	3805.52	0.51	[.612]
vowel × context (vs. /a/ × /k/)					
/i/ × /χ/	–4.55	28.41	3805.93	–0.16	[.873]
/u/ × /χ/	–54.55	26.22	3807.69	–2.08	*
vowel × sex (vs. /a/ × female)					
/i/ × male	10.66	21.42	3767.45	0.50	[.619]
/u/ × male	3.66	21.13	3808.63	0.17	[.862]
context × sex (vs. /k/ × female)					
/χ/ × male	–23.67	18.67	3805.84	–1.27	[.205]
vowel × location (vs. /a/ × rural)					
/i/ × urban	–62.67	21.32	3766.16	–2.94	**
/u/ × urban	–10.86	20.94	3806.96	–0.52	[.604]
context × location (vs. /k/ × rural)					
/χ/ × urban	–3.82	18.53	3805.35	–0.21	[.837]
sex × location (vs. female × rural)					
male × urban	31.13	25.38	111.41	1.23	[.222]

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Table D1. Continued

	Estimate	Std. error	*df*	*t*-value	Significance
vowel × position (vs. /a/ × following)					
/i/ × preceding	–63.84	22.06	3807.40	–2.89	**
/u/ × preceding	–49.03	22.57	3806.82	–2.17	*
context × position(vs. /k/ × following)					
/χ/ × preceding	–91.24	20.00	3805.02	–4.56	***
vowel × stress (vs. /a/ × unstressed)					
/i/ × stressed	–26.44	22.96	3807.56	–1.15	[.250]
/u/ × stressed	–7.06	22.25	3806.03	0.32	[.751]
context × stress (vs. /k/ × unstressed)					
/χ/ × stressed	3.22	21.05	3805.16	0.15	[.878]
vowel position × stress (vs. /k/ × unstressed)					
/χ/ × stressed	2.21	20.82	3805.50	0.11	[.092]
vowel × context × sex (vs. /a/ × /k/ × female)					
/i/ × /χ/ × male	1.28	30.33	3806.40	0.04	[.966]
/u/ × /χ/ × male	23.34	27.82	3807.51	0.84	[.402]
vowel × context × location (vs. /a/ × /k/ × rural)					
/i/ × /χ/ × urban	9.20	30.01	3805.55	0.31	[.759]
/u/ × /χ/ × urban	16.44	27.62	3807.22	0.60	[.552]
vowel × sex × location (vs. /a/ × female × rural)					
/i/ × male × urban	21.27	32.65	3826.45	0.65	[.515]
/u/ × male × urban	78.14	31.94	3807.22	2.45	*
context × sex × location (vs. /k/ × female × rural)					
/χ/ × male × urban	4.46	28.65	3805.40	0.16	[.876]
vowel × context × position (vs. /a/ × /k/ × following)					
/i/ × /χ/ × preceding	60.89	31.79	3807.68	1.92	[.055]
/u/ × /χ/ × preceding	86.96	29.59	3806.29	2.94	**
vowel × context × stress (vs. /a/ × /k/ × unstressed)					
/i/ × /χ/ × stressed	–21.47	31.41	3805.29	–0.68	[.494]
/u/ × /χ/ × stressed	52.94	29.66	3805.64	1.79	[.074]

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Table D1. Continued

	Estimate	Std. error	*df*	*t*-value	Significance
vowel × position × stress (vs. /a/ × following × unstressed)					
/i/ × preceding × stressed	38.89	32.20	3807.43	1.21	[.227]
/u/ × preceding × stressed	14.99	31.85	3807.39	0.47	[.638]
context × position × stress (vs. /k/ × following × unstressed)					
/χ/ × preceding × stressed	−12.30	28.23	3805.13	−0.44	[.663]
vowel × context × sex × location (vs. /a/ × /k/ × female × rural)					
/i/ × /χ/ × male × urban	61.72	45.92	3805.74	1.34	[.179]
/u/ × /χ/ × male × urban	8.04	42.11	3806.11	0.19	[.0849]
vowel × context × position × stress (vs. /a/ × /k/ × following × unstressed)					
/i/ × /χ/ × preceding × stressed	6.74	45.66	3807.19	0.15	[.883]
/u/ × /χ/ × preceding × stressed	−91.61	41.75	3806.50	−2.20	*

significance codes: *** = <0.001, ** = <0.01, * = <0.05

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