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An Investigation of the Articulatory Correlates of Vowel Anteriority in Kazakh, Kyrgyz, and Turkish using Ultrasound Tongue Imaging

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Abstract

This paper presents an articulatory study of vowel production in three Turkic languages (Kazakh, Kyrgyz, and Turkish) using ultrasound tongue imaging in order to determine what aspects of tongue position correspond to the vowel anteriority contrasts in these languages, especially regarding the tongue body (TB) and tongue root (TR).

The results of this study suggest that the Turkish vowel anteriority contrast involves mainly TB position, whereas the Kazakh and Kyrgyz vowel anteriority contrasts involve both TR and TB position. This latter pattern appears to confirm the existence of a type of vowel anteriority contrast whose existence has been hypothesised but not previously verified instrumentally.

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1 Overview

This paper presents an articulatory study of vowel production in three Turkic languages (Kazakh, Kyrgyz, and Turkish) using ultrasound tongue imaging in order to determine what aspects of tongue position correspond to the vowel anteriority contrasts in these languages, especially regarding the tongue body (TB) and tongue root (TR).

The results of this study suggest that the Turkish vowel anteriority contrast involves mainly TB position, whereas the Kazakh and Kyrgyz vowel anteriority contrasts involve both TR and TB position. This latter pattern appears to confirm the existence of a type of vowel anteriority contrast whose existence has been hypothesised (Vaux 2009) but not previously verified instrumentally.

This paper is structured as follows: Section 2 briefly overviews the literature on vowel anteriority and claims of TR involvement in the vowel systems of languages of Central Eurasia; Section 3 details the methodology used for data collection in this study; Section 4 presents the results; and Section 5 discusses the results and draws preliminary conclusions.

2 Background

Vowel “backness”, a type of anteriority, is a feature that distinguishes vowels in many attested vowel systems (Ladefoged and Maddieson 1996:ch. 9). It is understood to correspond to the front-back position of the tongue body: for front vowels, the highest part of the tongue body is further forward than for that of back vowels. Vowel height, in turn, corresponds to the height of the tongue during articulation. In terms of acoustics, vowel backness is inversely correlated with the second formant (F2), while vowel height is inversely correlated with the first formant (F1). Articulatory and acoustic models of vowels along these dimensions result in similar “vowel spaces” (cf. Lindau 1978).

Some attested languages have two types of anteriority contrast in their vowel systems: both a backness contrast and a tongue root contrast. In these languages, any given vowel is either front or back, as well as tongue-root advanced or retracted:¹ each vowel must match one of the four logical combinations, and vowels of all four types are present. This pattern is found most notably among quite a few Western African languages belonging to a range of language families (Ladefoged and Maddieson 1996:ch. 9). Articulatory and acoustic measurements of vowels in such a system (Akan) are shown in Figure 1. The main articulatory difference between vowels of the two tongue-root contrasted categories is the position of the tongue root, while the main acoustic differences are that the tongue-root retracted vowels have formant measurements indicative of “lower” (higher F1) and “further back” (lower F2) vowel qualities.

A number of Central Eurasian languages have also been described as exhibiting this sort of vowel system (i.e., one involving both a tongue body contrast and a tongue root contrast), including both Mongolic and Tungusic languages. The Mongolic languages include Western Buriat (Kang and Ko 2012), Buriat (Svantesson 1985, citing Bypaев 1959), Tsongol Buriat (Kang and Ko 2012),

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¹Such vowel systems may vary in terms of whether they contrast tongue-root advanced/neutral, advanced/retracted, or neutral/retracted.

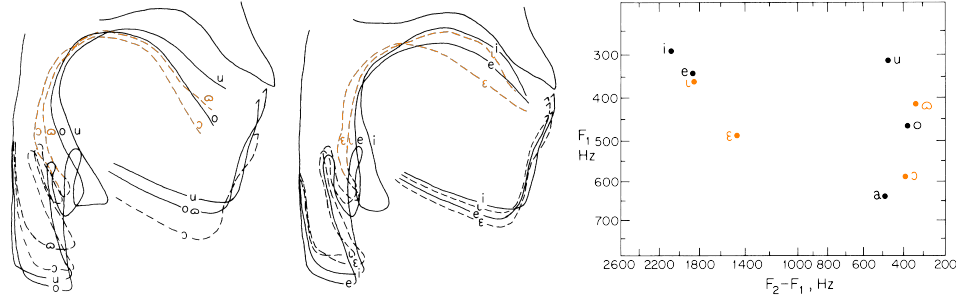


Figure 1: X-ray tracings of the articulation of some Akan vowels, showing four tongue-body back vowels (left pane) and four tongue-body front vowels (center pane), each category consisting of two tongue-root retracted vowels (broken lines) and two tongue-root advanced vowels (solid lines). Spectral measurements of these eight vowels are shown in the right pane (Lindau 1978). Adapted with permission from author.

Halh (Rialland and Djamouri 1984, Svantesson 1985, Svantesson et al. 2005), Baarin (Svantesson 1985), and Šiliingol (Svantesson 1985), and the Tungusic languages include Ola Even (Ard 1983), Solon (Svantesson 1985), Oroch (Tolskaya 2014), Bystraya District and Sebian-Küöl Even (Aralova et al. 2012, Aralova 2015), Eastern Ewen (Kang and Ko 2012), and Northeastern Oroqen (Lulich and Whaley 2012). Some of these sources infer the existence of a tongue-root vowel system based solely on phonological evidence, while most rely on acoustic measures. A few also use articulatory measures, but are limited to X-ray image sets produced for other studies, which, for the most part, consist of a single image per vowel category.

In terms of Turkic languages, Vajda (1994), using others' acoustic and articulatory data, argues that Kazakh is not like typical tongue-root languages such as the Mongolic and Tungusic languages above, but that it has a vowel system which contrasts *only* tongue root position, and not tongue body position. Additionally, based on phonological evidence, Vaux (2009) argues that Proto-Turkic had inversely linked [ATR] (advanced tongue root) and [back] features (meaning, e.g., that a given vowel is either [+ATR] and [-back] or [-ATR] and [+back]), and that modern Turkic languages have reorganised this system in various ways. Under this view, Proto-Turkic anterior vowels would have been [-back] and [+ATR] (in phonetic terms, TB front and TR advanced), while posterior vowels would have been [+back] and [-ATR] (TB back and TB retracted). Vaux argues that Turkish appears to have lost the link between [ATR] and [back], so that only [back] contrasts the anterior and posterior vowels, whereas Sakha has relinked [ATR] to [high], so that e.g. low vowels would be [-high] (TB low) and [-ATR] (TR retracted). Other Turkic languages are not discussed in detail, but Vaux (2009) seems to imply that they should be like Proto-Turkic unless demonstrated otherwise.

The Mongolic and Tungusic vowel systems as described in these sources fit into the existing understanding of vowel anteriority typology as described above, but the Turkic languages do not. A summary of this typology is presented in Table 1 with additional lines for the types hypothesized to exist but not quantified.

This study investigates the vowel anteriority contrast in three languages, each from a different typological category, to determine to what extent the TB and TR each play in the anteriority contrast: Turkish, claimed by Vaux (2009) on phonological grounds to have a TB-only backness contrast; Kazakh, claimed by Vajda (1994) to have a TR-only backness contrast; and Kyrgyz, a close relative of Kazakh expected by Vaux (2009) to have linked TR and TB anteriority. It is found that Turkish and Kyrgyz are correctly positioned in the typology, and that Kazakh may join Kyrgyz in the “correlated TR and TB anteriority” type—a type not previously documented articulatorily.²

A map showing where the Central Eurasian languages described in the literature as having a TR-related contrast are spoken is shown in Figure 2, in addition to Turkish and Kyrgyz, both examined in this study, but neither described as having a TR-related anteriority contrast.

²Since Kazakh appears to be the only language that has ever been suggested to have a TR-only system, it may also be safe to conclude that TR-only systems likely do not exist.

type	anteriority	examples	contrasting features		
			TB _h	TB _b	TR
no anteriority	none	Margi, Eastern Arrernte, Ubykh, Abkhaz	yes	no	no
backness	TB	English, Italian, Yoruba, <i>Turkish</i>	yes	yes	no
tongue root	TR & TB	Igbo, Akan, Ateso, <i>various Tungusic languages, various Mongolic languages</i>	yes	yes	yes
[hypothetical]	TR	<i>Kazakh</i>	yes	no	yes
[hypothetical]	TB, TR=TB _h	<i>Sakha</i>	=TR	yes	=TB _h
[hypothetical]	TR+TB	<i>other modern Turkic languages</i>	yes	=TR	=TB _b

Table 1: A brief typology of vowel anteriority, outlining well documented types (above the horizontal line), as well as the new types discussed above which have not been articulatorily documented or incorporated into current typologies (below the horizontal line). The languages discussed above are in italics, and the remaining languages are exemplary of the categories as discussed by Ladefoged and Maddieson (1996:ch. 9). TB_h stands for tongue body height, TB_b stands for tongue body backness, TR stands for tongue root anteriority, and ‘=’ indicates that two features are linked.



Figure 2: A map depicting where each Central Eurasian language is spoken for which TR anteriority has been explicitly described, as well as the two additional Turkic languages examined in this study.

3 Methodology

Native speakers of Kazakh, Kyrgyz, and Turkish read stimuli embedded in carrier phrases. Brief background on the participants is provided in Section 3.1, and the stimuli and carrier phrases are presented in Section 3.2. Audio recordings were made, and the position of the tongue was recorded using ultrasound imaging. Ultrasound imaging of the tongue (UTI) and the particular setup used in this study are discussed in Section 3.3 and the specific measures used in this study are described in Section 3.4. The results of the acoustic analysis (spectral properties and duration of the vowels) are not reported in this study, but may be found in Washington (2016).

3.1 Languages and Participants

Speakers of Kazakh, Kyrgyz, and Turkish were recruited to participate in this study in Bloomington, Indiana between 2014 and 2016. A total of four Turkish speakers, five Kyrgyz speakers, and three Kazakh speakers participated. Besides reporting educated native-speaker proficiency in the language of interest, all participants knew at least one other language well, and most at least two. Table 2 lists some background information reported by each participant.

Language	Code	Hometown	Gender	Age	Other languages
Kazakh	P01	Taldıqorǵan, Kazakhstan	F	26	Russian, English, some German
Kazakh	P02	Ürümchi, China	F	33	Chinese, English
Kazakh	P10	Almaty, Kazakhstan	F	29	Russian, English, some Uzbek, some Spanish, some French
Kyrgyz	P03	Naryn, Kyrgyzstan	F	32	Russian, English, some German
Kyrgyz	P04	Joon küngöy, Kyrgyzstan	F	42	Russian, Turkish, English, Arabic
Kyrgyz	P05	Temen-Suu, Kyrgyzstan	F	55	Russian, some English
Kyrgyz	P08	Nooqat, Kyrgyzstan	M	34	Turkish, Russian, Uzbek, some English
Kyrgyz	P12	Orto-Nura, Kyrgyzstan	F	23	Russian, English, some Turkish, some German
Turkish	P06	Adana, Turkey	M	30	English, Persian
Turkish	P07	Iğdır, Turkey	F	32	Azerbaijani, English, Mandarin, Persian, Khalkha, Tibetan, Arabic, Uyghur
Turkish	P09	İstanbul, Turkey	F	31	English, Persian, Ottoman, German
Turkish	P11	Şanlıurfa, Turkey	M	31	Kurdish, English, Persian

Table 2: Basic demographics of participants in this study. Ages are approximate (based on reported birth year) at time of recording.

Participants are from a geographically diverse set of areas within the regions where each language is spoken; hence, at least two distinct dialects of each language are represented in the study. The hometowns of the participants are shown on the map in Figure 3.



Figure 3: The hometowns of the 3 Kazakh speakers (P01, P02, P10), 5 Kyrgyz speakers (P03, P04, P05, P08, P12), and 4 Turkish speakers (P06, P07, P09, P11) who took part in this study.

3.2 Stimuli and Protocol

Speakers of the three languages read similarly structured carrier phrases containing words with a balance of consonant contexts for each vowel and a range of syllable structures and number of syllables. Short vowels in syllables of consistent shape in multi-syllabic words were measured for all speakers to avoid effects of vowel harmony, prosodic position, syllable structure, and phonemic vowel length contrasts. Properties of the stimulus set are provided in Table 3.

Language	# syllables	1st syllable	C ₁ (before measured V)	C ₂ (following measured V)
Kazakh	3	open	[k]~[q], [t]	[s]
	1	closed	[k]~[q], [t]	[s]
Kyrgyz	3	open	[k]~[q], [t]	[ʃ], [l]~[ɬ], [r]
Turkish	3	closed	[b], [d], [k], [kʲ]	[s], [z], [ʃ], [r]

Table 3: Properties of the stimuli measured for each language.

The stimuli measured consisted mostly of three-syllable words formed around CVC stems. Exceptions included the word /tæsəl/ in Kazakh, and the inclusion of CVC isolation forms with

“high” vowels in Kazakh (/ə/, /ʌ/, /ɐ/, /ʊ/), since these vowels are particularly prone to deletion in the environment of the other stimuli. In all cases, only the vowel of the first syllable was measured. For a detailed description of the carrier phrases, more information on the stimuli including the complete set recorded, and discussion of various other challenges encountered related to the stimuli that were measured, see Washington 2016(81–82, 106–107, and 140–142 especially).

3.3 Ultrasound Tongue Imaging and Equipment Used

Ultrasound imaging was used in this study to capture the shape of the tongue during the articulation of vowels. Ultrasound imaging allows for reasonably high-speed recording of the shape of the tongue surface during speech production (Stone 2005). A transducer is held in place under the chin, and standard 2-dimensional ultrasound systems are able to capture an area like that shown in Figure 4. In this study, a Philips EPIQ 7 ultrasound system was used with an X6-1 transducer. An Articulate Instruments Probe Stabilisation Headset (Articulate Instruments Ltd. 2008) was used to stabilise the probe. An image of the author wearing the headset and probe in a similar configuration as participants did is presented in Figure 4, along with a typical frame produced by the ultrasound system.

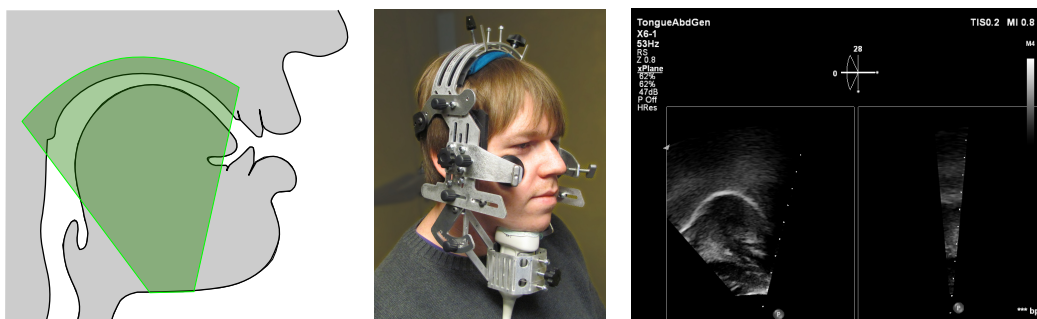


Figure 4: Left: an approximation of the area of the vocal tract imaged using ultrasound. Adapted from https://commons.wikimedia.org/wiki/File:Cardinal_vowel_tongue_position-front.svg © Wikimedia Commons User:Badseed / CC BY-SA 4.0. Center: the probe stabilisation headset and ultrasound transducer used, modelled by the author. Right: A raw frame of the ultrasound-imaged tongue. Left-most subframe: midsagittal view with the front of the tongue to the right (fade-out due to the “jaw shadow” caused by the mandible bone) and the back to the left; right-most subframe: a plane perpendicular to the midsagittal plane, not examined in this study.

There are several limitations to ultrasound imaging of the tongue. While the area from the tip of the tongue to the tongue root may be captured, the mandible and hyoid bones, respectively, create “shadows” in these areas. Also, because of how ultrasound imaging works, it is usually not possible to image anything beyond the tongue-air interface; in other words, any parts of the vocal tract above the surface of the tongue are not generally imaged. Audio and ultrasound recordings were controlled with the same foot pedal switch, allowing the recordings to be synchronised based on end times.

3.4 Measurements

Vowels of interest were delimited in Praat TextGrids (Boersma and Weenink 2016) aligned to the audio recordings. The ultrasound frames that corresponded to the half point of monophthongs and the one-third and two-thirds points of diphthongs were identified and extracted. The tongue surface in each frame was hand-traced using a Python script written by the author.

3.5 Analytical Methodology

To impressionistically understand the relative position of the tongue and parts of the tongue during the articulation of each vowel, the average tongue position for each vowel was plotted, along with

standard deviation bands. For each vowel category, these measures were calculated at 1° intervals using radial coordinates (a method supported by Mielke 2015), using the transducer as the origin (a method supported by Heyne and Derrick 2015), but plotted in axial coordinates, with pixels in the ultrasound image as the axes. Examples are shown in Figures 5, 7, and 9.

Additionally, a measure of tongue region differentiation was developed to understand the role that the position of different areas of the tongue plays in the anteriority contrast of each language.³ Plots were created to show how this measure was arrived at, with the angle as the x axis and the radial distance as the y axis. These plots (Figures 6, 8, and 10) show the following information: a blue line representing the difference in average radial distance from the ultrasound transducer of all traces of each category (here, anterior and posterior vowels) at 1° intervals; a blue band representing the standard deviation of this difference; a thick red line representing the Z-value, or the number of standard deviations of the average from zero, of the difference at each 1° interval; two thin vertical red lines representing the Z maxima, or the angles at which there is the greatest differentiation between the two categories on either side of the zero-crossing (where the two categories overlap/are not at all differentiated in tongue position).

The positive Z maximum in this data is the posterior area where the position of the tongue is most distinct between anterior and posterior vowels, while the negative Z maximum is the anterior area where the vowel categories are best distinguished. The number of degrees from the zero crossing—where the position of the tongue is not distinct for the two categories—to the two Z maxima is presented in the form of a ratio between their absolute values (posterior:anterior). Intuitively, this ratio approximates how far forward or back in the vocal tract the posterior position of the tongue is that is used to most contrast anterior and posterior vowels (Figure 11). When the tongue body is the primary contrast between two categories, the arc of the tongue will simply be offset between the categories, resulting in a low ratio. When the tongue root is also involved, then the additional differentiation in the posterior region will result in a larger ratio.

By using a dynamic reference system (the angular difference between a Z-value of 0 and Z maxima as a ratio), this measure has the potential to be speaker-agnostic, allowing for quantifiable generalisations at the level of the linguistic variety, as well as the ability to compare across linguistic varieties. It is also computationally simpler than the widespread SSANOVA approach (Davidson 2006), for which area of category differentiation is normally assessed visually, without quantification.

4 Results

The data for Turkish (Section 4.1) suggests that vowel anteriority is contrasted by position of the TB alone, while the data for Kyrgyz (Section 4.2) and Kazakh (Section 4.3) suggests that vowel anteriority is contrasted by position of both the TR and TB.

4.1 Turkish

The average tracings of the ultrasound-imaged tongue shapes are presented for the vowels produced by the Turkish-speaking participants in this study in Figure 5.

The anterior vowels are produced differently from the posterior vowels in one consistent way: the arched part of the TB is further forward in the anterior vowels. This results in a difference near the TR as well, where anterior vowels “bulge” back to some extent. However, the TR appears to be more of a pivot for the rotation of the TB than an independently controlled articulator, in that the most posterior imaged areas of the tongue for anterior and posterior vowels overlap for the most part.

Measures of the region of greatest difference in tongue position are presented for the Turkish-speaking participants in this study in Figure 6.

In these plots, the differentiation between anterior and posterior vowels (the thick red line, mainly, representing Z values) in posterior areas (the left portion of the plots) of the imaged tongue exhibits

³The methods overviewed in this section have been discussed in more detail in Washington 2016:66–70 and Washington and Washington 2018, and source code implementing these methods is available at <https://github.com/jonorthwash/ultrasound-processing>.

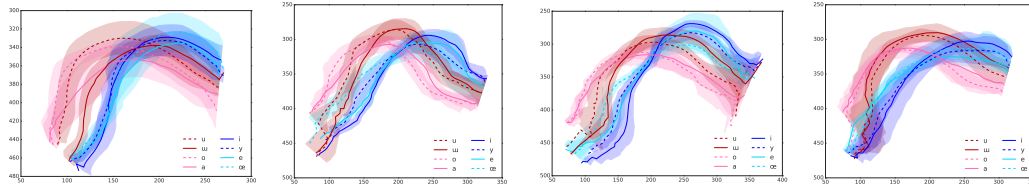


Figure 5: The imaged tongue surface during vowel articulation for P06, P07, P09, and P11, respectively. The front of the mouth is to the right. Red shades indicate posterior vowels and blue shades indicate anterior vowels; darker shades are higher vowels and broken lines are rounded vowels.

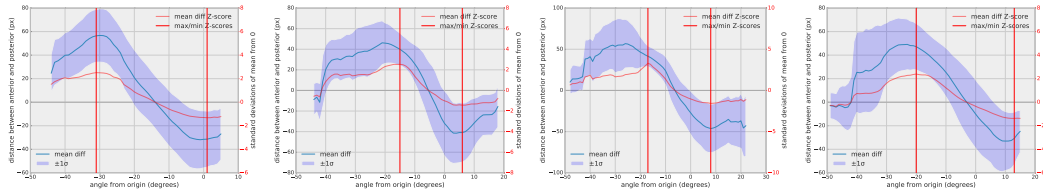


Figure 6: Area of differentiation plots for P06 (ratio 1.207), P07 (ratio 0.826), P09 (ratio 0.724), and P11 (ratio 1.129), respectively.

a return to (or towards) zero beyond the further back (positive) of the two Z maxima. Additionally, the posteriority ratios are low, around 1:1, further supporting the analysis that the TR is not actively involved in the contrast between anterior and posterior vowels, and that the main distinguishing factor in the articulation of these two classes is the TB.

4.2 Kyrgyz

The average tracings of the ultrasound-imaged tongue shapes are presented for the vowels produced by the Kyrgyz-speaking participants in this study in Figure 7.⁴

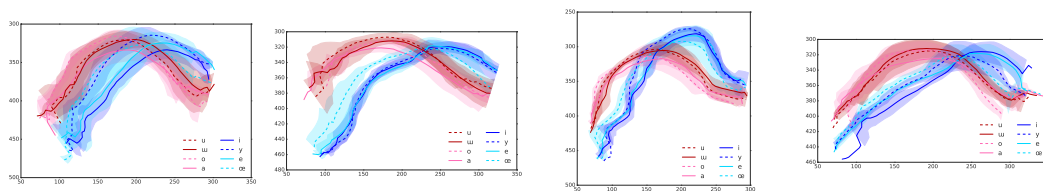


Figure 7: The imaged tongue surface during vowel articulation for P03, P04, P08, P12, respectively. Data representation is the same as in Figure 5.

The anterior vowels and the posterior vowels are produced differently in two consistent ways: the arched part of the TB is further forward in the anterior vowels, and the TR is further retracted in the posterior vowels. This is seen in that the posterior area of the tongue is, for the most part, parallel in the two sets of traces. This may be contrasted with the Turkish participants' vowels, where the TR remains relatively stationary, and the arched part of the tongue for the posterior vowels returns to similar position of origin as for the anterior vowels.

Measures of the region of greatest difference in tongue position are presented for the Kyrgyz-speaking participants in this study in Figure 8.

Participants P03, P04, and P12 exhibit a posterior Z maximum much further back than the anterior Z maximum is front, with all ratios well above 2:1, indicating that the average posterior area of vowel

⁴Data for P05 is not included in this discussion because the front of her tongue was not imaged well enough to analyse using the Z ratio methodology.

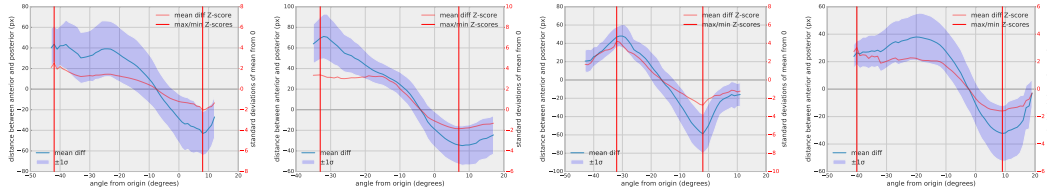


Figure 8: Area of differentiation plots for P03 (ratio 2.226), P04 (ratio 2.478), P08 (ratio 1.069), and P12 (ratio 3.261), respectively.

category contrast is much further back than for Turkish. Additionally, for these participants, there is no return of the differentiation or Z values to or towards zero beyond the posterior Z maximum. This is all interpreted as additional evidence that the TR is playing an important role in the differentiation of anterior and posterior vowels.

Participant P08 exhibits a different pattern than the other Kyrgyz-speaking participants, and is an outlier, in that the differentiation and Z values begin to return towards zero immediately after the posterior Z maximum.⁵ However, the averaged tongue traces for P08 in Figure 7 do not show a strong “pivoting” system—i.e., the posterior part of the tongue for posterior vowels does not seem to return to a position similar to that of the anterior vowels as strongly as for Turkish. This points to the presence of a TR contrast, and taken together with the significantly higher tongue arc for the anterior vowels, may suggest that anterior vowels are TR advanced for P08, as opposed to what appear to be TR retracted posterior vowels for the other participants.

The evidence suggests that at least some Kyrgyz speakers implement the anterior/posterior vowel contrast using linked positions of the TR and TB, with a pattern where TR front and back are linked to TB neutral and retracted, respectively.

4.3 Kazakh

The average tracings of the ultrasound-imaged tongue shapes are presented for the vowels produced by the Kazakh-speaking participants in this study in Figure 9.

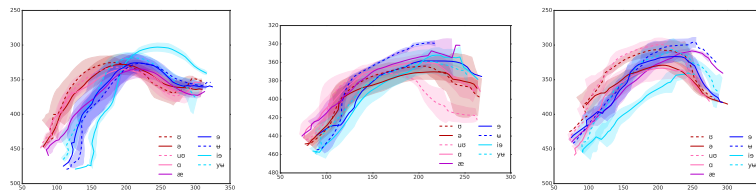


Figure 9: The imaged tongue surface during vowel articulation for P01, P02, and P10, respectively. Data representation is the same as in Figure 5.

While the data is somewhat messy, especially for P02 and P10 (for whom the front portion of the tongue was not consistently imaged well), generally it appears that anterior and posterior vowels are produced differently using both position of the TB and position of the TR. Additionally, the arched part of the tongue does not appear to return to a similar position of origin for the two sets of vowels. The [æ] vowel, which alternates in its phonological patterning between that of anterior and posterior vowels, appears to have characteristics of both anterior and posterior vowels.

⁵This is much like the pattern seen among the Turkish speakers’ data, and suggests that for P08, the position of the TB is the main correlate of vowel anteriority. This could be associated with P08’s particular dialect of Kyrgyz, but it may also have to do with the fact that he is male (there were no other male Kyrgyz speakers in the study), the fact that he grew up with knowledge of Uzbek (which none of the other participants knew), or the fact that he had spent a significant portion of his life in Turkey prior to participation in this study (e.g., his Kyrgyz vowel system may have become more Turkish-like).

Measures of the region of greatest difference in tongue position are presented for the Kazakh-speaking participants in this study in Figure 10.

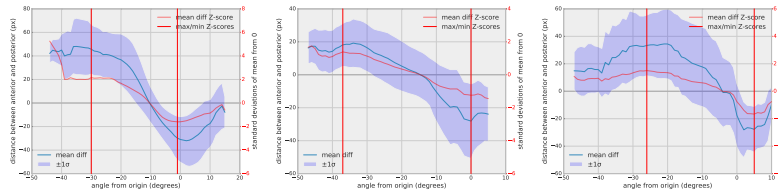


Figure 10: Area of differentiation plots for P01 (ratio 2.053), P02 (ratio 1.552), and P10 (2.263), respectively.

The three Kazakh-speaking participants exhibit differentiation ratios within 0.5 of 2:1, suggesting that anterior and posterior vowels are distinguished more strongly by the position of further back areas of the tongue. The data for P01, the best imaged of the three Kazakh speakers, shows no return of the differentiation or Z values to or towards zero beyond the posterior Z maximum. This is interpreted as additional evidence that the TR is playing an important role in the differentiation of anterior and posterior vowels. The data for P02 and P10 appear to be consistent with this finding despite less complete imaging.

It is possible to some extent to go beyond the simple question of whether TR and TB are involved in the vowel anteriority opposition in Kazakh. The tracings of the tongue during P01's articulation of vowels seem to show (ignoring for a moment the interaction of TB height) that /ʊ/, /ə/, /uʊ/, and /ɑ/ are TR retracted and TB back; /ə/, /ɨ/, and /yɨ/ are TR neutral and TB central; /iə/ is TR advanced and TR front; and /æ/ is TR retracted and TB central. If this is the case, then TR and TB anteriority are each linked in three distinct positions instead of the two evidenced in Turkish and Kyrgyz, yet are *not* linked for the vowel /æ/. More Kazakh data is needed to explore this possibility.

5 Discussion

The averaged tongue tracings examined in this study generally suggest that Turkish differentiates anterior and posterior vowels mainly by a difference in position of the tongue body, whereas Kyrgyz and Kazakh do so by a difference in position of both the tongue body and the tongue root. Further evidence comes from the Z maxima ratios, summarised in Figure 11. The Turkish-speaking participants exhibited ratios around 1, while Kazakh and Kyrgyz speakers exhibited ratios around 2 (with P08 an outlier for Kyrgyz, as discussed in Section 4.2).

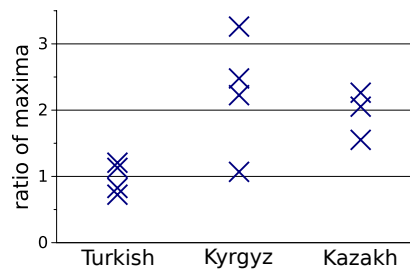


Figure 11: The ratio of Z maxima for each participant, by language.

These results contradict Vajda's 1994 conclusions, in that Kazakh does not appear to have a vowel system where TR alone contrasts the anterior and posterior vowels. Vaux's 2009 conclusions about Turkish and other Turkic languages besides Sakha are supported, however: the Turkish vowel anteriority contrast appears to be TB-based, accompanied by some "pivoting" around the TR, while the Kyrgyz and Kazakh anteriority contrasts employ the position of both the TB and the TR, with

coupled posteriority. Crucially, the position of the TR in these languages does not appear to be due to a phonetic effect as in Turkish. This represents a previously undocumented type of vowel system.

More work is needed to solidify these conclusions. In particular, data from more speakers of these languages should make it possible to understand the range of variation in each language and identify factors that contribute to variation. Additionally, examination of vowels in later syllables, which are subject to vowel harmony in these languages, may yield more insights into the vowel systems. Finally, investigation of Vaux's 2009 hypothesis that TR position is coupled with TB height (as opposed to TB backness) in Sakha has the potential to yield data that, when contrasted with data from other languages, could result in enhanced analytical methods.

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