Chapter 7

Experimental Investigation of Russian Liquid Production

In this chapter, an experiment examining the phonetics of Russian liquid consonants will be described. The broad aim of this experiment is to come to a better understanding of the goals of production of Russian liquids through an examination of dynamic articulatory and acoustic data.

Evidence from previous studies reviewed in Chapter 2 indicates that liquid approximants in English and other languages are produced with dorsal and pharyngeal gestures, and in Chapter 4 experimental evidence was presented showing that the coronal liquid consonants of Spanish are produced with an vowel-like dorsal gesture. In Chapter 6, it was shown that rhotics and laterals constitute a phonological class in Russian, by virtue of their common phonotactic distribution in the syllable and their shared participation in some phonological processes.

In this chapter, we will consider the extent to which the class-like behavior of the Russian liquids might be grounded in the phonetic domain. The hypothesis to be examined is that the Russian trills and laterals share the common property of being produced with a dorsal gesture, although it remains to be seen exactly how the palatalized liquids differ from their non-palatalized counterparts.

7.1 Method

A high-speed ultrasound study was conducted to compare liquid and stop consonant production by four speakers of Contemporary Standard Russian. Articulatory and acoustic data were acquired using the HOCUS system described in Section 4.2.

7.1.1 Subjects

Four native speakers of Russian – three female and one male – participated in the experiment.[1] All subjects were born in the Soviet Union or Russian Federation, and raised in an environment in which standard Russian was spoken. Two subjects (M1, W1) are L1 speakers of Russian with varying degrees of competence in English as a second language. Subject W2 is an L1 speaker of Russian, an L2 speaker of Kyrgyz, and has some competence in English as a third language. Subject W3 is a bilingual speaker of Russian and American English. Subjects' ages ranged from 18 to 32 years at the time of the study (Table 7.1). Subjects were paid for their participation in the experiment, and were naïve as to the purpose of the experiment.

SUBJECT	AGE	HOMETOWN	OTHER LANGUAGES	TIME IN US
M1	24	Kadamjay, Kyrgyzstan	US English, Turkish	2 years
W1	32	Kiev, Ukraine	US English, Ukrainian	7 years
W2	23	Bishkek, Kyrgyzstan	Kyrgyz, US English	6 months
W3	18	Zelenograd, Russia	US English	16 years

TABLE 7.1: **Participants in Russian liquids study.**

7.1.2 Experimental Procedure

Seated participants were asked to read out lists of pseudo-words presented in large font Cyrillic script. The experimental protocol was the same as that used in the Spanish liquids experiment, described in detail in Chapter 4: tongue motion was captured using ultrasound at 127 frames per second, speech was recorded at 22kHz, and the audio and video were later aligned from a synchronization pulse introduced into each signal. Midsagittal lingual articulation was analyzed using the method described in Section 4.2.4.

[1] One additional male Russian speaker participated in the experiment, but because the ultrasound images were not of sufficient quality, data from Subject M2 could not be included in the analysis.

7.1.3 Corpora

Russian coronal consonants were elicited in intervocalic environments in order to determine the salient articulatory differences between liquids and stops, and palatalized and non-palatalized coronal consonants.

Each of the four Russian liquids /r/-/rʲ/-/l/-/lʲ/ was elicited in four different intervocalic environments: front [e_e], back [u_u], low [a_a] and high [i_i/ɨ].[2] Voiced stops /d/-/dʲ/ were elicited in the same contexts for comparison. Artificial stimuli were used to ensure that each segment appeared in an identical phonological environment, and to reduce lexical frequency and prosodic effects as much as possible. The full experimental corpus is listed in Table D.1.

7.1.4 Dynamic Analysis of Lingual Articulation

The midsagittal profile of the tongue was tracked over time. For each consonant token, a sequence of frames was extracted from the ultrasound video, starting from the midpoint of the preceding vowel and extending to the midpoint of the post-consonantal vowel. Within this interval of 250 to 450 msec, every third video frame was selected, cropped, and corrected for head movement, resulting in a sequence of 12 to 22 video frames (depending on the duration of the utterance) sampled at 42.3 Hz.

Each video sequence was processed using EdgeTrak software (Li et al. 2005) and manually corrected where necessary. The resulting sequence of tongue edges was color-coded and superimposed on the same plot, producing a graphical representation of the tongue movement throughout the production of each VCV sequence.

In each of the following plots, the x- and y- axes represent horizontal and vertical displacement in millimeters from an arbitrary but consistent origin, and each of the colored curves represents the location of the midsagittal tongue edge at a given point in time. For each VCV token, the temporal origin was chosen at the midpoint of consonantal articulation. The formation of the consonantal closure is shown in frames with negative time values, and the consonantal release is captured in the sequence of frames with positive time values.

2 Vowel contexts cannot be not perfectly balanced in Russian, because all consonants which appear before the vowel [i] are inherently palatalized, and the high front vowel appears as the allophone [ɨ] after non-palatalized consonants. Although the high front vocalic context provides the greatest articulatory contrast with the other vocalic environments, consonants produced in this environment were often poorly imaged by the ultrasound, and tongue edges could not be consistently identified for all tokens and all subjects. For this reason, the mid-front vowel context [e_e] was used to contrast with [u_u] and [a_a].

7.2 Results: Articulation of Non-Palatalized Coronal Consonants

Articulation of Non-Palatalized Stops

The articulation of the token [ada] by a speaker of Russian is illustrated in Fig. 7.1. The first half of the sequence – ten frames beginning at the mid-point of the pre-consonantal vowel (yellow) and ending at the point of consonantal closure (red) – is illustrated in the left panel (-213 to 0 ms). The second half of the production sequence – ten frames commencing at the point of stop release (red) and ending at the midpoint of articulation of the post-consonantal vowel (yellow) – is shown in the right panel (0 to 189 ms).

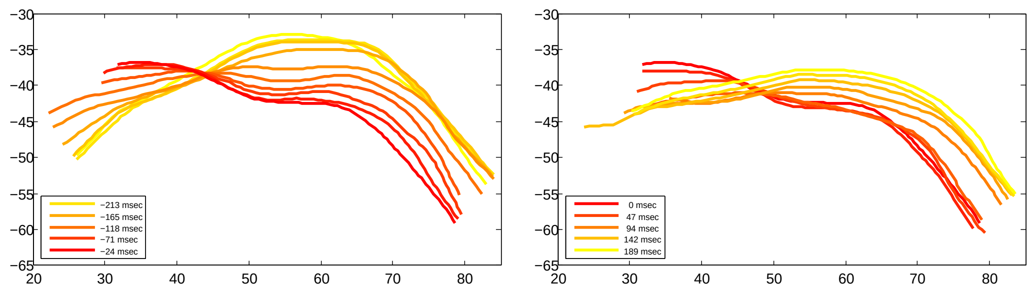

FIGURE 7.1: **Dynamic midsagittal lingual articulation of Russian non-palatalized coronal stop: [ada]** – subject W3. Left panel: consonant formation; Right panel: consonantal release.

The lingual motion captured in Fig. 7.1 reveals that the tongue dorsum begins and ends in a retracted position corresponding to the pharyngeal articulation of the context vowel. During stop closure, the dorsum is pulled forward and allowed to drop, but the back of the tongue remains shaped and broadly positioned in a lowered and retracted posture corresponding to the articulatory target of the context vowel /a/.

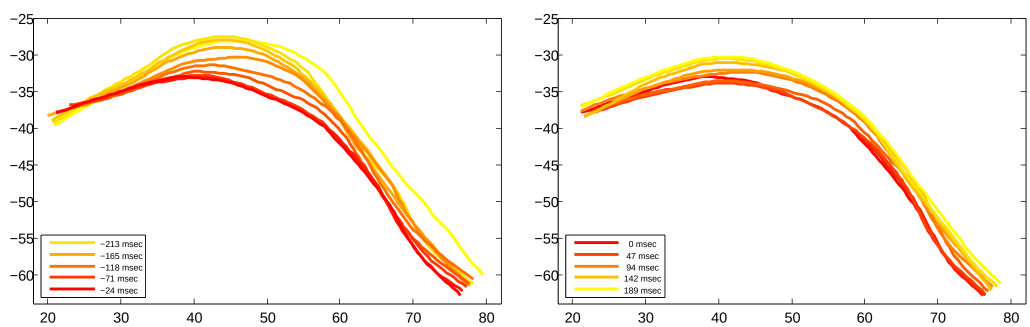

FIGURE 7.2: **Dynamic midsagittal lingual articulation of Russian non-palatalized coronal stop: [ede]** – subject W3. Left panel: consonant formation; Right panel: consonantal release.

Articulation of the voiced coronal stop by the same speaker in a front vowel context [ede] is illustrated in Fig. 7.2. Throughout the whole sequence, the tongue dorsum remains in an advanced position corresponding to the wide palatal target of the context vowel. As also observed in the back vowel context, the dorsum lowers (7 mm) and fronts (6 mm) during the formation of the stop – a total displacement of 9 mm in the direction dictated by the requirements of the coronal closure.

Similar patterns of articulation were observed in the other two vowel contexts, and for all four Russian subjects. In summary, all tongue body movement observed during the production of medial onset voiced coronal stops was consistent with one of two articulatory goals: maintaining the dorsal posture associated with the context vowel, and achieving coronal closure of the stop.

Articulation of Non-Palatalized Rhotics

The production of the Russian non-palatalized trill involves a different pattern of lingual movement to that observed in stop production. During trill formation (Fig. 7.3, left panel), the anterior lingual dorsum fronts to a raised, mid-oral position, while the posterior lingual dorsum advances slightly into a stable posture which is maintained throughout. The second half of the sequence is characterized by a remarkable degree of dorsal stability, during which the body of the tongue maintains a raised, advanced posture which is antagonistic to the pharyngeal target constriction of the context vowel (Fig. 7.3 right).

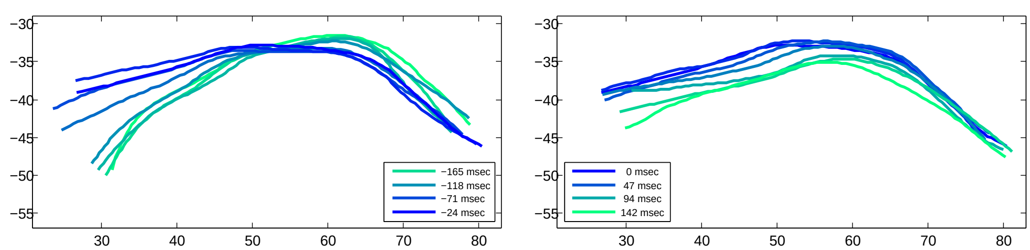

FIGURE 7.3: **Dynamic midsagittal lingual articulation of Russian non-palatalized trill: [ara]** – subject W3. Left panel: consonant formation; Right panel: consonantal release.

The independence of the rhotic dorsal constriction target can be seen even more clearly from the lingual trajectory of subject M1 producing the non-palatalized trill in the same context (Fig. 7.4): approximately 100 msec before the first coronal contact the dorsum raises to a mid-back position, where it remains throughout the trill produciton.

Trill articulation in a front vowel context is illustrated in Fig. 7.5. Dorsal motion is in the opposite direction to that observed during the production of the stop in

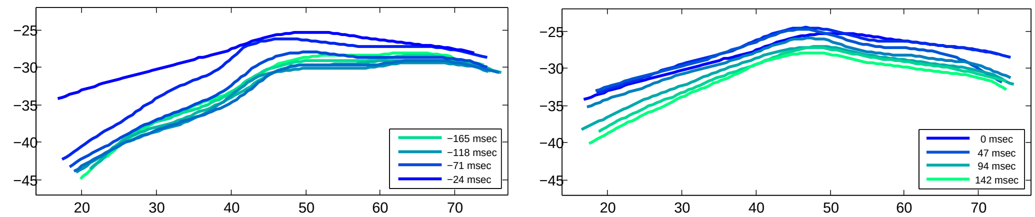

FIGURE 7.4: **Dynamic midsagittal lingual articulation of Russian non-palatalized trill: [ara]** – subject M1. Left panel: consonant formation; Right panel: consonantal release.

the same context (Fig. 7.2): during trill formation (Fig. 7.5 left) the apex of the tongue dorsum retracts (and raises) 10 mm. Since this is movement counter to that required for context vowel articulation or coronal closure, the data suggests that the tongue dorsum is being actively recruited in the production of the trill.

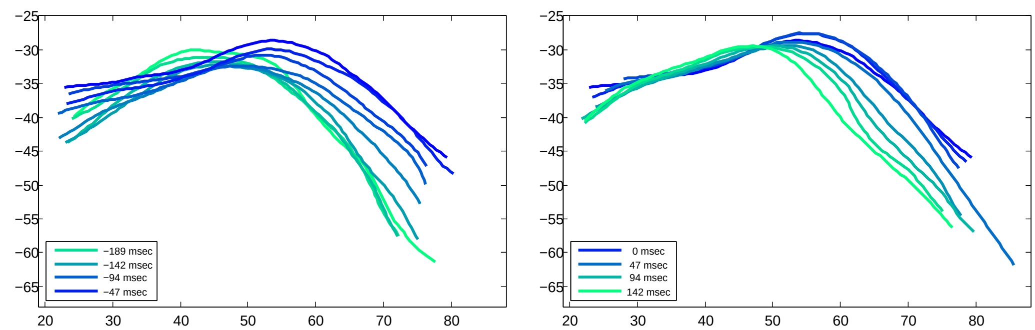

FIGURE 7.5: **Dynamic midsagittal lingual articulation of Russian non-palatalized trill: [ere]** – subject W3. Left panel: consonant formation; Right panel: consonantal release.

Articulation of Non-Palatalized Laterals

Even greater dorsal articulatory independence can be observed in the production of the Russian lateral (Fig. 7.6). Articulation of the posterior lateral constriction, located in the uvular-pharyngeal region (x = 71, y = -35), involves dorsal raising and retraction from the constriction posture associated with the pharygeal context vowel. Like the trill, and unlike the coronal stop, the production of the lateral is characterized by greater stability in the upper pharayngeal region ($75 < x < 90$mm) throughout the entire VCV token.

The same broad pattern of articulation observed in the trill can be seen during the production of the lateral in the front vowel context (Fig. 7.7). In this case, the dorsal gesture is even more pronounced than that observed in the trill: a retraction of 21 mm towards an uvular-pharyngeal target can be observed. The two non-palatalized liquids produced in the mid-front vowel context by speaker W3 exhibit

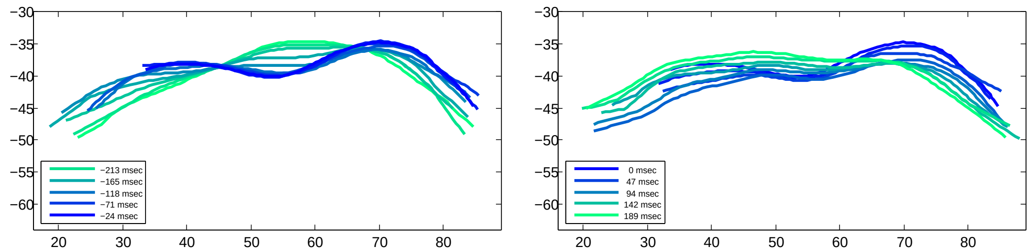

FIGURE 7.6: **Dynamic midsagittal lingual articulation of Russian non-palatalized lateral: [ala]** – subject W3. Left panel: consonant formation; Right panel: consonantal release.

a remarkable symmetry in their overall patterns of dynamic midsagittal articulation.

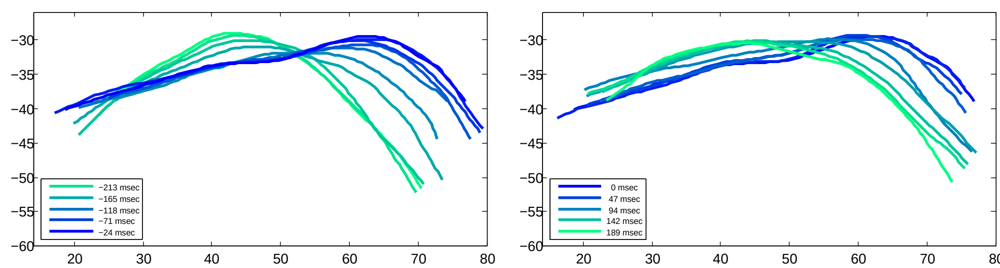

FIGURE 7.7: **Dynamic midsagittal lingual articulation of Russian non-palatalized lateral: [ele]** – subject W3. Left panel: consonant formation; Right panel: consonantal release.

7.2.1 Results – Comparison of Midconsonantal Dorsal Articulation

The dynamic analysis of Russian non-palatalized consonant production presented so far has revealed that one of the most important differences between the non-palatalized obstruents and liquids appears to be the way in which the tongue dorsum is articulated. In order to quantify this difference, the dorsal articulation at the mid-point of consonantal production can be compared across vowel contexts.

Effect of vowel context on stop articulation.

A comparison of the midsagittal articulation of the coronal stop uttered in three different vowel contexts by subject F3 is shown in Fig. 7.8. Tongue edges captured from two productions each of the tokens [ada], [ede] and [udu] have been superimposed in each panel. The tongue shapes in the left panel are taken from the first frame in the sequence, corresponding to the midpoint of the pre-consonantal vowel; those in the central panel are taken from the middle frame, corresponding to the mid-consonantal articulation; the tongue edges in the right frame are taken from the last frame in the sequence, corresponding to the midpoint of articulation of the post-consonantal vowel.

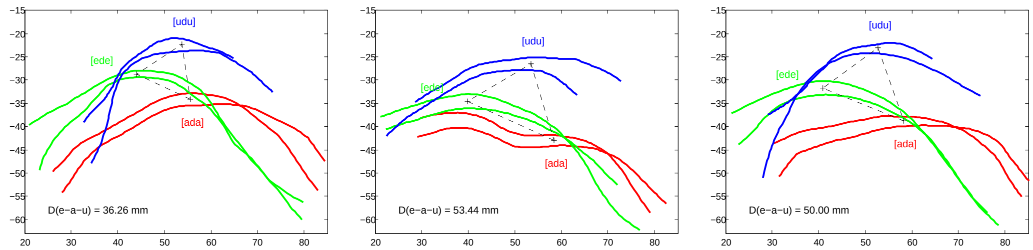

FIGURE 7.8: **Midsagittal lingual articulation of Russian non-palatalized coronal stops in three different vowel contexts**: [ada] (red), [ede] (green) and [udu] (blue) – subject W3. Left panel: pre-consonantal vocalic articulation; center panel: mid-consonantal articulation; right panel: post-consonantal vocalic articulation

The most important observation to be made about the stop production is that the tongue dorsum does not converge on a common constriction, but remains articulated in the gesture corresponding to the context vowel – low and back in the [ada] context, mid-front in the [ede] context, and high and back in the [udu] context.

Effect of vowel context on liquid articulation.

A comparison of the midsagittal articulation of a Russian non-palatalized trill uttered in three different vowel contexts by subject F3 is shown in Fig. 7.9. Two productions each of the tokens [ara], [ere] and [uru] have been superimposed in each panel: pre-consonantal (left), mid-consonantal (middle), and post-consonantal articulation (right). In Fig. 7.10, two productions each of the tokens [ala], [ele] and [ulu] have been superimposed to compare the midsagittal articulation of the non-palatalized lateral uttered in three different vowel contexts by subject F3.

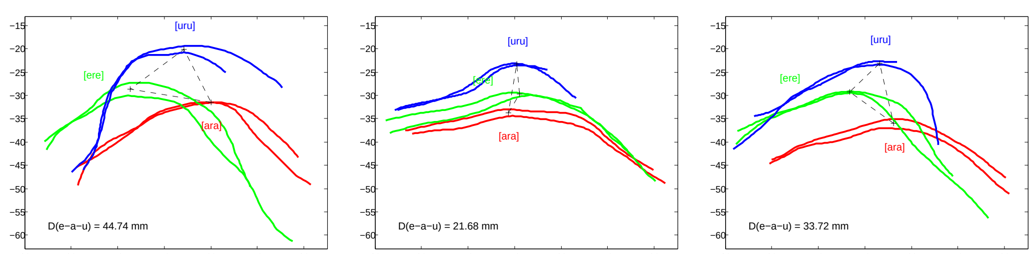

FIGURE 7.9: **Midsagittal lingual articulation of the Russian non-palatalized trill in three different vowel contexts**: [ara] (red), [ere] (green) and [uru] (blue) – subject W3. Left panel: pre-consonantal vocalic articulation; center panel: mid-consonantal articulation; right panel: post-consonantal vocalic articulation

Unlike in the stop production, the midconsonantal dorsal articulation of each liquid converges towards a central location. For speaker W3, the dorsal target con-

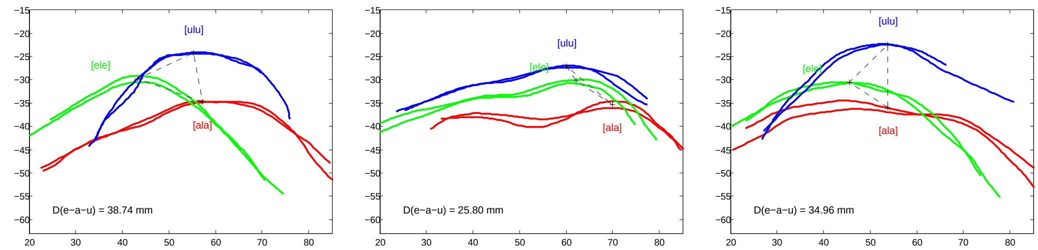

FIGURE 7.10: **Midsagittal lingual articulation of the Russian non-palatalized lateral in three different vowel contexts**: [ɑlɑ] (red), [ele] (green) and [ulu] (blue) – subject W3. Left panel: pre-consonantal vocalic articulation; Center panel: mid-consonantal articulation; Right panel: post-consonantal vocalic articulation

striction for the trill appears to be in the vicinity of a mid-central vowel, while the target constriction for the lateral appears to be in the vicinity of a mid-back vowel.

Quantification of Vowel-Consonant Coarticulation

The effect of vocalic coarticulation on consonantal production was quantified by calculating the area of a triangle constructed between the dorsal apices of consonants produced in different intervocalic environments. Differential dorsal displacements of Russian non-palatalized coronal stops and liquids, calculated using the method described in Section 4.3.6, are given in Fig. 7.11.

w1	V	C	V
/d/	88.2	37.4	79.0
/d/	57.8	47.5	51.3
/l/	98.5	20.3	43.8
/l/	80.6	22.0	36.6
/r/	93.8	6.9	44.8
/r/	71.7	31.2	69.3
Stop	73.0	42.5	65.1
Liquid	86.1	20.1	48.6

w2	V	C	V
/d/	72.6	73.8	94.3
/d/	57.0	40.6	69.2
/l/	43.8	27.9	72.4
/l/	42.3	26.8	78.6
/r/	61.5	56.1	72.0
/r/	41.1	31.2	44.1
Stop	64.8	57.2	81.8
Liquid	47.2	35.5	66.8

w3	V	C	V
/d/	84.7	129.1	126.5
/d/	53.4	147.4	116.3
/l/	73.1	3.6	44.4
/l/	87.5	10.8	4.9
/r/	88.2	8.4	49.3
/r/	81.7	12.9	46.2
Stop	69.0	138.2	121.4
Liquid	82.6	8.9	36.2

m1	V	C	V
/d/	19.4	22.1	46.0
/d/	50.8	24.5	88.8
/l/	72.3	2.6	55.3
/l/	87.6	12.1	143.8
/r/	20.1	10.4	2.0
/r/	125.1	10.6	8.3
Stop	35.1	23.3	67.4
Liquid	76.3	8.9	52.3

FIGURE 7.11: **Consonantal susceptance to vocalic coarticulation**, as measured by total dorsal displacement (mm^2) across three vowel contexts [e_e]-[ɑ_ɑ]-[u_u] – all subjects.

To compare susceptance to vocalic coarticulation across subjects, the data in Fig. 7.11 were normalized by dividing by the maximum dorsal displacement for each subject; mean normalized dorsal displacements were then calculated for each consonant across the experimental population, and are compared in Fig. 7.12.

As with the Spanish intervocalic coronal consonants, two main effects can be observed in these data:

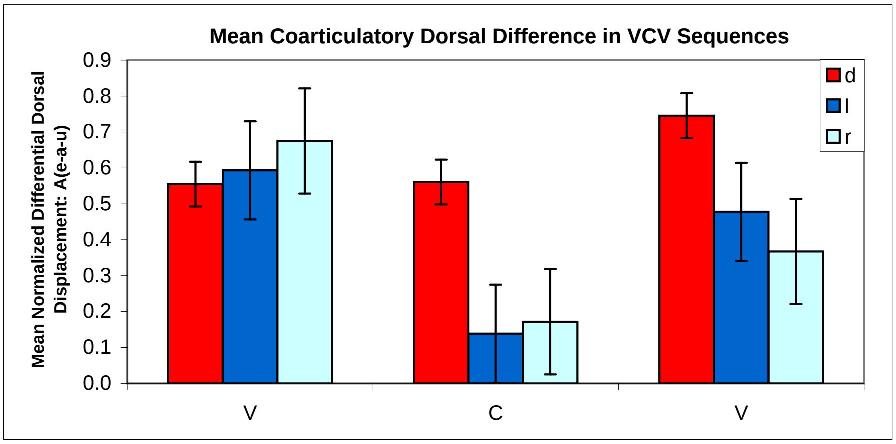

FIGURE 7.12: **Mean normalized differential dorsal displacement**: Russian non-palatalized coronal consonants – all subjects.

i. the effect of vocalic coarticulation (as measured by differential dorsal displacement in the consonant) is greater during the production of stops than liquids

ii. the effect of consonantal coarticulation on the post-consonantal vowel (as measured by differential dorsal displacement) is greater for liquids than stops

To examine these observations more closely, two tests were conducted:

i. a *one-way analysis of variance test* of the null hypothesis that dorsal coarticulatory effects (as measured by the differential dorsal displacement data) are the same for Russian coronal stops and liquids

ii. a *two-sided Wilcoxon rank sum test* of the null hypothesis that the differential dorsal displacement data for stops and liquids are independent samples from identical continuous distributions with equal medians, against the alternative that they do not have equal medians

The results of these tests are shown in Table 7.2. Both tests *accept* the null hypothesis that coarticulation does not differ between stops and liquids during the production of the pre-consonantal vowel (first column). Both tests reject the null hypothesis (at a 0.01 significance level) that coarticulatory differences in dorsal articulation do not differ for stops and liquids during mid-consonantal production (second column). Both tests reject the null hypothesis (at a 0.05 significance level) that coarticulatory differences in dorsal articulation do not differ for stops and liquids during post-consonantal production (third column).

These results suggest that, for Russian intervocalic non-palatalized coronal consonants:

TEST	$V1_{stop} = V1_{liq}$	$C_{stop} = C_{liq}$	$V2_{stop} = V2_{liq}$
ANOVA	0 (p=0.2563)	1 (p = 0.0013)	1 (p = 0.0284)
Rank Sum	0 (p=0.2573)	1 (p = 0.0020)	1 (p = 0.0156)

TABLE 7.2: **Hypothesis testing of Russian differential dorsal displacement by class** – Coronal Stops vs. Liquids. 1st column: dorsal displacement amongst pre-consonantal vowels; 2nd column: mid-consonantal dorsal displacement; 3rd column: dorsal displacement amongst post-consonantal vowels.

i. VCV sequences are syllabified as V.CV
ii. there is little anticipatory coarticulatory influence of any of the consonants on the preceding vowel
iii. dorsal articulation of coronal stops is a function of the context vowels
iv. dorsal articulation during liquid production is primarily due to components intrinsic to the consonant
v. there is no significant coarticulatory effect of the stops on the following vowel
vi. there is a significant coarticulatory effect of the liquids on the following vowel

Location of Liquid Dorsal Gestures

Evidence from the ultrasound data considered so far indicates that Russian non-palatalized liquids, but not coronal stops, are articulated with a dorsal gesture. We now consider the target location of this gesture, and how it differs between rhotics and laterals. As in the Spanish study, we can quantify the relative locations of the gestural targets for Russian liquids by calculating dorsal displacement from a nominal point chosen in the center of the lingual articulatory space, corresponding approximately to schwa.

Midsagittal articulation of intervocalic liquids by subject M1 are shown in Fig. 7.13. Centers of gravity were calculated using the same method described in Section 4.3.6, and used to provide an estimate of the mean dorsal target for each of the liquids. For subject M1, in the utterances compared below, the dorsal target of the lateral (x = 65.8, y = -18.4 mm) is located approximately 13 mm anterior to (12.2 mm forward of, and 4.3 mm below) that of the trill (53.6, -22.7). Mean lingual displacements from pre-consonantal vocalic centers for each liquid and each subject are given in Table 7.3).

Displacements of intervocalic liquid dorsal targets from the vocalic center are plot-

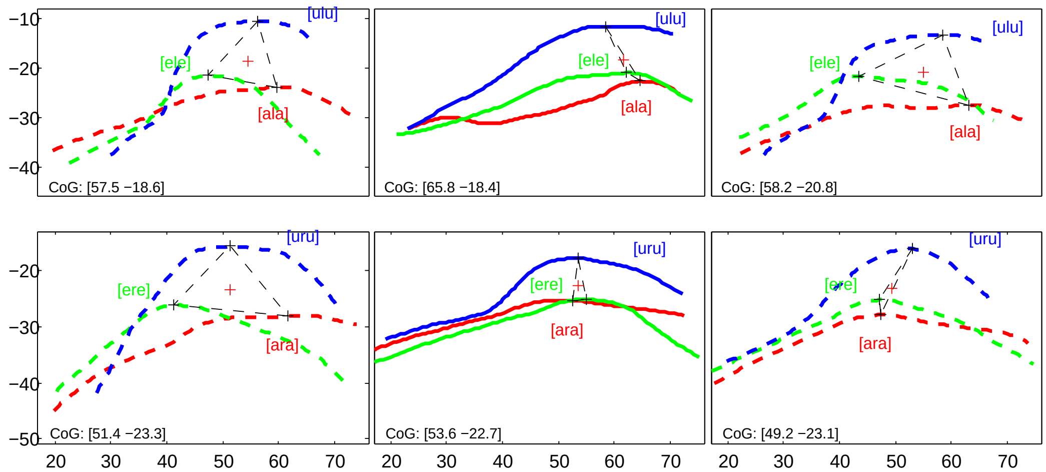

FIGURE 7.13: **Location of Russian non-palatalized liquid dorsal gestures**, estimated using centers of gravity of dorsal apices across vowel contexts [e_e]-[a_a]-[u_u] – subject M1.

	/l/		/r/	
	dx	**dy**	**dx**	**dy**
W1a	-11.38	5.86	0.61	5.41
W1b	-12.09	7.02	-2.60	5.99
W2a	-2.17	-2.03	1.32	-0.07
W2b	-1.82	-1.40	9.74	-0.16
W3a	-13.36	1.05	0.15	1.76
W3b	-10.06	1.06	-0.88	1.41
M1a	-12.14	-2.73	-0.19	-0.26
M1b	-8.24	-0.24	-2.25	-0.56
Mean	-8.91	1.07	0.74	1.69

TABLE 7.3: **Mean displacements (mm) of dorsal targets from pre-consonantal vocalic center**: Russian intervocalic non-palatalized liquids – all subjects.

ted in Figure 7.14. The data confirm the observations made in Section 7.2 that the dorsal target of the Russian non-palatalized lateral is posterior to that of the trill.

7.2.2 Summary of Results: Russian Non-Palatalized Consonants

Analysis of the Russian consonants /d/, /r/ and /l/ produced in intervocalic position by the four speakers in this study has revealed the following:

i. the tongue dorsum does is not actively recruited during the production of the

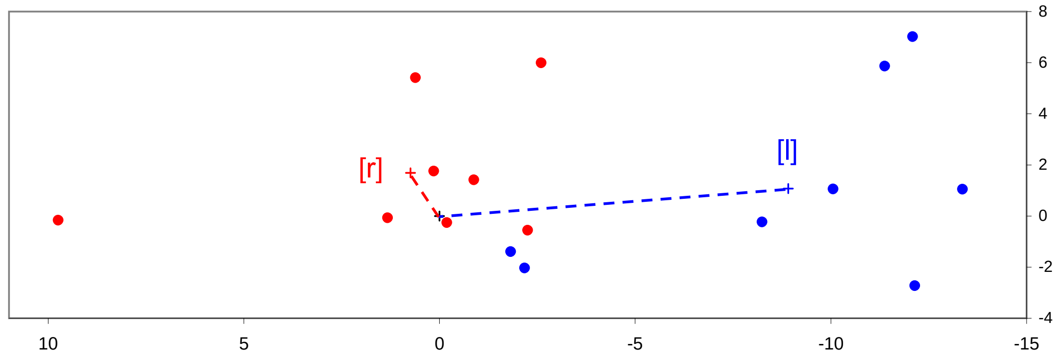

FIGURE 7.14: **Mean locations of Russian non-palatalized liquid dorsal targets with respect to 'schwa'.** Blue: intervocalic laterals; Red: intervocalic trills. Dashed lines indicate mean dorsal displacement from pre-consonantal vocalic center.

voiced coronal stop

ii. the trill is produced with a dorsal gesture with a mid-central target

iii. the lateral is produced with a dorsal gesture with a mid-back target

7.3 Results: Articulation of Palatalized Coronal Consonants

Articulation of Palatalized Stops

The articulation of the token [edʲe] by a speaker of Russian is illustrated in Fig. 7.15. The first half of the sequence – ten frames beginning at the mid-point of the pre-consonantal vowel (yellow) and ending at the point of consonantal closure (red) – is illustrated in the left panel. The second half of the production sequence – ten frames commencing at the point of stop release (red) and ending at the midpoint of articulation of the post-consonantal vowel (yellow) – is shown in the figure on the right.

The data in Fig. 7.15 show that, as coronal closure is achieved, the dorsum is advanced and allowed to drop, consistent with the behavior of an uncontrolled tongue body. In the interval immediately after stop closure (0 to 94 msec), approximation of the front of the dorsum towards the palate can be observed, before the tongue body lowers towards the mid-front target of the post-consonantal context vowel. Considerable displacement of the back of the tongue (dx $>$ 10 mm) can be observed throughout the production sequence.

Articulation of the palatalized stop by the same speaker in back vowel contexts is illustrated in Figs. 7.16 ([adʲa]) and 7.17 ([udʲu]). In each case, extensive advancement of the tongue back can be observed at the same time that the coronal closure

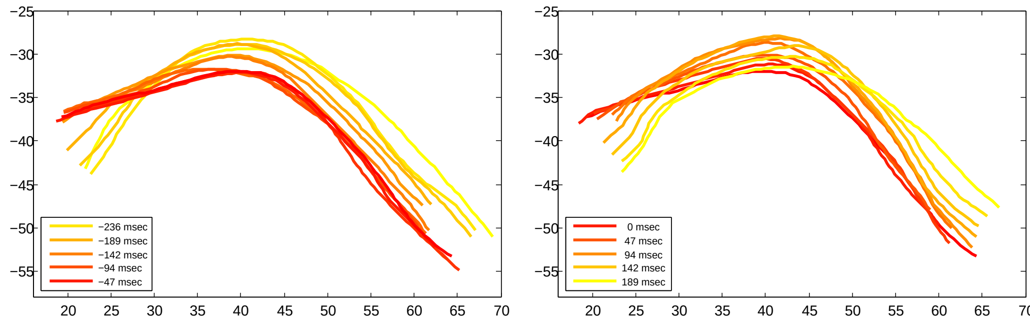

FIGURE 7.15: **Dynamic midsagittal lingual articulation of Russian palatalized coronal stop: [edʲe]** – subject W3. Left panel: consonant formation; Right panel: consonantal release.

and palatalization gestures are achieved, before the tongue body recovers towards the back targets of the context vowels. The production of the palatalized stop in the high-back vowel context [udʲu] involves lowering (dx ∼ -7 mm) of the dorsum towards the palatal approximation target.

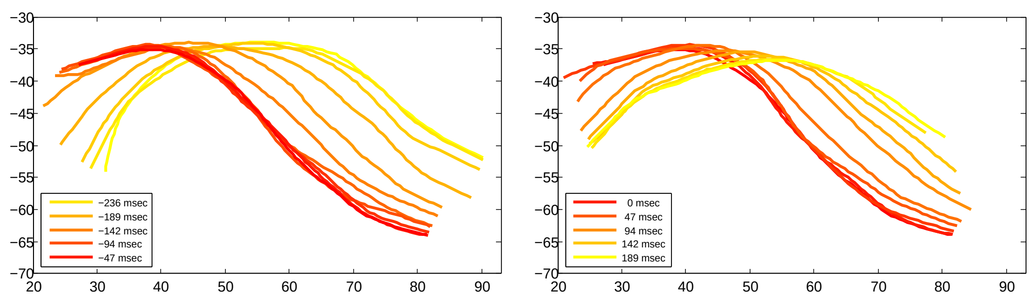

FIGURE 7.16: **Dynamic midsagittal lingual articulation of Russian palatalized coronal stop: [adʲa]** – subject W3. Left panel: consonant formation; Right panel: consonantal release.

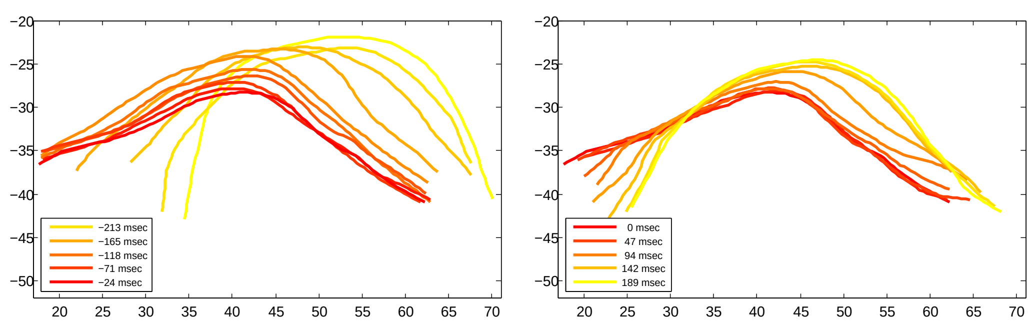

FIGURE 7.17: **Dynamic midsagittal lingual articulation of Russian palatalized coronal stop: [udʲu]** – subject W3. Left panel: consonant formation; Right panel: consonantal release.

Similar patterns of articulation were observed for the other three Russian subjects. In summary, all tongue body movement observed during the production of medial voiced coronal palatalized stops was consistent with one of two articulatory goals: approximation of the tongue blade towards the alveolar ridge, and approximation of the front of the tongue body towards the mid-palatal region. The combined effect of these dual articulatory goals results in the fronting and raising of the whole tongue during consonant production – even in the front vowel context – because there is no antagonistic articulatory goal intrinsic to the consonant which anchors the dorsum or perturbs its advancement.

Articulation of Palatalized Rhotics

The production of the Russian palatalized trill (Figs. 7.18 to 7.20) involves a different pattern of tongue movement to that observed during stop production. Although the same coronal gesture (approximation of the tongue blade towards the alveolar ridge) and anterior dorsal gesture (approximation of the front of the dorsum towards the palate) can be observed, the back of the tongue does not behave in the same way. In each token, less gross tongue movement can be observed than for the production of the palatalized stop in the same vowel context.

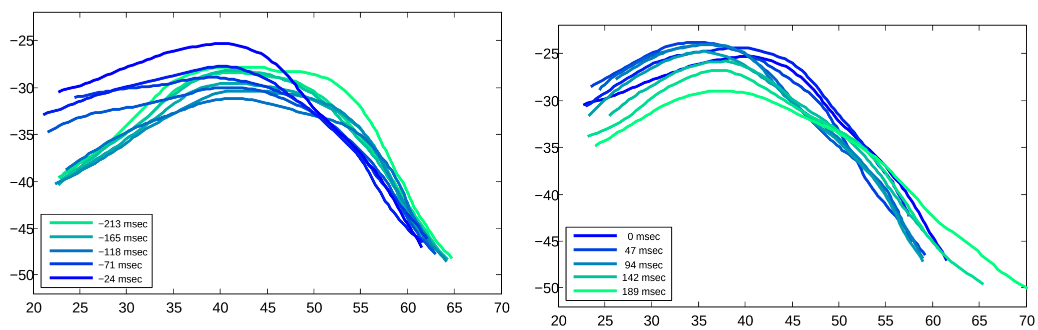

FIGURE 7.18: **Dynamic midsagittal lingual articulation of Russian palatalized trill: [erʲe]** – subject W3. Left panel: consonant formation; Right: consonantal release.

Most importantly, tongue movement during the production of palatalized rhotics appears to be constrained in such a way that, in each token, a single point of the tongue edge can be identified at which horizontal and vertical displacement is minimal (Fig. 7.18: x = 54, y = -37 mm; Fig. 7.19: x = 52, y = -36 mm; Fig. 7.20: x = 44, y = -22 mm). Stationary regions of this nature have been described as 'pivot' points by Iskarous (2004).

Articulation of Palatalized Laterals

Articulation of the palatalized lateral by a speaker of Russian is shown in Figures 7.21 to 7.23). As with the palatalized trill, but unlike the palatalized stop, a pivot point can be observed in each token. The coordinates of these pivots are similar to those identified for the palatalized trills produced in the same vowel contexts

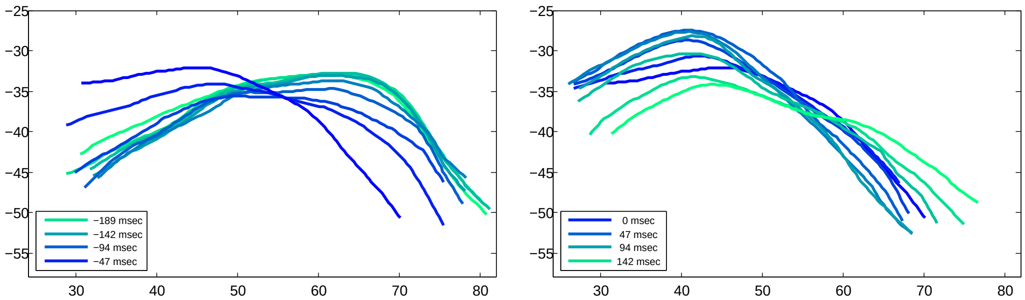

FIGURE 7.19: **Dynamic midsagittal lingual articulation of Russian palatalized trill: [arʲa]** – subject W3. Left panel: consonant formation; Right: consonantal release.

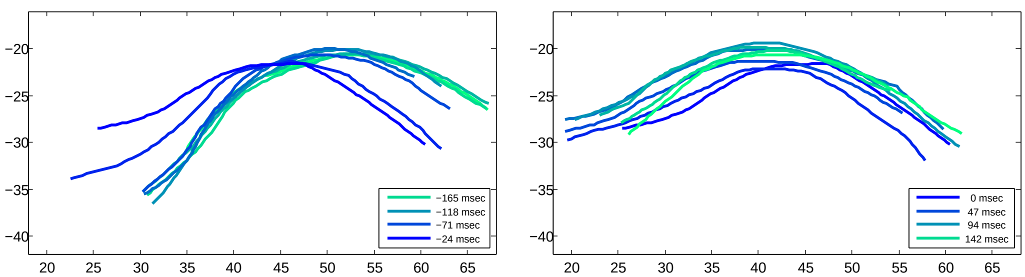

FIGURE 7.20: **Dynamic midsagittal lingual articulation of Russian palatalized trill: [urʲu]** – subject W3. Left panel: consonant formation; Right: consonantal release.

([elje]: x = 49, y = -32 mm; [alja]: x = 49, y = -33 mm; [ulju]: x = 40, y = -25 mm). As with the trills, the presence of these quasi-stationary regions suggests that the dorsum is more highly constrained than during stop production, where the tongue body moves as a whole in ways which are consistent only with the achievement of the coronal and palatalization gestures.

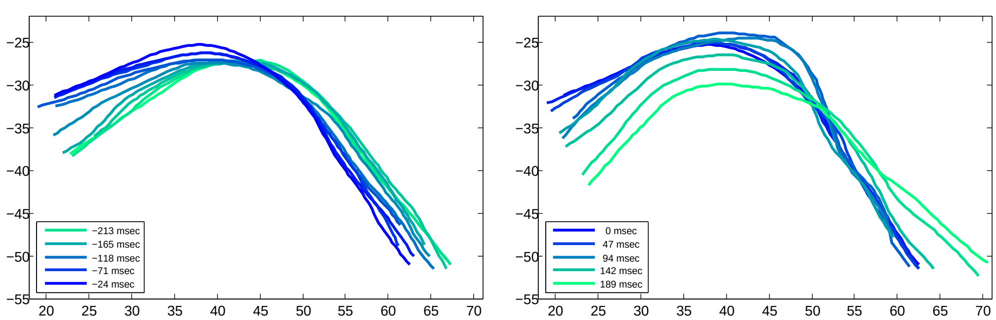

FIGURE 7.21: **Dynamic midsagittal lingual articulation of Russian palatalized lateral: [elʲe]** – subject W3. Left panel: consonant formation; Right: consonantal release.

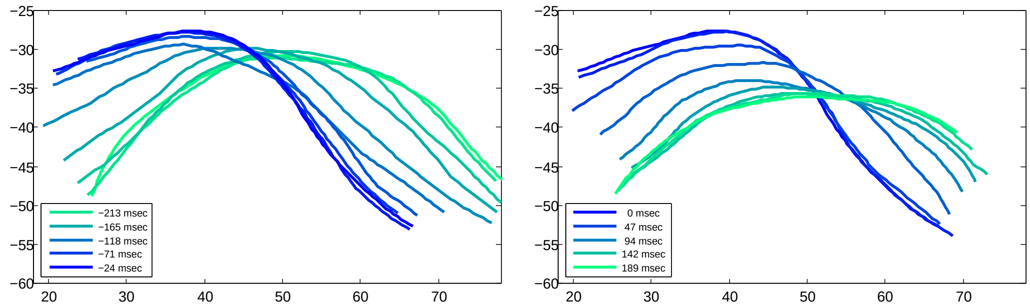

FIGURE 7.22: **Dynamic midsagittal lingual articulation of Russian palatalized lateral: [alʲa]** – subject W3. Left panel: consonant formation; Right: consonantal release.

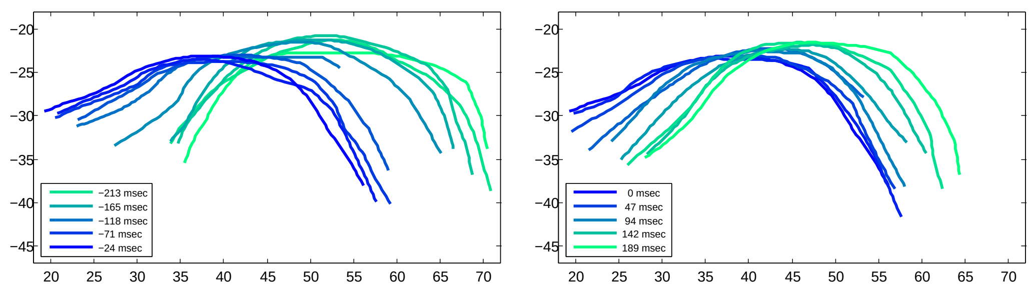

FIGURE 7.23: **Dynamic midsagittal lingual articulation of Russian palatalized lateral: [ulʲu]** – subject W3. Left panel: consonant formation; Right: consonantal release.

7.3.1 Summary of Results: Russian Palatalized Consonants

While the production of all three palatalized coronal consonants examined in this study (/dʲ/–/rʲ/–/lʲ/) involved an anterior dorsal approximation gesture, the tongue body was found to be more highly constrained during the production of palatalized liquids than during the stop. The evidence for these additional constraints is in a type of tongue movement described as 'pivotal' by Iskarous (2004), who proposes that the "effect of these patterns of tongue deformation is to make the acoustic signal as articulatorily-transparent as possible".

The methodology used to identify the constriction location of dorsal gestures in Spanish and Russian non-palatalized liquid consonants (Section 4.3.6) is not applicable to the Russian palatalized liquids because the dorsal apices are located at regions of the tongue corresponding to the palatalization gesture. More work is required to develop methods of quantifying lingual movement around the lingual pivot point in ways which will inform our knowledge of the linguistic goals of tongue movement in palatalized consonants; however, if we assume that the Russian palatalized liquids have similar dorsal gestural targets to their non-palatalized equivalents, then the patterns of lingual movement observed in this section might be explained as the result of competition on the tongue body to articulate both palatal and intrinsic liquid dorsal gestures. This characterization of palatalized liquids will be examined further, using gestural modeling, in Chapter 8.

7.3.2 Conclusions

In this chapter, the articulation of Russian intervocalic liquid consonants has been examined in detail. Non-palatalized liquids were found to be characterized by greater resistance to vocalic coarticulation than the non-palatalized voiced coronal stop. The non-palatalized trill was found to be produced with a dorsal gesture with a mid-central target. The non-palatalized lateral was found to be produced with a dorsal gesture with a mid-back target. These results suggest that, of the three non-palatalized coronal consonants examined in this study (/d/–/r/–/l/), only the lateral can be considered to be 'velarized' /$l^{ɣ}$/, although a better characterization of the constriction location of the posterior dorsal gesture of the lateral, for the speakers examined here, is uvular-pharyngeal.

The production of all three palatalized coronal consonants examined in this study (/d^j/–/r^j/–/l^j/) involved an anterior dorsal approximation gesture; however, the tongue body was found to be more highly constrained during the production of palatalized liquids than during the stop. These results suggest that palatalized liquids consist of two different intrinsic tongue body gestures: the palatalization approximation, and an anterior dorsal gesture equivalent to that identified in the non-palatalized liquid equivalent. More work is required to quantify the location and nature of the constituent gestures in Russian /r^j/ and /l^j/.

The results of this study are consistent with the central hypothesis of this dissertation: that liquid consonants are characterized by the coordinative production of intrinsic tongue tip and tongue body gestures. The specific importance of the Russian data is to demonstrate that such a characterization also holds for classes of consonants whose production involves additional gestures, such as a palatal approximation. In Chapter 8, phonological representations of Russian coronal consonants which are consistent with this analysis will be developed, and gestural models of palatalized segments will be examined more closely using computational simulation.