A LONGITUDINAL ANALYSIS OF THE VOCALIC NUCLEUS IN MODERN RUSSIAN

by

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Presented to the Faculty of the Graduate School of

The University of Texas at Arlington in Partial Fulfillment

of the Requirements

for the Degree of

DOCTOR OF PHILOSOPHY

THE UNIVERSITY OF TEXAS AS ARLINGTON

May 2009

ACKNOWLEDGEMENTS

I would like to express my thanks to the members of my dissertation committee for their work on this project. As chair, Dr. David Silva was the source of immeasurable support, guidance, and direction, not to mention patience, in all facets of this dissertation process. Dr. Jerold Edmondson provided direction in computational and acoustic studies since the beginning of my graduate career. Dr. Samuel "Pete" Smith Jr. endured countless unannounced micro-presentations of my discovery of "fascinating tidbits" of Russian phonology when my enthusiasm was brimming, and offered guidance and motivation to continue when my enthusiasm was struggling. Dr. Donald Burquest, who offered boundless enthusiasm and dedication to his students and provided me my introduction to phonology, was the sole factor for my choosing Linguistics as a field of graduate study, over the other options that laid before me. Dr. Doyle L. Hawkins Jr. provided tireless consultation and guidance, regarding the mathematical and statistical concepts and considerations of this dissertation.

I would also like to thank others, whose support and guidance assisted the completion of this dissertation. Dr. Yaroslav Malyuta offered great patience and expertise in review of the lexical data set and preparation of Russian language instructions to the participants. Dr. Nancy Rowe assisted in the selection of statistical tools and procedures for this project.

I would also like to thank others, whose keen interest and mentoring helped to shape my academic career in Linguistics and Russian studies. Col. James D. Wilmeth, my childhood neighbor and instructor of my first collegiate course in Russian, offered considerable motivation and helped me embark on a career in Russian studies. Throughout my studies and presence on campus, Col. Charles McDowell, who oversaw my Bachelor's program in Russian, was the most dedicated mentor and advocate that anyone could ask for. Dr. Robert Longacre was the source of much motivation and enthusiasm in the spheres of field methods and scholarly discovery.

Finally, I would like to add several personal "thank yous." My parents and family provided great support and motivation throughout my academic career. My friends Chris Matthews and Lisa Fain always provided encouragement for my academic development for the past decades. And I would like to thank my partner Joseph Bishop for the stability and motivation in my life that made the fulfillment of this process a reality.

March 23, 2009

ABSTRACT

A LONGITUDINAL ANALYSIS OF THE VOCALIC NUCLEUS

IN MODERN RUSSIAN

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The University of Texas at Arlington, 2009

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This instrumental acoustic study investigates coarticulation as the source of palatalization in Modern Standard Russian. This study posits that the nucleus is bifurcated, with nodes for a pre-kernel and a kernel. At the initial edge of a stressed vowel, coarticulation between the pre-kernel and the kernel creates the distinctive onset, attributed to preceding palatalized environments. At the terminal edge of a stressed vowel, coarticulation between the kernel and the next vocalic segment (the offglide, or the pre-kernel of the following syllable) creates the distinctive offset, attributed to following palatalized environments. In unstressed syllables, the kernel vowel is deleted,

and the nucleus adopts its vocalic identity from the surviving pre-kernel.

In Modern Standard Russian, the pre-kernel's sphere of influence originates during the consonant onset, and considerations for the pre-kernel's articulatory requirements take precedence over the vocalic kernel's and semi-vocalic offglide's requirements. In turn, the requirements of the offglide take precedence over the kernel. In stressed syllables, the kernel forms diphthongal and triphthongal coarticulations due to the tractive force of the surrounding vocalic nodes. In unstressed syllables, the surviving pre-kernel forms coarticulations with the surrounding vocalic nodes.

In this study, formant measurements taken at regular intervals across the duration of a syllable are modeled by mathematical equations, to identify change-points, which collectively represent the behavior of the syllable as a whole. Comparisons of the change-points of systems of syllables indicate that the acoustic behavior of syllables in connected speech must be categorized into more classifications than are permitted by the conventional binary contrast, which arises from a feature within the phonemic system, creating only two classes of consonants: soft vs. hard.

This study reveals that coarticulation with the segment /j/ in the pre-kernel node of the nucleus is the primary source of effects attributed to palatalization. Furthermore, additional coarticulation effects occur, for virtually every pairing of adjacent contrastive specified vocalic targets. The number of possible coarticulated combinations is decreased by phonological processes that cause vowel reduction. In Modern Standard Russian, coarticulation routinely occurs across an intervening consonant interlude, but may also occur across an intervening contrastive vowel in rare cases.

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CHAPTER 1

INTRODUCTION

1.1 Feature vs. Segment

In Modern Standard Russian, palatalization effects, such as partial allophonic fronting of stressed vowels and allophonic fronting of unstressed vowels to [i], have been attributed to a feature within the phonemic system, which contrasts soft consonants vs. hard consonants (Halle 1959, Jones and Ward 1969, Hamilton 1980). According to such studies (collectively referred to here as the "Dual Consonant Tradition" (DCT)), which have posited contrastive soft and hard consonants in the phonemic inventory (symbolized in this study as Ç and K, respectively), allophonic fronting occurs in stressed ÇVÇ sequences, and fronting of unstressed vowels to [i] occurs in ÇV sequences.

In the current study, it will be argued that palatalization effects should be attributed solely to the palatal segments /j č š ž/[1], with the glide /j/ being the segment responsible for the determination of the allophones of vowels. As such, the soft counterparts Ç, of the hard consonants K, do not exist as phonemes, and the phonemic inventory is limited to a single set of consonants C. Using the current single set of consonants C, allophonic fronting occurs in stressed CjVCj sequences. The fronting of unstressed vowels to [i] occurs in CjV sequences, after the kernel vowel V has been

[1] Appendix D contains a complete list of sign and symbol conventions used in this dissertation.

deleted, and only the sequence Cj remains.

Either of the two conventions (i.e., the DCT convention of dual sets consonants, or the current convention of a single set of consonants with a robust glide /j/) accounts for the majority of output of phonological processes, and evaluating the two conventions is primarily an issue of subjective debate.

To evaluate the two conventions on more objective terms, the current study investigates the acoustic shape of spoken utterances, in an effort to determine the phenomena that favor one convention over the other.

This dissertation also seeks to determine if vowel-to-vowel coarticulation across a consonant interlude is an active process in Modern Standard Russian (viz. Öhman 1966). Öhman concluded that Modern Russian does not exhibit this type of coarticulation; however, for Russian, Öhman only investigated coarticulations between successive syllables, with /e/ as the vowel in the first syllable. The current study seeks to expand upon the possible number of vowel combinations, and determine if coarticulations occur when the first vowel is anything other than /e/.

The current study will compare as many contrastive vocalic sequences occurring in actual lexical items, as can be identified for a consistent environmental frame of control, in the attempt to limit confounding factors. Since a consistent frame within the lexicon was not identified for all possible tautosyllabic vocalic sequences, an artificial frame will be provided, for the creation of nonce items, which will cover gaps in the lexical frame.

1.2 Instrumental Acoustic Study of Diphthongs

The current study seeks to investigate the behavior of vocalic sequences, whether they be tautosyllabic or heterosyllabic sequences. Consider the following twenty possible tautosyllabic sequences:

1) /y e a o u/ (Cyrillic <ы э а о у>, respectively)

2) /yj ej aj oj uj/ (Cyrillic <ый эй ай ой уй>, respectively)

3) /(j)i je ja jo ju/ (Cyrillic <и е я ё ю>, respectively)

4) /(j)ij jej jaj joj juj/ (Cyrillic <ий ей яй ёй юй>, respectively)

Thus, of the twenty possible tautosyllabic sequences, only the first five in set 1 do not involve the glide /j/. However, if the current analysis is correct, the nucleus /y/ <ы> is actually a diphthong [ɨi]. Thus, only four of the twenty sequences does not involve /i/ or /j/. Furthermore, if heterosyllabic coarticulations occur routinely, any syllable nucleus comprised of /e a o u/ from set 1, which occurs prior to a syllable containing a sequence from sets 3 or 4, will diphthongize with the leading /j/ of the second syllable, effectively converting the nucleus from set 1 into the corresponding sequence in set 2.

Thus, only four of the potential twenty tautosyllabic sequences (20%) will not involve a high front segment /i/ or /j/, but only 50% of the time, with regard to possible combinations. Therefore, only 10% of the potential nuclei in successive syllables will not involve coarticulation with a high front segment /i/ or /j/. Thus, 90% of the potential nuclei in Modern Standard Russian will involve diphthongization with /i/ or /j/, in some fashion. Therefore, to analyze the acoustic properties of vocalic sequences in Modern Standard Russian adequately, a technique must be capable of describing diphthongs.

Previous techniques for studying glides and diphthongs have analyzed different aspects of glidees and diphthongs: the rate of change of the glide (Gay 1970); the duration of the glide (Liberman 1956; Bond 1978); the duration of the steady-states (Lehiste 1961); the ratio of the duration of glides and steady-states (Gay 1968); and durations of the glide and the steady-states, along with the rate of change of the glide (Jha 1985).

The current research study seeks to build upon these approaches by evaluating a longitudinal method to describe the entire length of a vowel sequence, and capture the dynamic or static nature of the vowel, using mathematical models. These mathematical models also contain change-points and/or pseudo-change-points, which will also permit durational and rate of change analyses, as were performed in any of the previous studies noted.

CHAPTER 2

REVIEW OF APPLICABLE THEORY

2.1 Review of Phonological Considerations

In Modern Standard Russian, the contrast of minimal pairs such as ток /tok/ ‘current/flow’ vs. тёк /tjok/ ‘it flowed’ has been attributed to palatalization. This palatalization can be analyzed in three ways:

1) as a qualitative contrastive feature in the phonemic system, which produces a dual set of consonants, as proposed by Halle in *The Sound Pattern of Russian* (1959), which can be symbolized by K vs. Ç ([tok] vs. [t̡ok]);

2) as a secondary coarticulation to the consonant, symbolized as C vs. C^j ([tok] vs. [t^jok]), as proposed for Korean by H.-Y. Kim (1998); or

3) as a quantitative contrast between one segment and two segments, i.e., between a single consonant C vs. consonant+glide cluster Cj ([tok] vs. [tjok]), proposed in this research.

Ni Choisain (1994) observed that Russian was an example of languages that use multiple strategies, such that non-labials experience a change of point of articulation and labials experience double articulation, but Halle (1959) proposed that Modern Russian capitalizes solely on the first strategy.

Positing that Russian has a single strategy involving a phonemic glide between the onset and the kernel of the nucleus offers certain gains in efficiency by: 1) reducing the phonemic inventory and contrastive features; 2) isolating the source of onset palatal effects to a single node in the syllable structure; 3) equalizing the distribution of sonorants in the syllable structure; 4) specifying vowel quality in unstressed syllables more transparently; 5) accounting for fronted allophones of stressed vowels more clearly; 6) limiting the need for allomorphic information in the lexicon; and 7) relating Modern Russian to other Modern Slavic languages in terms of syllable structure and moraic processes. These gains come only at the expense of positing an additional node in the syllable structure.

Positing /j/ as a suitable candidate for the source of palatalization in consonant+glide sequences in Modern Russian is in harmony with observations regarding a variety of other languages. Previous studies support the notion that /i/ and /j/ are the same feature matrix, filtered by differing node requirements in the syllable. Salza (1988) found no difference to conclude two separate classifications for semi-consonant onglides /w j/ and semi-vowel offglides /i̯ u̯/. Guerssel (1986) concluded that the feature [syllabic] was unnecessary; there was no difference between glides and high vowels in Berber: their qualities were predictable based on their position in the sonority wave, as indicated by their node assignment in the syllable structure.

Previous studies have also shown that /i/ is a common source of palatalization. The segment /i/ is the source of palatalization of /t/ → [č] in Modern Japanese, and of /s/ → [š] in Modern Korean. Similarly, for Modern Icelandic, front vowels are the source of palatalization, and positing an underlying *yod* after velars would then account for their palatalization as well, and equalize the distribution of *yod* after consonants (Arnason 1978). Similarly, /j/ has been posited as the source of palatalization in the historical development of many languages. The sequence /kj/ became palatal in Mandarin (Schuessler 1996); consonants became palatalized in the environment __i/y in Korean during the 17th century (Toh 1977); front vowels /i e/ were the source of palatalization in many Oceanic languages (Lynch 1996); consonant + *yod* sequences were palatalized in the evolution of Latin to French (Jacobs 1991).

Clements describes palatalization as "involving higher degrees of approximation to the feature composition of front vowels" (1976: 97). This results in an irreversible diachronic evolution of place of articulation (towards coronal) and/or manner (towards maximal affrication). Clements asserts that front vowels should have the feature [+coronal], and therefore, they form a natural class with coronal consonants. Then, "The [+coronal] status of front glides is a consequence of our treatment of front vowels" (Clements 1976:103). The Bulgarian palatal consonants and front vowels are the same tongue gestures (Wood 1996).

By positing that the palatalization is caused by a glide, a position for the glide must be present in the syllable structure, creating two vocalic nodes. Positing that there are two nodes in the nucleus of Slavic languages is evidenced by contrastive vowel length in Czech, Slovak (Rubach 1998) and Serbo-Croatian (Inkelas & Zec 1988). Russian also had contrastive vowel length at one time in its history.

2.1.1 Phonemic Inventory and Contrastive Features

In *The Sound Pattern of Russian* (SPR) (1959), Halle's "binary" feature specification for [sharped] divided consonants of the phonemic system into classes. These major classifications of phonemes are presented in Table 2.1, with the consonants divided into sets, based upon Halle's feature [sharped].

According to Halle's model, most consonants contrast an otherwise identical consonant via a qualitative feature of [±sharped] in a relationship of K [–sharped] vs. Ç [+sharped]. Selection of K vs. Ç at any consonantal position in a sequence is specified in the lexical definition of a morpheme. There must be agreement of [sharped] within a consonant cluster, once the feature is selected for one consonant.

By attributing palatalization to the segment /j/ in a string, the K vs. Ç contrast is realized as K vs. Kj, and clusters are contrasted K^n vs. K^nj, instead of K^n vs. $Ç^n$. The underlying contrast is maintained; however, it is now considered quantitative, not qualitative. Furthermore, the contrast can be accomplished using only elements already specified in Halle's inventory. Since the contrast between K and Ç can be described as a contrast between K and Kj, the set of [+sharped] Ç can be eliminated.

Also, the set previously designated as [○sharped], consisting of consonants Č, can be combined with the remaining [–sharped] consonants K. While sequences K vs. Kj are contrastive, sequences of Č vs. Čj are not contrastive. Hence, Halle's three sets: [–sharped], [○sharped], [+sharped] can be collapsed into one set, and the feature [±sharped] can be removed from the phonemic system.

Table 2.1 Phonemes in *The Sound Pattern of Russian* (Halle 1959).

Consonants (29):																			
[–sharped]:	p	b	v	f	m	t	d		s	z	n	r	l	č†			k		
[○sharped]:								c						č†	š	ž		g	x
[+sharped]:	p̡	b̡	v̡	f̡	m̡	t̡	d̡		s̡	z̡	n̡	r̡	l̡				k̡		
Semi-consonant (1):																			
[–cons, –vocalic]:														j†					
Vowels (10):																			
[+accented]	í	é	á	ó	ú														
[–accented]	i	e	a	o	u														

†Originally specified as [○sharped], becomes [+sharped], by SPR Rule P5b.

2.1.2 The Syllable Structure: Nodes and Licensing

Positing that a glide is the source of palatalization requires a separate node in the syllable structure. The syllable structure of a language is a very powerful device for filtering potential sequences of segments and ensuring only grammatical sequences are realized as surface forms. The depiction of a syllable structure as a hierarchical tree will be used here. The syllable structure of Modern Standard Russian is similar to the Goldsmith's model of Modern English (1990: 142), depicted in Figure 2.1.

According to Goldsmith, a licenser can permit only one instance of a feature. Consider the English onset in Figure 2.1. Place of articulation (P-of-A) is licensed at the onset node, and it may permit only one selection to precipitate down to the leaf nodes. As Goldsmith writes, "Although the point of articulation may consist of several features, it counts as one unit for the purposes of licensing" (1990; 123). Here, [P-of-A] is one of {labial, alveolar, palatal, velar}; the same can be observed for sonorants, [manner] is one of {round, nasal, liquid, rhotic}. The sequence /pw/ cannot occur, because [+labial] at the onset node can create only /p/ or /w/, but not both. In this framework, certain features may be filled in afterwards by redundancy rules.

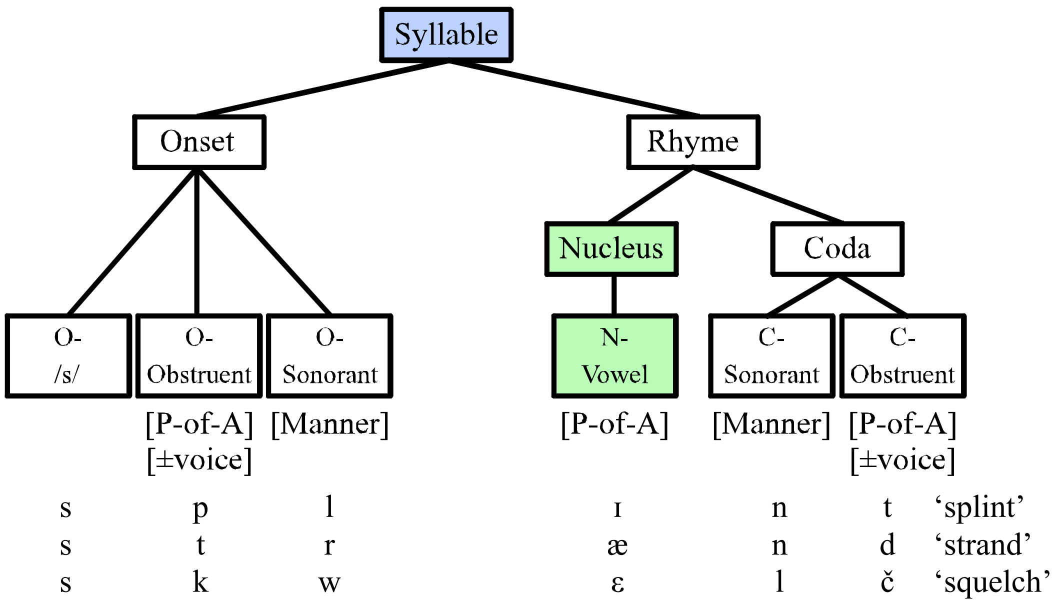

Figure 2.1 Syllable Structure for English. [P-of-A] is used here as an abbreviation for point-of-articulation feature matrix. [Manner] pertains to manner of articulation: nasal, lateral, etc.

Therefore, if the features [+voiced], [P-of-A = alveolar] and [+liquid] are passed by the onset node, [P-of-A = alveolar] and [+voiced] can settle into the Obstruent node and select /d/, and the [liquid] feature can settle into the Sonorant node and select /r/, and the sequence /dr/ occurs. Redundancy rules will then specify that /r/ is also alveolar by default. If [–voiced], [P-of-A = alveolar], and [+round] are passed by the onset, [–voiced] and [P-of-A = alveolar] can settle into the Obstruent node and select /t/, and [+round] can settle into the Sonorant node and select /w/, and the sequence /tw/ occurs.

Table 2.2 Sample Onset Sequences for Modern Standard Russian.

Item	Ω- Sonorant	O- Sibilant	O- Obstruent	O- Sonorant	Remainder:	Cyrillics:	Gloss:
10			d		ok	док	‘dock’
11			t		ok	ток	‘current, flow’
12		s	t		atj	стать	‘to stand’
13		š	t		at	штат	‘state’
14		š	p		at	шпат	‘spar’
15		z	d	r	ávo	здраво	‘sensibly’
16		ž	d		atj	ждать	‘to wait’
17			k̡	n̡	íga	книга	‘book’
18			d̡	n̡	epr	Днепр	‘Dnieper River’
19			d̡	m̡	ítri	Дмитри	‘Dmitri’
21	f̡	s̡	t̡	r̡	et̡ít̡	встретить	‘to meet’
22	f	s	p	r	ýsk̡ivat̡	вспрыскивать	‘to sprinkle’
23	v̡	z̡	g̡	l̡	ad	взгляд	‘(a) glance’
24		š	t	r	af	штраф	‘fine, penalty’
25		z	d	r	ávstvovat̡	здравствовать	‘to be well’
26		ž	d		at̡	ждать	‘to wait’
31			d̡	l̡	iná	длина	‘length’
32			t̡	l̡	et̡	тлеть	‘to decay’
33			č	l̡	en	член	‘member’
34			č	r̡	edá	чреда	‘succession’
40			č	m	ókat̡	чмокать	‘to smack lips’
41		z	g	n	oít̡	сгноить	‘to rot’ perf.
42			g	n	oít̡	гноить	‘to rot’
43			k	n	ut	кнут	‘whip’
44			d̡	n̡	épr	Днепр	‘Dnieper River’
51			k	v	art̡íra	квартира	‘room/quarters’
52			d	v	a	два	‘two’ masc.sg.
53			d̡	v̡	e	две	‘two’ fem.sg.
54		z	d	v	oít̡	сдвоить	‘to double’
55			d̡	m̡	ítri	Дмитри	‘Dmitri’
61*	s̡	f̡			éra	сфера	’sphere’
62*	s	x			od̡ít̡	сходить	‘go down’
63*		z			al	зал	‘hall’
64*		ž			al̡	жаль	‘pity’
61b		s̡	f̡		éra	сфера	‘sphere’
62b		s	x		od̡ít̡	сходить	‘go down’
65		š	x		úna	схуна	‘schooner’
63b			z		al	зал	‘hall’
64b			ž		al̡	жаль	‘pity’
66			v	r	ač	врач	‘doctor’
67			z	n	ak	знак	‘sign, mark’
68			z	l	o	зло	‘evil’

Table 2.2 - *Continued*.

Item	Ω-Sonorant	O-Sibilant	O-Obstruent	O-Sonorant	Remainder:	Cyrillics:	Gloss:
70	m̡	s̡	t̡		ít̡el̡	мститель	‘avenger’
71	m	z	d		a	мзда	‘bribe’
72	m		g	l	a	мгла	‘haze’
73	m̡			n̡	e	мне	‘me’ dat.
74	m			l	adój	младой	‘young’
75	n			r	áv̡it̡	нравить	‘to please’
76	r̡		d̡		et̡	рдеть	‘to glow’
77	r			v	at̡	рвать	‘to tear, rip’
78	l̡		g		óta	льгота	‘privilege’
79	l		g		at̡	лгать	‘to lie, fib’
80?	p	s			a	пса	‘dog’ gen.sg.
81?	p	s			árn̡a	псарня	‘kennel’
82?	p	s			óvyj oxóta	псовый охота	‘chase’
83?	p̡	s̡			ína	псина	‘dog smell’
84			p̡		ós	пёс	‘dog’
85?	p		t		áška	пташка	‘birdie’
86?	p̡		t̡		íca	птица	‘bird’
87?	p̡		t̡		ičij	птичий	‘avian’
88?	p̡		t̡		en̡ec	птенец	‘nestling’
91?	t		k		at̡	ткать	‘to weave’
92?	t		k		ač	ткач	‘weaver’
93?	t		k		ányj	тканый	‘woven’
94?	t		k		an̡	ткань	‘cloth’

For Modern Standard Russian, however, place of articulation cannot be specified solely at the onset node, to be filtered down to a single node. Instead, place of articulation must be licensed lower in the onset structure. Multiple nodes in the onset can bear the contrast of place of articulation.

To demonstrate this, consider selected pairs of lexical items in Table 2.2. Item 13 /štat/ vs. item 14 /špat/ contrast on point of articulation at the O-Obstruent node; item 12 /statj/ vs. item 13 /štat/ contrast on point of articulation at the O-Sibilant node;

and item 18 /ᶁᶇepr/ vs. item 19 /ᶁᶆítri/ contrast on point of articulation at the O-Sonorant node. Thus, point of articulation must be licensed at each of these nodes. The feature [±voiced] need only be licensed at the O-Obstruent node.

To ensure that a viable syllable structure has been constructed for the upcoming discussion on the placement of [+sharped] and to demonstrate licensing in the Russian syllable structure, consider voicing in the clusters of word-initial onsets. Beginning with the largest clusters possible, an onset structure that will support Halle's underlying phonemic sequences can be constructed quickly, and then tweaked to accommodate any additional lexical items that remain.

In SPR, Halle identifies the largest onset as four consonants, in the lexical item встретить /ᶂᶊƫᶉe.ƫiƫ/ 'to meet.' This item is parsed in Table 2.2, as item 21. (Larger clusters can occur, but they involve heterosyllabic coda+onset sequences, and thus are not considered here.)

In Table 2.2, **Ω**-Sonorant is an extrametrical node, and may only occur word-initially, as it usually involves prefixation before the root with loss of syllabic element of the prefix morpheme, e.g. взлетать /vzljɛtatj/ = {voz} + {ljetatj} 'up/off of' + 'to fly.' Coronal-**Ω** is an extrametrical node which may only occur word-finally, and usually involves absence of a syllabic segment in a zero-suffix and then resyllabifying the remaining consonantal segment(s) to the final coda of the root e.g. центр [cɛntr] 'center' nom.sg vs. центра [cɛn.tra] 'center' gen.sg. This concatenation by resyllabification can only occur successfully if the segment is a coronal or a sonorant. However, in the case of sonorants, syllabic variants of the sonorants do exist, and thus the extrametrical segment is likely to be a new syllable and not a purely consonantal node.

Therefore, only coronal non-sonorants may occur in this extrametrical node, e.g. фрахта [frax.ta] 'freight' gen.sg. vs. фрахт [fraxt] 'freight' nom.sg. If a zero-suffix leaves a non-sonorant non-coronal at this extrametrical node, then a process must be invoked and an epenthetic vowel must be inserted, e.g. кошка [koš.ka] 'cat' nom.sg. vs. кошек [ko.šek] gen.pl.

Anticipating the need for adherence to the Sonority Cycle, consider the following syllable structure as a tentative prototype for Modern Standard Russian:

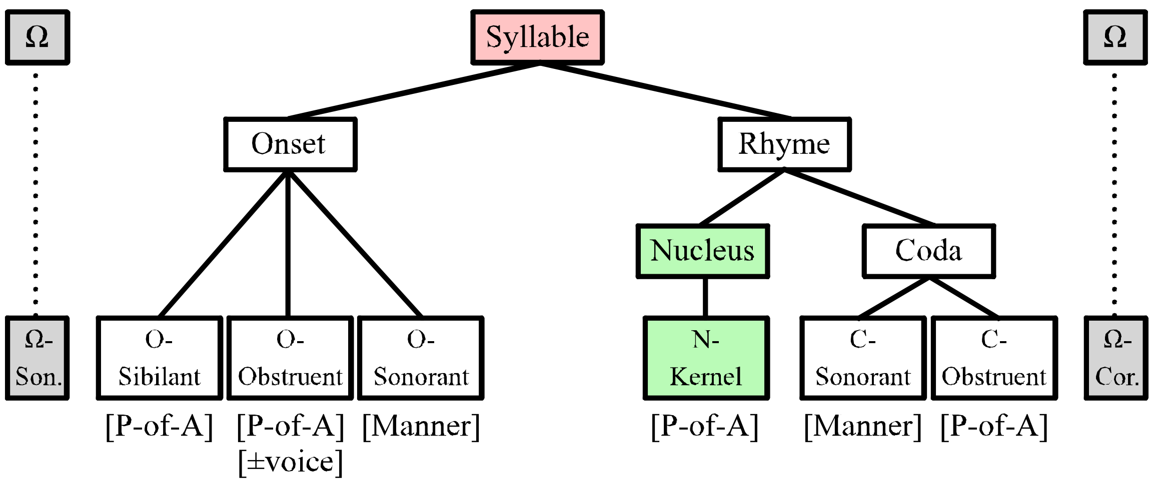

Figure 2.2 Preliminary Syllable Structure for Modern Russian, With Word-Initial and Word-Final Extrametrical Nodes.

Excluding the two extrametrical nodes, the syllable structure is greatly similar to other Indo-European languages. However, Russian has fewer constraints on the feature specifications of the nodes, and hence, permits a wider variety of combinations of phonemes in the onset than Germanic and Romance languages.

Based on observations of the lexicon from Smirnitsky's dictionary, in terms of number of roots with similar onsets and actual realization of potential onset sequences, one can assert generalizations about the syllable structure. The **Ω**-Sonorant node is almost exclusively filled by allophones of /v/, originating from prefixes {vo} 'into/onto,' and {voz} 'off of.' Examples of the most frequent membership for the **Ω**-Sonorant node are provided in items 21-23 of Table 2.2.

The O-Sibilant node is almost exclusively filled /s/, but can be filled with any of the coronal fricatives /s z š ž/, as shown in items 21-26 of Table 2.2. The O-Obstruent node is most frequently occupied by stops and affricates, and can be defined as [–continuant, –sonorant]. The O-Sonorant node is most likely designed for /r/, since /r/ appears here most often, although /l/ appears frequently as well. The voicing of the extrametrical **Ω**-Sonorant node and the O-Sibilant node must agree with the O-Obstruent node; the liquids are voiced by redundancy rules.

Modern Standard Russian does not favor words with /dl/ or /tl/ onsets, but does not absolutely prohibit them either. Lexical items with /dl/ or /tl/ onsets are uncommon, but grammatical. Item 31 /d̡l̡iná/ and item 32 /t̡l̡et̡/ of Table 2.2 are examples with these onsets.

If the interior O-Sonorant node is expanded beyond coronal liquids, to include coronal nasals, as shown in items 40-44 of Table 2.2., then many additional items can be accommodated without violating the Sonority Cycle, and without creating onsets which are structurally more complex. In fact, onsets with nasals have fewer elements than those already considered. The only element that can exist before the O-Obstruent node is a perfective prefix for a few verbs, and these is rare. Item 41 /zgnoíţ/ is an example of the most complex onset with a nasal in the interior O-Sonorant node of the onset.

If the O-Sonorant node is further relaxed and opened to non-coronal sonorants, as shown in items 51-54 of Table 2.2, then even more residue and some borrowings from Latin can be accommodated, without violating the Sonority Cycle. Thus, without regard to the feature [sharped], the current tentative status of the O-Sonorant node of the onset permits all sonorants /r l n m v/, and excludes only /j/.

With the exception of a few lexical items with two obstruents in the onset (which will be considered later in the presentation), stops can only occur in the onset, if they occupy the O-Obstruent node. Item 10 /dok/ and item 11 /tok/ of Table 2.2 are examples of a minimal pair, which contrasts [voice] in the initial stop. The O-Obstruent node must then be licensed for [voice] to permit this contrast.

To accommodate lexical items with voiced sibilants, two options exist: either the O-Sibilant node can be licensed for [voice], as presented in items 63* /zal/ and 64* /žaļ/ of table 2.2; or the Obstruent node can be modified from [–continuant] to include fricatives [±continuant] (that is, it can be described merely as [–sonorant]), as presented in items 63b and 64b of Table 2.2.

A few additional lexical items involve two fricatives in the onset. If the O-Obstruent node were not relaxed to permit fricatives, then the O-Sibilant node must be relaxed to permit non-coronals, and also the extrametrical node must be relaxed to permit non-sonorant continuants. Since non-coronal fricatives do not precede obstruents beyond those already accounted for in the extrametrical node (items 21-23), then the option of relaxing the Sibilant and Extrametrical nodes is discarded in favor of relaxing only O-Obstruent node. Permitting fricatives in the O-Obstruent node allows [voice] to be selected for fricatives in this position, and accounts for all items with voiced fricatives that are not preceding by voiced stops. Therefore, it is not necessary to license [voice] at any node other than the O-Obstruent node.

Some additional items can be accounted for, involving two sonorants or sonorant+obstruent, by a single relaxation of the constraints of the initial extrametrical node. The initial extrametrical node is either reserved for prefixes, or it is reserved for potential syllabic sonorant consonants. In item 70 /m̡s̡t̡ít̡el̡/ of Table 2.2, the initial /m/ is not a prefix, and hence, the analysis that the extrametrical node is reserved for sonorants is accepted. Thus, onsets with two sonorants could be accommodated by expanding the initial extrametrical node beyond the /v/ of prefixes {vo-} and {voz-}. This can be reconciled with the Sonority Cycle in the same fashion as the word-final extrametrical node: sonorants can appear in these locations, because they can be syllabic if needed.

The remaining residue includes a number of lexical items involve the onset /ps-/ in ‘psalm,’ ‘pseudo’ and ‘psych-‘ and /ks-/ in ‘xenon,’ ‘xeroform,’ ‘xylophone,’ and a few roots with two obstruents in the onset, such as items 80-94 in Table 2.2.

Thus, the onset (with the word-initial extrametrical node) can be stated concisely as a filter, with the following restrictions and licenses for variability, as shown in Table 2.3. The table includes the restrictions and licenses at each node, and the membership of the phonemic inventory that fulfill these requirements, excluding the feature [sharped].

Thus, [voice] is only licensed once, at the O-Obstruent node. Since the feature is licensed only once, it can be raised in the structural hierarchy to the Onset node. Agreement in voice is accomplished by a single rule that spreads the value of [voice] specified at the O-Obstruent node leftwards to the O-Sibilant node, and then to the Ω-Sonorant node. This onset structure accounts for most of word-initial clusters.

Table 2.3 Updated Onset of the Preliminary Syllable Structure for Modern Russian.

Ω-Sonorant	O-Sibilant	O-Obstruent	O-Sonorant		
[+son] [P-of-A] [manner]	[+cont,+cor] [P-of-A]	[–son] [P-of-A] [±cont] [±voice]	[+son] [P-of-A] [manner]	} Restrictions } Licenses	
v/f	s/z	p t k	r	} members	↑ common
		b d g	l		
		s z x	n		occurrence
	š/ž	c č š ž	v		
m n r l		v f	m		↓ rare

However, the feature [sharped] cannot be economized in same fashion as [voice]. Since stops can only be assigned to the O-Obstruent node, if they are to be contrastive for [sharped] (e.g., items A1 and A2 of Table 2.4), the O-Obstruent node must have access to licensing for the [sharped] feature.

The feature [sharped] must also be posited in the extrametrical Ω-Sonorant node, because, as in the items B1 and B3 of table 2.4, the non-sonorant nodes provide the only other consonantal information in the onset, but (per Halle) the segments /š ž/ are not specified for [sharped], and can not be the source of [+sharped] value of /v̦/ in B1 and B3.

Table 2.4 Selected Palatalized Onset Sequences for Modern Standard Russian.

Item	Ω-Sonorant	O-Sibilant	O-Obstruent	O-Sonorant	Remainder:	Cyrillics:	Gloss:
A1			t		ok	ток	‘current’
A2			t̡		ok	тёк	‘(it) flows’
B1	v̡		ž		imat̡	вжимать	‘to press’
B2?	v̡		š		ivát̡	вшивать	‘to sew’
B3	v̡	š			ivát̡	вшивать	‘to sew’
C1		s̡	ž		imat̡	сжимать	‘to squeeze’
C2*	s̡		ž		imat̡	сжимать	‘to squeeze’
D1				r	ad	рад	‘glad’
D2				r̡	ad	ряд	‘row, queue’
D3?	r̡				ad	ряд	‘row, queue’
D4			ž	r̡	ec	жрец	‘priest’
D5		š		m̡	el̡	шмель	‘bumble-bee’
D6*		š	m̡		el̡	шмель	‘bumble-bee’
B1	v̡		ž		imat̡	вжимать	‘to press’
C1		s̡	ž		imat̡	сжимать	‘to squeeze’
A2			t̡		ok	тёк	‘(it) flows’
D4			ž	r̡	ec	жрец	‘priest’

The same reasoning holds for the O-Sibilant node. In items C1 and C2* of Table 2.4, the /s̡/ phoneme can potentially be placed in one of two positions, prior to the O-Obstruent node. Relaxing the [+sonorant] requirement of the extrametrical Ω-Sonorant node (that was established while investigating [voice]), and permitting sibilants into the extrametrical Ω-Sonorant node would avoid licensing [sharped] at the O-Sibilant node. However, since there are no onsets of the shape sibilant-sibilant-obstruent, one can safely expect that sibilants are not permitted in the extrametrical Ω-Sonorant node, and that the requirement that its occupants be sonorant has not been relaxed to include non-sonorant sibilants.

Finally, the pre-nucleic O-Sonorant node must be licensed for [sharped] as well, since it can be the only node where the specification can occur in the absence of [+sharped] obstruents (as is the case of item D4 of Table 2.4), unless the [–sonorant] restriction is lifted from the O-Obstruent node. However, doing so would permit two sonorants after the O-Sibilant node (for which there is only a single lexical item: /smrad/ ‘stench’) and also would permit onsets with three sonorants (for which there are no lexical items). There is insufficient evidence to support that sonorants are routinely permitted into the Obstruent node.

As shown at the bottom of Table 2.4, the feature [sharped] must be specified at each and every node of the onset. Therefore, if the feature [sharped] exists, it cannot be treated the same as [voice]. For the feature [voice], the feature is licensed only once in the onset, and the feature can then be elevated in the hierarchy to the onset node, and the entire onset can exhibit agreement in voicing. In contrast, the feature [sharped] violates Goldsmith licensing criterion: [sharped] must be licensed at each and every node of the onset, even though there is supposedly agreement in this feature through the onset.

The issue dissipates if the feature [sharped] is removed from the system and the source of palatalization is attributed to the pre-kernel /j/ of the nucleus. Doing so isolates the source into a single node, and the effect can potentially spread to the left via a cyclical rule, or via coarticulation. If the effect is a result of coarticulation, then it becomes an issue of proximity to the source.

2.1.3 [sharped] in Clusters and Redundancy in the Syllable Structure

If [sharped] is in fact a feature as Halle proposes, then it must be licensed at each node of the syllable onset. This is not strictly prohibited, since point of articulation is licensed at each node. However, onsets need not exhibit agreement of point of articulation, but onsets supposedly must exhibit agreement for [sharped]. Furthermore, there must be rules to spread the feature both left and right from the node(s) at which it is detected, so that onsets lacking agreement for [sharped] do not occur. The rules must step through each node of the onset, and be prepared to proceed cyclically in both directions from the point at which a [+sharped] feature is encountered.

Alternatively, the [sharped] specification can be removed from the individual leaf nodes of the onset entirely, and moved higher in the syllable structure, to the Onset node itself. If the feature is removed from the leaf nodes and elevated to the Onset node, then it is likely not a part of the segmental phonemic system, since it cannot be attributed to any specific segment placed in the onset.

By embracing the alternative (of adding a node into the syllable structure for /j/), the syllable structure becomes slightly more complex in terms of number of nodes, but more economical in terms of licensing requirements, and in terms of spreading the palatalizing effect to ensure agreement amongst segments in the cluster.

In this framework, the contrastive effect of the binary [±sharped] quality is obtained by the binary presence/absence of the phoneme /j/ in the sequence of underlying segments, and thus specified (or "licensed") only once in the syllable structure. It is deposited to the right of the entire consonant onset, in a position poised to spread its palatalizing effect leftwards through the entire cluster by means of a single, uni-directional (left-spreading) process.

Placement of this node between the onset sonorant and the nucleic vowel is in accordance with the Sonority cycle. The segment /j/, being a vocoid, is more sonorant than liquids and nasals (and also Russian's labio-dental sonorant /v/), and it is less sonorant than a syllabic vowel.

To summarize, specifying the location of palatalization within the syllable structure can be economized by eliminating the redundancy of licensing all four nodes of potential onsets with [sharped], and locating the source of the effect at a single location to the right of the onset. Spreading processes can be economized by eliminating the need for a right-spreading rule altogether. As such, only a left-spreading process is required. Furthermore, the spreading process is constrained to monitor a single specific node for activation of its cyclical application. Creation of this node in the syllable structure has not violated the naturalness of the Sonority Cycle, but rather, it conforms to it faithfully.

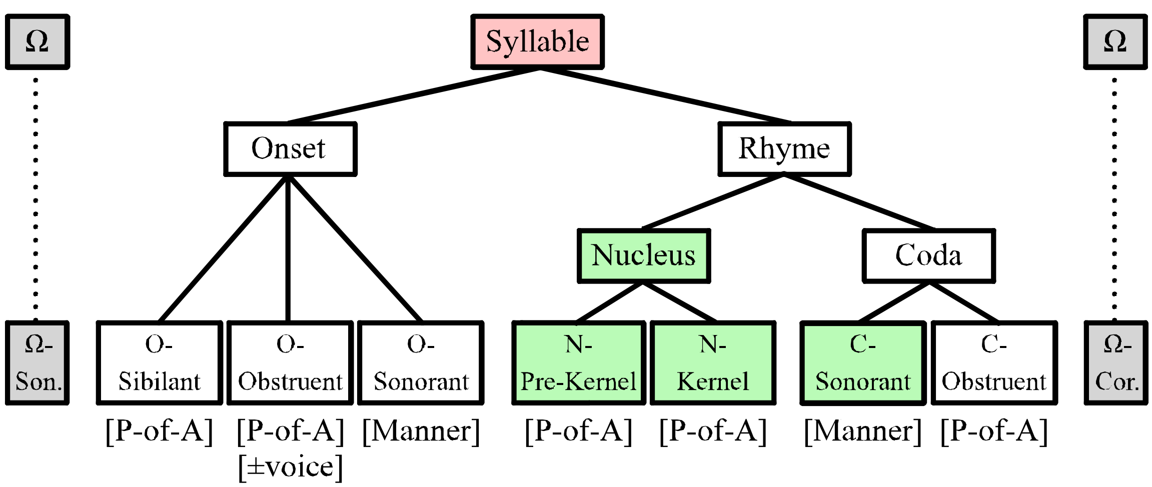

Figure 2.3 Proposed Syllable Structure for Modern Standard Russian.

The position of this /j/ node is established within the Sonority Cycle. However, the hierarchical structure of this new node is still in question. There are numerous arguments for the appropriate hierarchical placement (and existence) of a glide node between the onset and the nucleus. This is particularly relevant to many Asian languages in which the previously accepted structure was fairly simple: one onset node and one nucleus node. Debate has arisen as to where should the third set of information (from the glide) be posited (CW Kim 1977; CW Kim & HY Kim 1991; HY Kim 1998; HS Wang & CL Chang 2001).

To determine the appropriate hierarchical position for a glide node in Korean, H.-Y. Kim (1998) evaluated a variety of structures and theories. Kim could not firmly assert that one strategy was overwhelmingly more defendable than another, and thus how these three elements are syllabified and produced acoustically is still debatable. H.-Y. Kim did assert, however, that secondary articulations [±labialized] and [±palatalized] are not part of the feature systems, and thus there are only simple consonants and the two glides /w/ and /j/ in the phonemic inventory; that contrast is recorded as quantity and not quality at the phonemic level in the lexicon. However, some languages show that complex structures and numerous nodes are possible. Argentinian Spanish monosyllabic /trwen/ 'thunder' requires a node between the onset sonorant and the vowel (Harris & Kaisse 1999); the glide position could conceivably be the first of two vowel nodes in a bifurcated nucleus. In Frisian, however, the requisite glide node occurs between the sonorant and the vowel, and in some cases, cannot be in the nucleus, which is already filled by a long vowel (viz. monosyllablic /blio:u/ 'stay' (Booij 1989)).

2.1.4 Equalizing the Distribution of Sonorants

As demonstrated in examples under the discussion on syllable structure, the full range of consonantal sonorants /r l n m v/ may potentially occur in the extrametrical onset position. The full range may also occur in the pre-vocalic sonorant position of the onset, in combination with other consonants. A parallel distribution of the full range these sonorants may appear post-vocalically, either as a simple coda, or in combination with other consonants. The full range of sonorants may appear intervocalically as well. And finally, again as noted in the discussion on syllable structure, the full range of these sonorants may appear in the extrametrical coda position, as part of a consonant cluster.

In summary, the sonorants /r l n m v/ have a substantially parallel distribution. The segments /n m/ have slightly less flexibility in the onsets (and the word-final extrametrical position, which arises from coda+onset concatenation without a final syllabic vowel). However, as proposed by Halle (first row of Table 2.5), /j/ can only appear the onset in the absolute word-initial position (and arguably in the intervocalic position). By establishing a separate pre-vocalic node in the syllable structure (last row of Table 2.5), /j/ acquires a distribution parallel to that of the other sonorants.

Table 2.5 The Distribution of Sonorants in Modern Standard Russian.

segment	Ω-onset	Onset	Intervocalic	Coda	Ω-coda
/j/(Halle)	-[jCV]µ	#j	VjV	Vj(C)(C)(C)#	prohibited
/r/	rCV	#(C)(C)(C)rV	VrV	Vr(C)(C)(C)(C)#	V(C)(C)(C)r #
/l/	lC(C)V	#(C)(C)(C)lV	VlV	Vl(C)(C)(C)#	V(C)(C)l #
/n/	nCV	#(C)(C)nV	VnV	Vn(C)(C)(C)(C)#	V(C)n #
/m/	mC(C)V	#(C)(C)mV	VmV	Vm(C)(C)(C)#	V(C)m #
/v/ (w)	wC(C)(C)V	#(C)(C)wV	VwV	Vw(C)(C)(C)#	V(C)(C)(C)w #
/j/(current)	-[jCV]µ	#(C)(C)(C)(C)jV	VjV	Vj(C)(C)(C)#	V(C)(C)(C)j #

2.1.5 Vowel Allophones: Unstressed vowels

Unstressed vowel allophones can be used to illuminate the palatal effect. Unstressed vowels after [+sharped] consonants lose their contrast and are neutralized to [i], e.g. лес [l̦ɛ́s] 'forest' nom.sg. vs. в лесу [vl̦isú] 'in (the) forest.'

DCT Reduction Rule 1: V → [i] / Ç__

In addition to the phonemes (Ç) that Halle describes as [+sharped], the phonemes /j/ and palatal consonants (Č), which Halle describes as [○sharped], also produce some of the stressed and unstressed allophones noted above. Thus, Halle's assignments for binary features of [sharped] generate four sets of segments that affect vowel quality:

a. [–sharped] consonants K contrast with the other three sets in minimal pairs. They do not trigger the rule to convert [–accented] vowel to [i] / K__. Nor do they trigger the allophone /a/ → [æ] / K__K. They may occur as an absolute onset or in combination with other segments in the onset (K)K or K(K). Examples: стол [stol] 'table,' трос [tros] 'rope;'

b. [○sharped] consonants Č contrast with the other three sets in minimal pairs. They do not trigger the rule to convert [–accented] vowel to [i] / Č__ (except the vowel /e/). However, they do in fact trigger the allophone /a/ → [æ] / Ç__Č or Č__Ç or Č__Č. They may occur as an absolute onset or in combination with other segments in the onset

ČK or ČÇ or ČČ. Examples: жнут [žnut] '(one) reaps,' змыхи [zmyxí] 'oilcake;' жнец [žn̦ec] 'reaper;' жжоный [žžónyj] 'burnt'

c. [+sharped] consonants Ç contrast with the other three sets in minimal pairs. They do in fact trigger the rule to convert [–accented] vowel to [i] / Ç__. And they do in fact trigger the allophone /a/ → [æ] / Ç__Ç. They may occur as an absolute onset or in combination with other segments in the onset (Ç)Ç or Ç(Ç). Examples: стенка [șțɛ́nka] 'wall, sea-wall,' треба [țr̦ɛ́ba] 'religious rite;'

d. /j/ contrasts with the other three sets in minimal pairs. It does in fact trigger the rule to convert [–accented] vowel to [i] / j__. And it does in fact trigger the allophone /a/ → [æ] / j__j. It may only occur as an absolute onset and may not occur in combination with other segments in the onset. Example: юг [jug] 'south.'

Table 2.6 Palatalization Behavior of Halle's Consonant Sets Contrasted by Feature [sharped]. Substitute the appropriate set into the C in the column headings.

Set	Contrastive	V → [i] / C__C	/a/ → [æ] / C__C	Complex Onset
a. [–sharped] K	yes	no	no	yes
b. [○sharped] Č	yes	no (except /e/)	yes	yes
c. [+sharped] Ç	yes	yes	yes	yes
d. /j/	yes	yes	yes	no

Table 2.7 Palatalization Behavior of Current Consonant Sets. Substitute the appropriate set into the X in the column headings. †Due to epenthetic /j/ before /e/, the sequence /Če/ becomes [Čje], which is then a member of set 3.

Set	Contrastive	V → [i] / X__X	/a/ → [æ] / X__X	Complex Onset
1. [–pal] K	yes	no	no	yes
2. [+pal] Č	yes	no†	yes	yes
3. [–pal] C + j	yes	yes	yes	yes

If the model of the syllable structure In Figure 2.3, containing a node for /j/, is embraced, Table 2.6 can be reformed into table 2.7. /j/ is permitted in onsets, eliminating the difference between set 'c' and set 'd' above. These two sets are combined, with set 'd' (i.e., /j/) becoming the sole source of the contrast between set 'c' and set 'a.'

By defining the contrast between set 1 and 3 as the presence of a pre-kernel /j/ in the syllables of set 3, two vocoid targets are thereby posited underlyingly in the syllable: $V_j V_k$. If the rule for specifying vowel quality of unstressed syllables for two-target nuclei is defined as:

Reduction Rule 2a: $\underset{[-\text{stress}]}{V_k} \rightarrow Ø \, / \, j\_\_$

The context of Reduction Rule 2a is now free of the consonant stipulation from Reduction Rule 1, and will apply to any two-target nucleus it encounters, with /j/ in the pre-kernel position.

Although it is not unnatural that a vowel may acquire feature information from surrounding consonants as a result of a rule, it is more transparent that a nucleus be realized from the information contained directly within the nucleus. Furthermore, the rule $V_j V_k[-\text{stress}] \rightarrow V_j$ accurately describes the behavior of another troublesome nucleus of Modern Russian: /y/. The nucleus /y/ is not actually realized acoustically as a high central vowel monophthong; rather, it is realized as a traveling two-target sequence which begins in the vicinity of [ɨ] and terminates in [i]. By positing that syllables containing this /y/-nucleus actually contain a two-target diphthong /ɨi/, then a single general rule will correctly describe the surface forms of unstressed "sharped" syllables (which Halle accounts for) and unstressed "unsharped" syllables of /y/ (which Halle does not account for). A greater degree of transparency and a greater degree of generalization is achieved by positing a pre-kernel jer node in the syllable structure.

Reduction Rule 2b is designed to apply only to two-target nuclei; however, it may have broader more general use in some dialects. If /i/ is defined underlyingly as a two-target string /ji/, then the rule will result in only a loss of duration and not a loss of feature specification. If the two-target rule is reformulate as:

Reduction Rule 2b: $$\underset{[-\text{stress}]}{V_k} \rightarrow \text{Ø} \,/\, V_j \,\_\_$$

then the contrast in V_j is neutralized. V_j acquires whatever mora consideration is afforded to unstressed nuclei, and the nucleus only retains the feature information in V_j. The generalization can absorb single-target nuclei as well. Single-target /e/ is never unstressed, therefore it never meets the structural description and does not participate. This leaves only three nuclei remaining: the monophthongs of back vowels /a o u/. V_j node is reserved for jers; the back vowels are not jers and must be posited underlyingly in the V_k node. In a pilot study involving a family of speakers of the St. Petersburg dialect, all unstressed back monophthongs become schwa. If the maximally underspecified vowel for the family of speakers of the St. Petersburg dialect is schwa, then unstressed back vowels have their feature specifications deleted in Rule 2c.

Reduction Rule 2c: $\begin{matrix} V_k \\ [+\text{back}] \\ [-\text{stress}] \end{matrix} \rightarrow \varnothing \;/\; \_\_$

Since monophthong /e/ is never unstressed, and /i/ can be defined as /ji/, then the requirement [+back] is irrelevant. The remaining rule is the contained in Rule 2d.

Reduction Rule 2d: $\begin{matrix} V_k \\ [-\text{stress}] \end{matrix} \rightarrow \varnothing \;/\; \_\_$

The vowel quality of unstressed syllables for the family of speakers of the St. Petersburg dialect is determined by deleting the features of the kernel in the nucleus and projecting a single mora with the features that remaining: /j/-jer (for jV nuclei), /ɨ/-jer (for /y/ ~ /ɨi/ nuclei), or maximally-underspecified schwa (for the remaining single-target back vowel nuclei). Thus, from St. Petersburg data, a single rule (which is context free of consonants) accounts for the vowel quality of all unstressed syllables.

2.1.6 Vowel Allophones: Stressed Vowels

There are allophones of stressed vowels in modern Standard Russian that are useful for diagnostic purposes as well. The vowels /ɛ a o u/ have allophones [e æ ö ü] (Hamilton 1980). Since Halle attributes the palatal effect to the consonants, the allophones can be described in the following way: the front vowel [ɛ] is raised to [e] in the environment __Ç, e.g. место [m̡ɛ́sta] 'place' nom.sg. vs. о месте [o m̡és̡t̡i] 'about (the) place' prep.sg.; the back vowels /a o u/ are fronted to [æ ö ü] in the environment Ç__Ç, e.g. ряд [r̡ad] 'row/queue' nom.sg. vs. о ряде [o r̡æd̡ɛ] 'about (the) row.'

Öhman (1966) asserted that there could be V-to-V coarticulation between nuclei in VCV sequences. By positing a jer pre-kernel node in the syllable structure with an underlying /j/ in phonemic sequences, coarticulation of the type that Öhman described would involve V-j coarticulation in VCj sequences. Halle and Hamilton observed stressed V phonemes were also fronted before a post-vocalic tautosyllabic /j/ in the coda, e.g. семьёй [s̡im̡jöj] 'family' instr.sg. Clearly, a vowel V plus a post-vocalic tautosyllabic /j/ is a Vj coarticulation.

Öhman's coarticulation is defined as a left-spreading process from the leading edge of a nucleus. By positing a /j/ in the jer pre-kernel node of the nucleus and allowing for Öhman's coarticulation, the phenomenon attributed to Halle's [sharped] feature of the onset can be defined as a left-spreading process from the leading edge of a nucleus. Tautosyllabic Vj sequences are clearly coarticulations. The three concepts merge, and the perceived palatalization (which is perceived in the quality of the surrounding vowels) becomes the result of V-j coarticulation.

By positing a /j/ in the jer pre-kernel node of the syllable and removing the feature [+sharped], Halle/Hamilton's environment Ç__Ç which produces fronted or raised stressed vowel allophones can be redefined as C_1j__C_2j. Öhman's VCV coarticulation indicates that the intervening C segment does not significantly alter the V-V trajectory, i.e., __(C)j. Thus, the environment that produces the fronted/raised allophones consisted solely of vocalic segments: (C_1)j__C_2j → j__(C_2)j → j__j.

By plotting formant transitions (in vowel-space defined by F2 vs. F1) for tautosyllabic #jV sequences and tautosyllabic sequences Vj (in which the underlying /j/ phoneme is not contested), distinctive stable two-target trajectories through vowel-space can be observed. It can be observed that the location of [e] is squarely situated on the trajectory of [jɛ], that is to say, the location of [e] (specified by its formants) lies arithmetically between the locations of [i] and [ɛ]. [e] arises in the environment Ç__Ç, recast above as j__j. The locus of [ɛ] is not merely raised in this sequence; but, rather it is not fully obtained. The trajectory from [j] to [ɛ] in the sequence /j-ɛ-j/ reverses "prematurely." The [e] allophone of /e/ in so-called Ç__Ç environment has the same formant pattern as the [e] allophone of tautosyllabic /jej/ in ей [jej] 'her' dat.sg.

Similarly, it can be observed that the location of [æ] is on the trajectory of tautosyllabic /ja/ or /aj/. [æ] from /a/ arises in the environment Ç__Ç, and has the same formant pattern as the [æ] of tautosyllabic /jaj/ in яйца [jǽjca] 'eggs.' The locus of /a/ is not fronted in the sequence /j-a-j/; rather, it is not fully obtained. The trajectory from /j/ to /a/ in the sequence /j-a-j/ reverses "prematurely." The same is true of what Hamilton designates as [ö] and [ü] allophones of /o/ and /u/.

The raising of the front vowel [ɛ] to [e] and the fronting of back vowels (/a/ to [æ], etc.) are precisely the same general process: "premature" reversal in a round-trip trajectory jVj. The effect of this is to cause the realization of the nucleic vowel target to become closer spatially to the surrounding j-glides. This is the concept embraced by Toh for Korean historical development.

> "As is well known, palatalization of consonants in the environment of __i/y occurred in the middle of the 17th century. I regard monophthongization as a case of palatalization of vowels. In this view, palatalization becomes an extremely general rule that applied to both consonants and vowels in the same environment of __i/y." (Toh 1977: 182)

Furthermore, it is the concept that Clements expressed for palatalization of consonants.

> "If front vowels are described as coronal segments, then the various types of palatalization can be viewed as involving successively higher degrees of approximation to the feature composition of front vowels." (Clements 1976: 97)

Therefore, the palatalization of consonants and the realization of fronted vocalic allophones in Russian are the same single process, precipitated by the presence of glides in the syllable structure.

2.1.7 Allomorphs in the Lexicon

Hamilton (1980) often avoids the issue of fronting and raising of vowels in the Ç__Ç context, and avoids some of Halle's rules, such as SPR Rule P1a: C → Ç / __/e/; i.e., Ce → Çe, which is re-interpreted here as Glide Insertion Rule: V_j → j / C__/e/, i.e., Ce → Cje.

Table 2.8 Allomorphs in the Lexicon.

Item	Surface form	Underlying Allomorphs	Gloss
место	[m̡ɛ́sta]	{m̡ɛst} + {o}	'place' mon.sg.
о месте	[m̡és̡t̡i]	{m̡es̡t̡} + {e}	'about (the) place' prep.sg.
ряд	[r̡ad]	{r̡ad}	'queue/row' nom.sg.
о ряде	[r̡æd̡i]	{r̡æd̡} + {e}	'about (the) queue/row' prep.sg.
мука	[muka]	{muk} + {a}	'torment' nom.sing.
муки	[muk̡i]	{muk̡} + {i}	'torments' nom.pl.
мучить	[mučit̡]	{muč} + {i} + {t̡}	'to torment' citation form

Hamilton does so by positing multiple allomorphs in the lexicon. Halle posits underlying contrastive segments through the morpheme; these segments are generally static, except at the trailing edge of morphemes. Suffixation with morphemes that have front vowels can cause palatalizing and fronting effects. Hamilton, on the other hand, chooses a strategy that lists the allomorphic variants that will be employed, rather than generating them by rules.

Thus, Hamilton prefers a strategy in which the lexical item /mest-/ ‘place’ would have two allomorphic roots {m̡ɛ́st} and {m̡és̡t̡} both recorded in the lexicon, and /muk-/ ‘torment’ would have three allomorphic roots {muk}, {muk̡} and {muč]. This strategy may be economical in terms of rules, but costly in terms of the size of the lexicon and requires the expanded dual set of consonants. It also misses the generalization that morphemes can be combined in productive ways, because all effects of combination are fossilized in the lexicon.

2.1.8 Relating Modern Standard Russian to other Modern Slavic Languages

Positing a jer pre-kernel node in the syllable structure would give Modern Russian a two-target nucleus. Modern Czech, Slovak and Serbo-Croatian have contrastive vowel length, and hence, have two-target nuclei. In addition to long vowels, Slovak has diphthongs /uo ie ia/ which pattern as long vowels, and serve to fill in gaps in the long-short contrast. In unstressed environments, these diphthongs lose one of their targets (the glide) and retain the other (the kernel), to become single-target vowels /o e a/ (Kenstowicz & Rubach 1987). As already presented, in unstressed environments, Russian nuclei can be analyzed as diphthongs /ɨi je ja jo ju/, which lose one of their targets (the kernel) and retain the jer, to become [ɨ] or [i].

In addition to vowel length, Serbo-Croatian has a pitch accent system with four tones. Inkelas and Zec (1988) handily explain the four tones as a bimoraic high tone, which is associated lexically to a vowel mora; the four contours arise when the bimoraic pitch accent spreads leftwards to a second mora assignment in the preceding syllable (if it exists).

Stressed syllables with diphthongs in Slovak and Russian retain both vowel targets. Since Slovak has long vowels (bimoraic vowels), and diphthongs pattern with long vowels, it would seem that diphthongs in Slovak are bimoraic. Two-target nuclei in Russian could be analyzed the same way, and thus diphthongs in Russian could be bimoraic. Mora accumulation in bimoraic structures could also account for the emergence of every other jer in surface forms of lexical items, where jers are posited as the only vocalic information in successive "syllables."

2.2 Review of Phonetic Considerations

The source of palatalization can be illuminated by observing the acoustic shapes of contrastive pairs. The acoustic shape of uncontested onsets KV and #jV can be compared to the acoustic shape of contested onsets ÇV/CjV. If the contrast is a qualitative feature of the consonantal system as Halle proposes, then the acoustic shape of consonant onsets in contrastive pairs must contrast between ÇV onsets and KV and #jV onsets. On the other hand, if the contrast is the presence or absence of a glide, then the acoustic shape of the nucleus must reflect the presence of a glide, i.e., the nuclei of #jV and CjV will not be significantly different.

This research will evaluate these options by comparing putative [–sharped] and [+sharped] consonantal onset transitions, and by comparing #jV and ÇV/CjV nuclei. In order to observe acoustic shape of consonantal transitions, the acoustic shape of the underlying "steady-state" vowels must be understood. Similarly, jV nuclei are realized as diphthongs, and in order to understand the acoustic shape of these two-target diphthongs, the acoustic shape of single-target monophthongs must be understood.

2.2.1 Monophthongs: Single-target Nuclei

The acoustic nature of monophthongs is not clearly defined in the literature. In an attempt to illustrate the separated regions of vowel-space for Modern English, Peterson and Barney (1952) sampled numerous tokens of syllables containing the monophthong vowels /i ɪ ɛ æ ʌ a ɔ ʊ u ɚ/. Peterson and Barney measured each token at single instant in time, near the middle of the syllable in a test frame /hVd/. They concluded that, "There is generally a part of the vowel following the influence of the [h] and preceding the influence of the [d] during which a practically steady-state is reached" (Peterson & Barney 1952: 587). In 1961, Peterson and Lehiste compared the syllable nuclei of short "lax" monophthongs [ɪ ɛ ʌ ʊ] and long "tense" monophthongs [i æ a ɔ u]. The contrast they discovered was the ratio of three zones in the nucleus: onglide, target, and offglide. Lax vowel [ɪ] had ratio percentages of zones 29:47:24, whereas tense [i] had ratio of zones 23:32:45. Note that in the 1952 study, a reading was taken when the monophthong syllable was a "practically" steady-state, and in the 1961 study, 53% of the lax monophthong was dynamic and 68% of the tense monophthong was dynamic. Hence we see that, classification of syllables as steady-state monophthongs appears to be a result of pre-supposition, ignoring the dynamic nature of the majority of the observed syllable.

Sounds can also be perceived as steady-state monophthongs, even if they are continuously dynamic. In 1956, Liberman, et. al., conducted an experiment on the classification of synthetically produced speech sounds. Participants were asked to distinguish the perceived sounds as stops, glides, or vowels (b/w/u and g/j/i). The researchers produced hand-painted spectrograms, in which they controlled the duration of the pre-nucleic transition. The perception of [b] shifted to [w], if the duration was more that 40 msec, and from [g] to [j] around 55 msec. The perceived division between [w] and [u] was about 150 msec, and between [j] and [I] at about 200 msec. In this study, nuclei were perceived at monophthongs [i] and [u], even though they never achieved steady-state, but rather were actually a continuously changing transition (at a fixed rate).

These three studies do not offer a consistent account of monophthongs. The salient feature of the 1952 and 1961 studies is that the "practically" steady-state of the perceived target is achieved in the middle of the syllable; however, the 1956 study generates perceived monophthongs, in which a steady-state is never achieved.

One salient feature of monophthongs identified in the 1952 study is that monophthongs enjoy a reserved portion of vowel-space. The syllable may be perceived as steady-state monophthong, if the majority of the duration of the syllable remains within the area reserved for a specific vowel. During that duration, the formants may gradually rise and/or fall or oscillate randomly. In order to determine whether the dynamic nucleus remained within a specific region of vowel-space, it would be necessary to monitor both formant patterns and moraic timing simultaneously.

2.2.2 Diphthongs: Two-Target Nuclei

There is also no unanimous definition of a diphthong in the literature. "…'True' diphthongs are characterized by the presence of two vocalic targets, with the majority of the duration of the diphthong being devoted to the glide between the two targets. However, at fast rates of speech, the second steady-state portion of the diphthongs tends to be eliminated" (Gay 1968, via Bond 1978). Dutch diphthongs are described as "genuine" vs. "pseudo": genuine diphthongs are "vertical" and involve raising /ei ʌy au/; pseudo diphthongs are horizontal and involve fronting or backing /aj oj uj iw ew/ (Collier, Bell-Berti & Raphael 1982). Romeo (1968) conducted a study of bi-vocalic sequences in Italian involving mathematically exhaustive combinations of all vocalic targets; and Romeo found that examples of virtually all pairs exist, for tautosyllabic and heterosyllabic realizations (including coarticulations which did not contain a [+high] target). Traditional Italian phonetics define diphthongs as consisting of two phones (one [+high], and one [–high]), with two targets resulting in a single nucleus (tautosyllabic sequences); in contrast, vowel clusters that are not a single nucleus are not diphthongs, but rather heterosyllabic sequences (with hiatus) (Salza 1988). Öhman (1966) demonstrates that a two-target continuous vocalic coarticulation can occur, even across an intervening consonantal interlude.

Observations by some researchers of the characteristics of diphthongs often violate the definitions offered by others. Kenstowicz and Rubach (1987) posited that a language cannot have both rising and falling diphthongs, that is, the diphthongs in a language must consistently have the same structure, either always vowel+glide, or always glide+vowel. However, Booij (1989) asserted that the most economical and elegant explanation of all syllables in Frisian can be accomplished by positing both rising and falling diphthongs. Booij attempts to reconcile Kenstowicz and Rubach's constraint by positing that the two types of diphthongs in Frisian have differing structure within the syllable: one type involves two targets within a complex nucleus, and the other involves one target in the nucleus and one target in the coda. This explanation, however, violates the constraint imposed by Italian that the two targets must co-occupy the nucleus. Romeo's examples of two-target tautosyllabic nuclei which of two non-high segments, violates the constraint that one of the target must be [+high]. Öhman's coarticulation violates the constraint that the segments must even be adjacent.

Most of the definitions and observations can be reconciled by differentiating between coarticulations and diphthongs. Coarticulations can be defined as the continuous vocalization between two targets. The targets may be adjacent or may have intervening gestures. Adjacent coarticulations do not have intervening interlude; this differentiates Öhman's VCV coarticulations from VV coarticulations. Diphthongs are a subset of VV coarticulations, in which the two targets occupy the same nucleus. This co-occupation can be determined by excluding those which do not co-occupy the same nucleus. The test for non-co-occupation can be borrowed from the tentative definition offered under monophthongs: A monophthong remains within the vowel-space reserved for a single phoneme for the majority of a syllable (i.e., for the majority of one moraic unit). Therefore, diphthongs and successive monophthong sequences can be differentiated by monitoring the duration that the targets are "maintained." This leaves only two issues: the constraint that all diphthongs must have the same structure within a language, and how to differentiate one diphthong from another.

Diphthongs can be differentiated from one another by formant patterns of the beginning and ending targets, by the duration of the target steady-states, and by the duration of the glide between them. Also, the rate of change of the glide can be used to differentiate, but, of course, this is a function of the beginning and ending formant patterns and the duration between them.

Acquiring these acoustic measurements is problematic. In order to measure the duration of the steady-states of the targets and the duration of the glide, one must be able to identify the boundaries between them. But, as discussed above, the nature of the monophthong target is not clearly defined. Without understanding the nature of the target, identification of its boundary is tenuous. Furthermore, identification of its formant pattern is tenuous. Identification of measurements for diphthongs appears to be based upon as much presupposition as the identification of monophthongs. Case in point, Salza (1988) reported using "F2 halfway criterion" (as described in Klatt 1973), whereby the boundary of the sonorant glide is identified "as the point in time when the second formant passes through a frequency halfway between estimated initial and final target values" (Salza 1988: 101). As already stated, speaking speed may cause a target not to be achieved; therefore, boundaries are often established based on arithmetic means of values of presupposed targets, which may not even appear in the samples; and furthermore, the measurements taken on these presupposed targets are conducted in such a way as to dismiss the majority of the syllable because of dynamic patterns.

The characteristics of some diphthongs measured do not differ appreciably from those of established monophthongs. Gay (1968) differentiates the American diphthongs /ɔɪ aɪ aʊ eɪ oʊ/. Gay observed that the five diphthongs can be grouped in three sets: 1) /ɔɪ aɪ/ behaved similarly, having a steady-state:glide ratio of 30:70; 2) /aʊ/ had a ratio of 15:85; and 3) /eɪ oʊ/ patterned together with a ratio of 5:95. These observations are consistent with the general notion that the majority of the diphthong is devoted to the glide portion. However, revisit Peterson and Lehiste's (1961) characterization of the tense monophthong [i] (onglide-target-offglide being 23:32:45). The steady-state of monophthong [i] is maintained for 32% of the syllable duration, whereas the steady-state of diphthong [aɪ] is maintained for 30% of the syllable duration. For both [i] and [aɪ], the longest zone is the offglide. The grounds for the categorical distinction between monophthong [i] and diphthong [aɪ] appears to be no more great than the grounds for non-categorical distinction between [aɪ] and [aʊ]. Again, the criterion for classification appears to be arbitrary and pre-supposed. The nucleus [i] is judged to be a monophthong, despite its dynamic nature, whereas the nucleus [aɪ] is judged to be a diphthong, because of its dynamic nature.

There is also no consensus regarding how to quantify or model the acoustic shape of diphthongs. The Liberman et. al. (1956) study modeled vowel-to-vowel coarticulations as three straight lines: two horizontal plateaus with a third diagonal line connecting them. This model was appropriate to their study, because their study involved perception of hand-painted formant tracks. The sharp corners of intersecting lines permitted distinct boundaries of zones, and hence, permitted reliable measurements of duration. However, due to inertia, physical mass cannot make instantaneous changes of direction, and the true nature of spectrograms created from organic speech sounds produces formant tracks that are "smooth" and curvilinear. These curvilinear patterns contain the traces of acceleration and deceleration necessary to accommodate inertia. The utility of a 3-straight-line model of vowel-to-vowel coarticulations is that it captures several pieces of vital information: the formant patterns of any achieved targets, the duration of these patterns at those targets, the duration of the glide between them, and the rate of change of frequencies (slope) in the glide (Jha 1985). All of these pieces of information pivot on accurately identifying the boundaries of the changes of state of the gesture(s). Additionally, the 3-straight-line model fails to address acceleration and deceleration.

Gay (1968), Collier, Bell-Berti & Raphael (1982), Jha (1985) modeled the diphthongs as vectors, with a fixed specified starting point in vowel-space and a fixed rate of rate of change of formants F2 and F1 from that starting point, while the end point is left unspecified. Gay notes that the endpoint of /aɪ/ can vary from [ɛ] to [i]. He also notes that with increased speaking rate, "the decrease in glide duration is accompanied by a decrease in second-formant offset frequency … rather than a modification of second-formant rate of change. In other words, the glide course remains stable with the gesture simply terminating before reaching the offset target." This is essentially Jha's observation. A vector then captures the notion of a path and that the endpoint is variable (as long as it remains on the path), but fails to capture the variable nature of the starting point. A vector also cannot capture the notion of elapsed time of a lingering stability of a steady-state at either endpoint.

Jha concludes that there are not sufficient tools to describe diphthongs. "From our findings and from what the literature has to say on this topic, it may be concluded that the phonetic features emerging from the consideration of diphthongs in a particular language are not necessarily sufficient or optimal to characterize the phenomenon in general" (Jha 1985: 114).

This research study then seeks to develop a method for observing formant patterns of vowels, whether they be “static” monophthongs or dynamic diphthongs and coarticulations. This method will capitalize on identifying change-points, which can served as boundaries between steady-states and transitions, or can provide information regarding the rate of change of a transition. This change-point method will then by applied to formant tracks of spoken utterances of Modern Standard Russian, which are expected to contain a vast variety of dynamic coarticulations.

CHAPTER 3

METHODOLOGY

The basic design of this research study was to elicit a collection of simple syllables from native speakers of Russian, and then to increase the complexity gradually, by adding elements one at a time to these syllables, observing any changes in acoustic behavior after each addition. Digital recordings of the native speaker performances were processed in software designed for acoustic analysis. The output of the acoustic software was then imported into a spreadsheet for editing, mark-up and analysis. Finally, the marked-up data was processed with a statistical software package.

The major departure of this research from traditional acoustic studies is that the formant pattern of a token was not sampled only once at the steady-state of the vowel; rather, it was sampled repeatedly, at a standardized interval, for the duration of the token. Then, a model was constructed of the continuous shape of the token, by identifying points at which the formant pattern changed, through the application of mathematical models. The frequency of a formant at a point-of-interest was established by averaging consecutive measurements. Corresponding points-of-interest from multiple tokens were averaged, creating a composite token, to represent the type as a whole. Finally, the behavior of the composite tokens was compared, to determine which properties and environmental factors provide differentiation between contrastive types of syllables.

3.1 Construction of the Syllables to be Elicited

Starting with a collection of bare vowel syllables, the test items for this study were strategically constructed as a progression of increasing complexity, as follows:

1) Six bare vowel syllables /i y e a o u/ were collected, to create a set of syllables of the shape V, and to establish a baseline of behavior for nucleic vowels.

2) To the bare vowel syllables, the semi-vowel /j/ was added as an onglide, as an offglide, or both, to create a total of twenty viable tautosyllabic monophthongs, diphthongs, or triphthongs, of the shape (j)V(j). Only twenty viable syllables resulted, since some sequences were ungrammatical (e.g., **/jy/ and **/jyj/) or were non-contrastive (e.g., /ij/ vs. /jij/).

3) To these twenty viable vocalic sequences, consonants were added to the onset, to the coda, or both, to create eighty monosyllables of the shape (C)(j)V(j)(C).

4) To the forty monosyllables of Step 3 that are consonant-final, a variety of vowels were "suffixed," to create disyllabic forms, of the shape (C)(j)V(j)CV.

5) Since suffixed nonsense syllables were performed with the default stress paradigm, specific lexical items were chosen which contrast similar suffixed disyllabic sequences by stress pattern only, e.g., /bóku/ vs. /bokú/.

6) In addition, lexical items were chosen which contain heterosyllabic diphthongs and triphthongs involving the vowels of step 1 (e.g., /ka.ík/, /pa.úk/), in order to establish the parameters of viable pathways through vowel-space from one steady-state vowel to another.

3.1.1 The Creation of Tautosyllabic Vocalic Sequences

An array of the twenty monosyllables from steps 1 and 2 of the basic design is presented in Table 3.1. These syllables have the shape (j)V(j), where V is any single-target vowel. The potential sequences **/jy/ and **/jyj/ have been discarded, because they are ungrammatical. The pair /i/ vs. /ji/ is not contrastive, nor is the pair /ij/ vs. /jij/, so these pairs have been coalesced into a single cell each. However, the pair /i/ vs. /ij/ is contrastive for duration and voicing structure, and therefore, remains in two separate cells.

Table 3.1 Monosyllables of the shape V, jV, Vj, and jVj. The table includes the orthographic Cyrillic sequence presented to the native speakers, the intended phoneme(s), the expected phonetic value(s) (according to Hamilton 1980), and gloss.

Root Vowel / Environment	/i y/	/e/	/a/	/o/	/u/
Hard Onset, Zero Coda	‘ы’ /y/ [ɨ] the letter ы	‘э’ /e/ [ɛ] the letter э	‘а’ /a/ [a] ‘and/but’	‘о’ /o/ [o] ‘about’	‘у’ /u/ [u] ‘by’, ‘with’
Soft Onset, Zero Coda	‘и’ /i/ [i], [ji] ‘and’	‘е’ /je/ [jɛ] the letter е	‘я’ /ja/ [ja] ‘I’	‘ё’ /jo/ [jo] the letter ё	‘ю’ /ju/ [ju] the letter ю
Hard Onset, Offglide Coda	‘ый’ /yj/ [ɨj] nonsense	‘эй’ /ej/ [ej] ‘hey!’	‘ай’ /aj/ [aj] ‘oh!’	‘ой’ /oj/ [oj] ‘oh!’	‘уй’ /uj/ [uj] nonsense
Soft Onset, Offglide Coda	‘ий’ /ij/ [ij], [jij] nonsense	‘ей’ /jej/ [jej] ‘her’ (dat.)	‘яй’ /jaj/ [jæj] nonsense	‘ёй’ /joj/ [jöj] nonsense	‘юй’ /juj/ [jüj] nonsense

As shown in Table 3.1, more than half of the twenty syllables are lexical items (at least minimally). Nine of the syllables are grammatical items or common interjections. Five of the syllables are minimally lexical items, appearing in isolation only as names of letters of the Cyrillic alphabet. Six of the resulting syllables never occur in isolation in Modern Standard Russian, and as such, are nonsense syllables created for this study. Thus, the final set of twenty vocalic syllables, selected for elicitation, is: /y e a o u i je ja jo ju *yj ej aj oj *uj *ij jej *jaj *joj *juj/ (where "*" refers to nonsense forms).

3.1.2 The Creation of Monosyllables with Obstruents in the Onset and/or Coda

In Step 3 of the basic design, a consonant was added to the onset and/or the coda of the twenty vocalic syllables from Step 2, creating syllables of the shape $(C_1)W(C_2)$, where W is a vocalic sequence (j)V(j). In order to compare the difference between the marginal effects of the onset and the marginal effects of the coda of any given syllable, the consonant in the onset and coda was standardized, such that $C_1 = C_2$.

The consonant /p/ was selected as the standardized consonant; all other potential candidates were disqualified for a variety of reasons.

1) Voiced consonants and sonorants were disqualified because they were expected to produce a more gradual transition in sonority at the consonant-vowel interface, making the identification of the initiation and termination of sonorous phonation more difficult. As such, the delineation between voiceless consonants and sonorous vowels was expected to be more readily identifiable.

2) Coronal consonants were disqualified because they were expected to produce lingual coarticulations with the vowel at the consonant-vowel interface, and because they

can block coarticulation across a consonant interlude, even if coarticulation processes are permitted by other consonants of the phonemic inventory (Graetzer 2007, p. 893).

3) Velar consonants were disqualified because they do not have the full range of contrast for hard/soft environments in Modern Standard Russian, i.e., velars must be soft before front vowels, and they must be hard before back vowels.

4) Although all of the participants were capable of producing /h/, it was disqualified because it is not a phoneme in Modern Standard Russian, and as such, /h/ was not available for lexical items, which would be included later in the design. However, the phoneme /h/ might still be useful for similar research with other Modern Slavic languages which do contain /h/. In a pilot study involving Modern Korean (Benham 2006), the phoneme /h/ proved to be the most useful consonant for tracking coarticulation across the interlude. As a pharyngeal consonant, /h/ has little affect on the point of articulation of lingual vowels on either side of the interlude. As a fricative, /h/ generates sufficient relevant acoustic noise that formant tracks across the interlude are contiguous and well-formed.

5) /f/ was disqualified, because [f] occurs most often as a allophone of /v/, which behaves like a sonorant in Modern Standard Russian.

Therefore, /p/ was selected as the standardized consonant for the onset and/or coda of the twenty syllables from Step 2, creating syllables of the shape /(p)W(p)/, where W is the vocalic sequence (j)V(j). The resulting eighty syllables occurred in four sets:

1) Types of the shape /W/ without obstruents /y e a o u i je ja jo ju *yj ej aj oj *uj *ij jej *jaj *joj *juj/.

2) Types of the shape /pW/, with obstruent in the onset only /*py pe pa po *pu *pi *pje *pja *pjo *pju *pyj *pej paj *poj *puj *pij *pjej *pjaj *pjoj *pjuj/. A few of these types are actual lexical items: /pa/ ‘pas, step’; /paj/ ‘share’; /po/ ‘on, along’; and /pe/ is the name of the letter <п> of the Cyrillic alphabet.

3) Types of the shape /Wp/, with obstruent in the coda /*yp *ep *ap *op *up *ip *jep *jap *jop *jup *yjp *ejp *ajp *ojp *ujp *ijp *jejp *jajp *jojp *jujp/.

4) Types of the shape /pWp/, with obstruent in the onset and coda, /*pyp *pep pap pop pup *pip *pjep *pjap *pjop *pjup *pyjp *pejp *pajp *pojp *pujp *pijp, *pjejp *pjajp *pjojp *pjujp/. The sequences /pap/, /pop/, and /pup/ are actual lexical items пап ‘papa’ gen.pl., поп ‘pope’ nom.sg., and пуп ‘navel’ nom.sg., respectively.

3.1.3 Stress Patterns for Nonsense Items

All of the (p)W(p) items were monosyllables, and therefore, the final (and only) syllable of these roots was stressed. (For the monosyllabic nonsense items, the single (p)W(p) syllable will be referred to as the final syllable of the “root”.) Most of the (p)W(p) sequences were nonsense items, although a few sequences were lexical items. Those sequences, which were actual lexical items, all belonged to the default stress paradigm, which has immobile stress on a specific fixed syllable of the root, regardless of suffixation.

When concatenated with a vowel, to mimic suffixation structure, the disyllabic sequences of a nonsense “root” plus a “suffix” vowel (i.e., (p)WpV sequences) were performed by the participants with stress on the “root” syllable, in parallel fashion with the default stress paradigm.

The resulting array of nonsense items to be collected with “suffixes” is presented in Table 3.2. Included in Table 3.2 are the expected phonetic allophones [ɨ ɛ æ ö ü] of the kernel vowels /i e a o u/, respectively, according to the Dual Consonant Tradition (Hamilton 1980).

The nonsense items were collected as monosyllables, and they were also collected as disyllabic forms with /-i -a -u/ “suffixes.” In the case of the three lexical items of table 3.2, the /-i/ suffix creates a nonsense string, since the inflection paradigm specifies an /-ы/ suffix for these roots. For the nonsense roots, the /-e/ and /-o/ suffixes were sacrificed in the interest of limiting the duration of the recording sessions with participants to two hours.

Table 3.2 Nonsense Items of the Shape pWp. Of the twenty possible syllable types, three are lexical items. These lexical items exhibit the default stress paradigm, and as such, they were performed with the same stress pattern as the non-lexical items.

Root Vowel / Environment	i, y	e	a	o	u
Hard Onset, Zero Coda	<пып> /pyp/ [pɨp] nonsense	<пэп> /pep/ [pɛp] nonsense	<пап> /pap/ [pap] ‘papa’ gen.pl.	<поп> /pop/ [pop] ‘pope’ nom.sg.	<пуп> /pup/ [pup] ‘navel’ nom.sg.
Soft Onset, Zero Coda	<пип> /pip/ [pip] nonsense	<пеп> /pjep/ [pjɛp] nonsense	<пяп> /pjap/ [pjap] nonsense	<пёп> /pjop/ [pjop] nonsense	<пюп> /pjup/ [pjup] nonsense
Hard Onset, Offglide Coda	<пыйп> /pyjp/ [pɨjp] nonsense	<пэйп> /pejp/ [pejp] nonsense	<пайп> /pajp/ [pajp] nonsense	<пойп> /pojp/ [pojp] nonsense	<пуйп> /pujp/ [pujp] nonsense
Soft Onset, Offglide Coda	<пийп> /pijp/ [pijp] nonsense	<пейп> /pjejp/ [pjejp] nonsense	<пяйп> /pjajp/ [pjæjp] nonsense	<пёйп> /pjojp/ [pjöjp] nonsense	<пюйп> /pjujp/ [pjüjp] nonsense

3.1.4 Lexical Items

The nonsense disyllabic "suffixed" forms were performed with the default stress paradigm. This created a uniform pattern of tonic roots, followed by post-tonic suffix vowels. In order to elicit patterns other than the default paradigm, lexical items were selected, which have a variety of stress paradigms.

Although it was desirable for the lexical items to contain a /pWp/ sequence as the final syllable of the root (as was used in the creation of nonsense syllables), the number of lexical items with this configuration was limited. To generate a selection of lexical items with the greatest variety of contrastive final root vowels and stress paradigms, the constraints that the consonant of the onset and coda be equivalent and that the consonant be voiceless were relaxed. Thus, lexical items with a final syllable of the shape /BWG/ were selected, where B is any labial, W is the vocalic complex (j)V(j), and G is any velar.

As shown in Table 3.3, the final selection of lexical items contrasts 19 of the possible 40 combinations of kernel vowels vs. tonic stress placement. These lexical items were inflected into grammatical cases, which allowed a variety of vowels in the leading position of the suffix. For any given lexical item, it was possible to rotate up to six different vowel targets into the leading position of the suffix. The vowels of interest were /i y e a o u/, and the "zero" suffix. For any given lexical item, only one of /i/ or /y/ may be a potential suffix nucleus, but not both.

Since recording all allomorphs in the lexicon to account for surface forms has been rejected during the review of theory as a desirable solution, in favor of a single underlying form which is subjected to phonological processes, it was expected that selecting a given lexical root and varying its suffixes would ensure that all of the observed allophones for this root would have a single underlying phonemic representation. As such, systematically varying the suffixes for a selection of lexical items with contrastive vowels in the final root syllable generated an array of root vowel vs. suffix vowel pairings, and patterns of coarticulation became evident.

Table 3.3 Selected Lexical Items of the Shape /BWG/. The table includes the phonetic shape of the final syllable of the root.

Root Vowel / Environment	/i y/	/e/	/a/	/o/	/u/
Tonic Root, Hard Onset, No Offglide	кавы́ка [vý́k]	э́к [ɛ́k]	соба́ка [bák]	бо́к, sg. [bók]	бу́к [búk]
Pretonic Root, Hard Onset, No Offglide	бык [byk] (5)	Not Available	табак [bak]	бок, pl./loc. [bok]	чубук [buk]
Tonic Root, Soft Onset, No Offglide	пи́ка [pík] ежеви́ка [vík]	узбе́к [bjɛ́k] ве́к, sg. [vjɛ́k]	бя́ка [bják]	лепёха [pjóx]	(утюг) [tjug] (6)
Pretonic Root, Soft Onset, No Offglide	Not Available	век, pl./loc. [vjɛk]	здоровяк [vjak]	Not Available	Not Available
Tonic Root, Hard Onset, with Offglide	Not Available	Not Available	ба́йка [bájk]	попо́йка [pójk]	Not Available
Pretonic Root, Hard Onset, with Offglide	Not Available	Not Available	Not Available	Not Available	Not Available
Tonic Root, Soft Onset, with Offglide	латви́йка [víjk]	набе́й-ка [bjéjk]	Not Available	Not Available	Not Available
Pretonic Root, Soft Onset, with Offglide	Not Available	Not Available	Not Available	Not Available	Not Available

3.1.4.1 Default Root Stress Paradigm

The default stress paradigm in Modern Standard Russian has immobile stress assigned to a fixed syllable of the root for all inflected grammatical cases. The specific syllable that receives stress is marked in the lexicon. Since many of the lexical items chosen are monosyllables (i.e., only the final syllable is present), only those polysyllabic roots with stress on the final syllable were chosen. The lexical items in this category of the default stress paradigm were:

1) Masculine nouns:

бук /búk.Ø/ ‘beech tree’

узбек /uz.bjɛ́k.Ø/ ‘Uzbek person or language’

2) Feminine nouns:

кавыка /ka.výk.a/ ‘inverted comma’

собака /so.bák.a/ ‘dog’

пика /pík.a/ ‘spade (card suit)’

бяка /bják.a/ ‘nasty/lousy person/thing’

лепёха /lje.pjóx.a/ ‘flatbread’

байка /bájk.a/ ‘comic story/fable’

попойка /po.pójk.a/ ‘drinking party’

латвийка /lat.víjk.a/ ‘Latvian woman’

3) Colloquial forms: эк /ɛ́k.Ø/ ‘what a!, such a!’

4) Numerical forms: два /dva/ ‘two’

5) verbal command: набей-ка /na.bjéjk.a/ ‘hit/strike (it)!’ (informal)

Of these lexical items with the default stress pattern, two lexical items were unfamiliar to some participants. The term кавыка /ka.výk.a/ 'inverted comma' more commonly appears as the diminutive form кавычка /ka.výč.ka/ 'inverted comma'. The diminutive form was known to all participants. The chosen non-diminutive form has the same syllable count and the same stress pattern as the familiar diminutive form; furthermore, since this stress pattern is the default stress paradigm, participants pronounced the item кавыка naturally (as expected), without practice.

The lexical items with an offglide in the coda (i.e., байка /bájk.a/ 'comic story/fable', попойка /po.pójk.a/ 'drinking party', латвийка /lat.víjk.a/ 'Latvian woman') cannot be performed with "zero" suffix, without modifying the root. With the "zero" suffix, these items receive an epenthetic syllable following the offglide of the final syllable of the root, producing the forms: баек /bá.jek.Ø/, попоек /po.pó.jek.Ø/, латвиек /lat.ví.jek.Ø/. These "zero" suffixed forms involve a significant change to the final syllable of the root, and as such were not analyzed. They served only as distractors during the recording sessions.

The verbal command набей-ка /na.bjéjk.a/ is already an inflected form, and cannot be inflected further; therefore, it is not possible to vary the vowel of the suffix. In this instance, the verbal command /bjej/ occurs before an informal command suffix /–ka/. The concatenation of verbal root with the verbal suffix creates a sequence similar to the nominal forms (байка /bájk.a/, попойка /po.pójk.a/, латвийка /lat.víjk.a/), and appears to be syllabified in the same manner as the nominal forms.

The phoneme /e/ ([ɛ]) cannot be performed after a hard consonant. Halle's rule (SPR Rule P1a) converts the hard onset to a soft onset, prior to /e/. However, the phoneme /e/ ([ɛ]) can be produced in an onsetless syllable. Thus, the colloquial hyperbole form эк /ɛ́k/ 'what a!, such a!' was chosen.

The colloquial form эк, which adheres to adjectival declension paradigms, was unfamiliar to some participants. Participants, who were unfamiliar with the term, performed the item with the default stress paradigm, which, in this case, is the correct paradigm assigned in the lexicon. Participants were shown the selected forms of this item (i.e., эк /ɛ́k/ (masc. short form), экий /ékij/ (masc.nom.sg.), экая /ɛ́kaja/ (fem.nom.sg.), экого /ɛ́kovo/ (masc.gen.sg.), экую /ɛ́kuju/ (fem.acc.sg.)) prior to recording, and were allowed to practice the forms prior to recording.

In hindsight, one additional avenue of producing a few instances the phoneme /e/ ([ɛ]) with a hard onset may be available. The preposition {o} 'about' has a variant /ob/ which may be used before lexical items that are vowel-initial. Thus, the /ob/ variant is used before the demonstrative article этот /ɛ́t.ot/ 'this', as in the phrase об э́ту по́ру /ob ɛ́tu póru/ 'by this time'. Since many of the Modern Standard Russian prepositions are clitic, speakers might syllabify the phrase as /o.bɛ̀.tu.pó.ru/, which would create a hard consonant onset for the phoneme /e/ (provided that syllabification occurs after the application of Halle's SPR Rule P1a).

The preposition {o} 'about' requires the prepositional case for its object, and another preposition {o} 'against, on' requires the accusative case for its object. Use of these two prepositions could be used to generate such phrases as:

об эких типах /o.bè.kix.tí.pax/ ‘about such types’.

об эком типе /o.bɛ̀.kom.tí.pje/ ‘about such a type’.

об экую стену /o.bɛ̀.ku.ju.stjɛ́.nu/ ‘against such a wall’.

which contain the sequences: /bè.ki bɛ̀.ko bɛ̀.ku/, resepectively. It may be possible to convince participants to suspend their sensibilities regarding the tenuous semantic value of these constructed phrases, and perform these phrases naturally.

While on the topic of constructed phrases involving the demonstrative article этот /ɛtot/ 'this' (and the hyperbolic article эк /ɛk/), it may also be possible to construct phrases that are parallel to types with the prepositional suffix /-e/.

When /-e/ is suffixed to a root, Halle's SPR Rule P1a is invoked and the final consonant of the stem becomes soft, if it was not already so (e.g. /buk/ 'beech' nom.sg. is expressed as [búkjɛ] ‘beech’ prep.sg.). However, if sequences (such as “бук этого типа” [buk ɛ́təvə típə] ‘a beech of this type’ or *“бук экого типа” [buk ɛ́kəvə típə] ‘a beech of such a type!’) can be performed fluently without pause between the noun and the genitive phrase, then these sequences might possibly be syllabified as [bú.kɛ̀.tə.və.tí.pə] and *[bú.kɛ̀.kə.və.tí.pə]. This would establish an [ɛ] after the hard allophone of the final consonant in the root, in the same position as the suffix /-e/, which can only occur after a soft consonant.

However, as a caveat, such phrasal constructions may introduce confounding prosodic effects, which are not present with the isolated inflected lexical items in the elicitation frame. For instance, the suggested phrases create a sequence of two stressed syllables: the root (which receives primary stress), followed by the article (which receives secondary stress in the descriptive genitive phrase). This sequence of two stressed syllables is not usually encountered with inflected forms in isolation.

Also, the constructed phrase with the hyperbolic article is more desirable for diagnostic purposes, because the first coronal segment is not encountered until several mora after the final consonant of the root, whereas with the demonstrative article, the first coronal segment after the root occurs within one or two mora. However, the phrase with the demonstrative article is grammatical, whereas the grammaticality of the hyperbolic phrase is tenuous, at best. The strained grammaticality of the hyperbolic phrase may introduce additional prosodic features (such as pause), which would counteract the criterion that the sequence should be performed without pause to generate the desired syllabification.

3.1.4.2 Suffix Stress Paradigm

Another stress paradigm in Modern Standard Russian uniformly assigns primary stress to the first syllable of the suffix, for all grammatical cases. In the case of the "zero" suffix, stress is shifted to the preceding syllable, namely, the final syllable of the root. A number of masculine nouns were chosen, to contrast with lexical items from the default paradigm: бык /byk/ 'bull'; табак /ta.bak/ 'tobacco'; чубук /ču.buk/ 'mouthpiece of a stemmed pipe'; клобук /klo.buk/ 'cowl'; здоровяка /zdo.ro.vjak/ 'healthy person'; туфяк /tu.fjak/ 'idiot, dunderhead'; утюг /u.tjug./ 'flat-iron'.

The lexical items чубук 'mouthpiece of a stemmed pipe' and клобук 'cowl' were unfamiliar to some participants. Since these lexical items do not have the default stress paradigm, it was not anticipated that participants would perform these as desired, without practice. Therefore, participants were shown these items before recording, and the suffix stress paradigm was practiced with these items. In addition, participants were prompted verbally with the desired stress pattern during the recording session. The items клобук 'cowl', туфяк 'idiot, dunderhead', and утюг 'flat-iron' were included in the set as distractors and potential alternates for analysis.

3.1.4.3 Mixed Root-Suffix Stress Paradigms

In Modern Standard Russian, additional stress paradigms exist which do not uniformly assign primary stress to a fixed syllable of the root or to a fixed syllable of the suffix for all grammatical cases. Two of these paradigms assign stress to the root for singular grammatical cases, and then to the suffix for plural grammatical cases, or vice versa. Lexical items from these types of stress paradigm are particularly valuable, because they permit a single, fixed underlying vowel of the final root syllable to be observed in a range of environments, which is wider than that of either the uniform default stressed root paradigm or the stressed suffix paradigm.

Three lexical items from the singular stressed root vs. plural stressed suffix paradigm were chosen: бог /bog/ 'god'; бок /bok/ 'side' and век /vjek/ 'age/century'. In addition to contrastive stress in singular and plural forms, these two lexical items are also involved in idioms and phrases with irregular stress patterns. For instance, the phrase бок о бок /bòk.ó.bok/ 'side by side' involves an [ò] with secondary stress in the first instance of the root, followed by an unreduced [ó] with primary stress, the combination of which is rare for dialects in which /o/ undergoes vowel reduction. The phrase also permits comparison of the unstressed root at the end of the phrase before "zero" suffix with the stressed root before "zero" suffix when the item бок is in isolation. The item бог 'god' is included in the set as a distractor or an alternate form for analysis.

3.2 Presentation of Elicitation Forms to the Participants

The selected syllables and phrases were printed on 5x8 cardstock, and subsets of the list of selected items were arranged into smaller decks of cards, which required approximately 5-10 minutes to perform[2]. This series of smaller sub-decks presented the participants with ample opportunity to stretch, take a break or drink some water, and would also permit the researcher with opportunity to perform administrative maneuvers, such as saving a file on the laptop for each sub-portion of the recording session.

3.2.1 The Decks of Elicitation Forms

Before the recording phase of the study began, each sub-deck was shuffled repeatedly to create a random ordering of the items in the sub-deck. The sub-deck was then padded with two or three distractors at the beginning and at the end of the deck, in an effort to minimize list effects from occurring for pertinent items of the sub-decks. The randomized ordering of items in each sub-deck was then fossilized and recorded, and each participant was presented this same standardized random ordering of each sub-deck.

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[2] During a dress-rehearsal practice recording session of the elicitation list with a native speaker, the items were organized by the phonetic shape of the suffix shape (e.g., all lexical items ending in an /-a/ suffix were put into one deck), regardless of whether the inflected form was feminine normative singular, masculine genitive singular, neuter nominative plural, or masculine nominative plural of irregular forms. The native speaker experienced confusion in recognizing the stress pattern and lexical selection of some of the items which had identical orthographic forms as other contrastive forms (e.g. веку /vjéku/ 'eyelid' dat.sg. vs. веку /vjekú/ 'age/century' loc.sg.). The native speaker recommended that sub-decks be organized by grammatical category, rather that phonetic shape of the suffix

This would provide the researcher with a known contextual reference and facilitate the researcher's ability to correlate the recorded output of each item with its corresponding cue-card, even if a performance of an item failed to meet the researcher's expectations of the item.

3.2.1.1 The Characteristics of Items for Elicitation Decks

By organizing the cue-cards by grammatical category, the total list of items was sub-divided into nine sub-decks:

1) Items with no grammatical case or non-nominal forms:

    a) Selected consonants of the alphabet

    b) Vowels of the alphabet

    c) Monosyllabic lexical/nonsense diphthongs without consonants

    d) Phrases and idioms involving the lexical items бок and век

    e) Colloquial forms: эк, экий, экая, экого, экую

    f) Numerical forms: две, два, двух

    g) Verbal forms: набей-ка; past tense of печь and мочь

2) Lexical items with heterosyllabic diphthongs

3) Selected lexical items in nominative case, answering the prompt кто?/что? [kto]/[što] 'who?/what?': forms ending in plural suffix /-i/, feminine singular suffix /-a/, neuter singular suffix /-o/, and masculine singular "zero" suffix.

4) Selected lexical items in prepositional case, answering the prompt ком?/чём? [kom]/[čom] 'whom?/what?': forms ending in singular suffix /-e/ and plural suffix /-ax/.

5) Selected lexical items in oblique cases:

a) Genitive case, answering the prompt кого?/чего? [kɐvó]/[čivó] ‘whom?/what?’: forms ending in masculine/neuter singular suffix /-a/, masculine plural suffix /-ov/, and feminine/neuter plural “zero” suffix. Forms with feminine singular suffix /-i/ were not collected, as similar forms were collected in deck 3.

b) Accusative case, answering the prompt кого?/что? [kɐvó]/[što] ‘whom?/what?’: forms ending in feminine singular suffix /-u/. Masculine singular accusative forms were not collected, as similar forms were included in decks 3 or 5a, based upon inanimate or animate status, respectively. Suffixed plural forms were not collected, as similar forms were collected in decks 3 or 5a.

c) Dative case, answering the prompt кому?/чему? [kɐmú]/[čimú] ‘whom?/what?’: forms ending in masculine/neuter suffix /-u/. Feminine forms with /-e/ suffix were not collected, as similar forms were collected in deck 4.

d) Instrumental case, answering the prompt кем?/чем? [kjɛm]/[čɛm] ‘whom?/what?’: singular forms ending in masculine/neuter suffix /-om/ or feminine suffix /-oj/.

6) Monosyllabic nonsense items of the form: /W pW Wp pWp/, in which W is vocalic sequence /(j)V(j)/.

7) Disyllabic “inflected” nonsense items of the form: /pWpa pWpi pWpu/, in which W is vocalic sequence /(j)V(j)/.

3.2.1.2 The Specific Selection of Items for Elicitation Decks

In the construction of group 1a of Deck 1, the intent of eliciting alphabetic consonants <п б в к г т д з ц ч ж> is to obtain the phonetic sequences [pɛ bɛ vɛ gɛ tɛ dɛ]. However, several of the participants pronounced these letters as [pi bi vi gi ti di]. The remaining consonants were included as distractors in Deck 1.

In the construction of group 1b of Deck 1, the intent of eliciting the vowels of the Cyrillic alphabet <у о а э ы ю ё я е и> was to obtain isolated stressed vowels in the monosyllables of the shapes V and jV. And then in group 1c, the diphthongs <ей эй ай ой *ёй *ий *уй *ый *юй *яй> provided monosyllables of the shapes Vj and jVj.

In the construction of group 1d of Deck 1, the intent of eliciting selected phrases and idioms was to gather samples of fossilized forms with unusual stress patterns, and also to break up potential list effects from the short syllable elicitations of groups 1a-1c.

In the construction of group 1e of Deck 1, the intent of eliciting the colloquial forms эк, экий, экая, экого, экую ([ɛk ekij ɛkaja ɛkovo ɛkuju]; hyperbole ‘what a!’ in short form, masc.nom.sg., fem.nom.sg., masc.gen.sg., fem.acc.sg., respectively) was to obtain a stressed [ɛ] without an onglide, before a variety of suffix vowels, and to remove the non-nominal forms form the sub-decks of nominal forms.

Also in group 1f of Deck 1, the intent of eliciting the numeric forms <две два двух> (/dvje dva dvux/; ‘two’ masc.nom., fem.nom., gen./prep., respectively) was to obtain the monosyllabic sequence [dvjɛ], in which /d/ must occupy the obtruent position of the onset, /v/ must occupy the sonorant position of the onset, and /e/ ([ɛ]) must occupy the kernel position of the nucleus. If the element responsible for palatalization is the /j/

(i.e., a segment instead of a feature), then /j/ must occupy a position between the sonorant of the onset and the nucleic kernel. Therefore, a separate node in the syllable structure must exist.

Table 3.4 Selected Phrases and Idioms with бок /bok/ 'side' and век /vjek/ 'age'. The stress patterns for the majority of these idioms are recorded in Smirnitsky 1977.

Russian Phrase or Idiom	Phonemic Sequence	Sequence of Interest	Gloss
схватиться за боќа	/sxvatitsja za boká/	/boká/	'to split one's sides'
по бокáм	/po bokám/	/bokám/	'on each side'
пóд боком	/pód bokom/	/bokom/	'nearby'
бóк ó бок	/bòk ó bok/	/bòk ó/ /bok/	'side by side'
с бóку нá бок	/s bóku ná bok/	/bok/ /bóku/	'from side to side'
на бокý[3]	/na bokú/	/bokú/	'on its side'
пó боку	/pó boku/	/boku/	'aside'
во вéки векóв	/vo vjéki vjekóv/	/véki/ /vekóv/	'for all time' lit. 'in ages of ages'
средние векá	/srjednije vjeká/	/veká/	'the Middle Ages'
от вéка к вéку	/ot vjéka k vjéku/	/véka/ /véku/	'from century to century' or 'from generation to generation'
на векý	/na vjekú/	/vekú/	'in a century'
на моём векý	/na mojom vjekú/	/vekú/	'in my day/lifetime'

[3] The stress pattern for the idiom на бокý is recorded the table of "Masculine Nouns with Locative Case in Stressed -У/-Ю" on the russianmentor.net webpage.

In the construction of group 1g of Deck 1, the past tense of печь /pječj/ 'to bake': пёк, пеклá, пеклó, пекли́; and мочь /močj/ 'to be able': мог, моглá, моглó, могли́ (masc.sg., fem.sg., neut.sg., and plural, respectively) were elicited. The intent of eliciting these past tense verb forms was to observe the allophones of stressed and unstressed /jo/ and /o/ in the root (assuming that the underlying root vowel of пёк/пеклá/пеклó/пекли́ is always <ё> /jo/). However, the leading /l/ of the verbal suffixes colored the offset of the root nucleus uniformly and neutralized any contrast in the root syllables of all of the disyllabic forms. Therefore, the verbal past tense forms was not analyzed further.

Selections 1a-1g were combined into a single deck (Deck 1). This deck was padded with non-essential letters of the alphabet at the beginning and end of the deck.

In Deck 2, the intent of eliciting lexical items with heterosyllabic diphthongs was to establish pathways in vowel-space between steady-state vowels. These pathways were then compared to the pathways of tautosyllabic diphthongs and other vowel-to-vowel coarticulations. The selected items of Deck 2 are listed in Table 3.5.

Deck 3 contained nominative singular and nominative plural forms of all of the applicable items on Table 3.3. The lexical items бог /bog/ 'god', туфяк /tufjak/ 'idiot/dunderhead', клобук /klobuk/ 'cowl', and утюг /utjug/ 'flat-iron' were added to sub-decks 3-5 as alternates and distractors.

Deck 4 contained prepositional singular and prepositional plural forms of all of the applicable items on Table 3.3. As with Deck 3, Deck 4 was padded with non-essential distractors at the beginning and end of the deck.

Table 3.5 Selected Lexical Items with Heterosyllabic Diphthongs.

Lexical Item	Phonemic Sequence	Gloss
бьюик	/bjú. ik/	‘Buick automobile’
австрияк	/av. stri. ják/	‘Austrian’
зодиак	/zo. di. ák/	‘zodiac’
мозаика	/mo. zá. ik. a/	‘mozaic’
Каин	/ká. in/	‘Cain’
каик	/ka. ík/	‘kayak’
каяк	/ka. ják/	‘kayak’
свояк	/svo. ják/	‘brother-in-law’ or ‘close friend’
бояка	/bo. ják. a/	‘bogey-man’ or ‘scaredy cat’
боёк	/bo. jók/	‘rifle firing pin’
паёк	/pa. jók/	‘(food) rations’
боа	/bo. á/	‘boa constrictor’
поэт	/po. ɛ́t/	‘poet’
боец	/bo. jɛ́c/	‘fighter’
боевик	/bo. je. vík/	‘action movie’ or ‘thriller’
бои	/bo. í/	‘fights’
стоик	/stó. ik/	‘stoicism’
тапиока	/ta. pi. ók. a/	‘tapioca’
маниок	/ma. ni. ók/	‘tapioca plant’
кекуок	/ke. ku. ók/	‘cakewalk’
бивуак	/bi. vu. ák/	‘bivouac’
паук	/pa. úk/	‘spider’
каюк	/ka. júk/	‘The End’ or ‘Curtains!’

Deck 5 consisted of forms from the oblique grammatical cases, generating forms ending in /-a -ov -om -oj -u/, and “zero” suffix, if not similar forms were not already included in Decks 3 and 4. As with Decks 3 and 4, Deck 5 was padded with non-essential distractors at the beginning and end of the deck.

Deck 6 consisted of nonsense monosyllables of the shape pW, Wp, or pWp, in which W is one of the twenty (j)V(j) monosyllables from Table 3.1. In addition to nonsense syllables with the obstruent /p/, the monosyllables **tit, *tat, tut* 'here', **tjat, *tjut, *čič, *čač, *čuč, *kik, kak* 'how', **kuk* were added to Deck 6 for comparison with syllables **pip, pap* 'papa' gen.pl., *pup* 'navel', **pjap, *pjup*.

Deck 7 consisted of the disyllabic "suffixed" forms of the nonsense pWp "roots." Only the /-i -a -u/ suffixes were used.

3.2.2 The Elicitation Frame

For Decks 1-7, participants were asked to read an item or phrase "TOKEN" off of a cue-card, and insert the item or phrase into the elicitation frame:

"TOKEN. Она сказала 'TOKEN по-русски. TOKEN."

/ TOKEN. oná skazála TOKEN po rússki. TOKEN./

[TOKEN. aná skazálə TOKEN pa rússki. TOKEN.]

" 'TOKEN.' She said 'TOKEN in Russian. 'TOKEN.' "

A number of factors were considered during the construction of the frame:

1) Grammaticality

2) Semantic transparency

3) Brevity

4) Reduction of coarticulation between the frame and the elicited item

With regard to grammaticality and semantic transparency, it was anticipated that the likelihood that the utterance would be performed naturally would be decreased dramatically, if the elicitation frame were ungrammatical. Also, since the elicitation frame involves a quotation formula, it was anticipated that the second inserted token would receive the focus of the sentence, and that the status of this embedded token as a nonsense, lexical or phrasal entity would not have impact.

It was expected that using a quotation formula would be less likely to be rejected as artificial by the participants, as opposed to frames such as:

"I see TOKEN printed on a card." Or "This card contains TOKEN." or

"She put the TOKEN on the table."

It was anticipated that the quotation formula itself would be sufficiently backgrounded, that only the embedded elicited token would be foregrounded. And also, since the embedded token was a direct quote, it can exist out of context, and grammatical rules would not attempt to inflect the embedded token based upon issues such as gender, number, or animate vs. inanimate.

Regarding brevity, having three identical environments in the frame (i.e. repeating the quotation formula three times: "She said TOKEN in Russian. She said TOKEN in Russian. She said TOKEN in Russian.") has its merits of attempting to provide identical environments for all tokens. However, performance of this triple quotation formula would have increased the duration of the recording session, and would likely have created its own list effects. Eliminating all quotation formulas would have produced the most brief elicitation frame of merely three iterations of the item: "TOKEN. TOKEN. TOKEN." However, again, this "frame" has its own internal list structure. Therefore, a single, medial quotation formula was deemed suitable for the issues of naturalness and brevity at hand.

3.2.2.1 Junctures in the Elicitation Frame

The elicitation frame has six junctures between the inserted tokens and the frame:

[(silence) TOKEN. aná skazálə TOKEN pa rússki. TOKEN. (silence)]
(1) (2) (3) (4) (5) (6).

Regarding reduction of interference imparted by the frame, it was anticipated that unstressed vowels (especially reduced vowels) at each juncture of the frame would generate less interference than stressed vowels. As such, the six junctures involve:

(1) Silence

(2) Pre-tonic reduced /a/

(3) Post-tonic reduced /a/ ([ə])

(4) Labial plus pre-tonic reduced /o/ ([a])

(5) Post-tonic /i/

(6) Silence

The impact of interference from the frame could be reduced further by affording ample pause at junctures 2 and 5. And indeed, it was common for participants to insert sufficient pause at these two junctures. On occasion, participants inserted pause at juncture 4, as well. Of the internal junctures 2-5, juncture 3 was the only position at which participants never inserted a pause.

The labial of /po-russki/ ‘in Russian’ at juncture 4 produced the most amount of interference with the embedded tokens. However, this only occurred on vowel-final elicited items. Vowel-final items included nonsense syllables and the suffixes of inflected forms. All lexical roots and many nonsense items were consonant-final.

The vowel, which was of primary focus of this study, is the final syllable of the root (particularly of lexical items), and since all lexical items are consonant-final, the critical vowel of interest was buffered from the interference effects of the labial in the frame at juncture 4. Thus, the interference from the /p/ at juncture 4 became a non-issue for all pertinent lexical items and for any nonsense item which was consonant-final.

3.3 Participants and Recording Sessions

Participants were recruited for the research based upon recommendations by native Russian speakers available on the UT Arlington campus. Initial efforts to recruit participants via flyers, postings and advertisements failed to generate a response; participants were only likely to respond by filtered invitation accomplished through social networking. After having the format of the research explained to them, a few native speakers of Russian on campus agreed to contact a number of their acquaintances, and forwarded contact information to the researcher for those persons who showed an interest in volunteering.

The researcher contacted the interested volunteers by telephone or via email and initially screened them for eligibility in the research, namely that they were native speakers of Russian and effectively only spoke Russian to communicate until after the age of 18.

A small number of the initial wave of interested eligible volunteers did arrange appointments to be recorded, and then in turn, they later contacted a number of their acquaintances to generate a second and third wave of potential volunteers. Interested volunteers were informed that there would be a short questionnaire (Appendix B) regarding their language history to be filled out, prior to their recording session. The basic contents of the questionnaire were discussed during the initial telephone/email exchange with the volunteers.

Participating subjects traveled to the researcher's place of work on campus, or the researcher traveled to the participant's home or office, as required. During the set-up of the recording equipment and arrangement of the recording environment, the participants completed their informed consent forms and the questionnaire of their language history. The recording session only proceeded on the condition that these forms were completed, and that the participants had self-identified that they were native speakers of Russian, who routinely communicated only in the Russian language until the age of 18.

Most participants indicated that they had been exposed to language classes in school in the Soviet Union or post-Soviet Russia. In particular, those participants, residing outside of the formal borders of the Russian Federation, indicated that they were ethnic Russians, had ethnic Russian parents, solely spoke Russian to communicate during childhood, and lived in Russian-speaking communities. They indicated that their effective exposure to verbal non-Russian languages (such as Ukrainian or English) was limited to compulsory cultural classes at school.

The pertinent demographic information regarding the ten participants is listed in Appendix B. Based upon self-identification and by comparison of the participants' treatment of irregular lexical items, the participants can be categorized into 5 dialectal groupings:

1) m-Group: Muscovites or self-identified speakers of Moscow dialect

2) p-Group: participants from St. Petersburg

3) u-Group: participants from the Ukraine

4) k-Group: a participant from the Crimea in the Ukraine

5) b-Group: a participant from Belorussia

Although all participants self-identified as being native speakers of Russian, the analysis and conclusions of this study focused primarily on the five members of m-Group and p-Group, who were born and raised on in Russia proper. The verbal behavior of the five participants of u-, k- and b-Groups, who were born and raised outside of Russia proper, was relegated to that of a secondary supportive role. On occasion, the speech behavior of the five secondary speakers will be forefronted, when facets of their speech offer counterpoints to the speech of the five primary speakers.

The recording environment was always arranged with the researcher facing the participant, and the researcher operating the recording laptop with the back of the screen facing the participant. The researcher managed the elicitation Decks, stopping between each sub-deck to save the recorded file to disk on the laptop. The researcher progressed through sub-decks, holding up each individual cue-card of a Deck at approximately the participant's eye level. If the recording occurred in an office space, the distance between the participant and the cue-card was approximately 4-6 feet. If the recording occurred at the participant's residence, the distance between the participant and the cue-card was approximately 10-15 feet.

Each cue-card contained a single syllable, lexical item, or phrase. The cue-cards were printed in the Cyrillic alphabet, with a sans serif font, at 128 pt., in a dark ink (black, navy blue or dark red).

The participants were provided a beverage (water or tea), and offered a choice of the seating stations available. The researcher then assumed a seating station facing the participant. The participants were encouraged not to choose a station that was mobile or possessed moving parts which would generate noise during the recording session. The participants were encouraged to make themselves comfortable, and were given the opportunity to settle into a stable, relaxed sitting position, while the researcher set up the recording equipment and arranged the environment.

After the participants had settled into a comfortable seated position, the researcher positioned a microphone stand with a three-foot boom extension arm near the participant's station. This arrangement of a short boom-mike arrangement was desirable in order to permit the participant the maximum amount of freedom possible, to make the mikeing procedure as un-intrusive and non-threatening as possible, and to avoid physical contact between the participant and the microphone, which might generate noise or static.

The boom microphone was swung into a position approximately 2-3 inches below and 4-5 inches in front of the participant's chin. During the recording session, the participants were permitted to shift their sitting position as needed, for comfort. If the participant shifted position, and the distance from the participant to the microphone changed more than an inch or two, the boom arm was re-positioned below and in front of the chin, to accommodate the participant's new posture. If it was necessary for participants to stand up and leave their seat, the microphone was re-positioned below and in front of the chin, after they had resettled.

The recording was accomplished with a Shure C606W Dynamic Cardioid microphone, routed through a Roland ED UA-30 USB audio interface external amplifier, into a laptop. The laptop was a Dell Inspiron 9400, with Intel Duo Core CPU, T2300 @ 1.66GHz, with 980/MHz/512 MB of RAM. The operating system for the laptop was Microsoft Windows XP/Media Center Edition/Version 2002/Service Pack 2. The recording software was Adobe Audition version 2.0. The Adobe Audition capture settings were: 44.1K sample rate; 16-bit, mono.

Printed instructions for the activities of the recording session were available in Russian, and these instructions were also digitally recorded in sound files in Russian for playback to the participants. However, all participants had sufficient aptitude in English for the researcher to present the instructions for the session verbally in English, during the set-up of the recording equipment and arrangement of the recording environment.

The recording software was activated during the set-up procedures. At this time, the level of recording gain of the individual participant's speech was adjusted to optimal levels during the first few minutes of the session, while the participant was practicing with the elicitation frame and with unfamiliar lexical items. Throughout the recording session, the researcher continued to monitor the recording gain levels of the incoming audio stream and adjusted volume gain as needed. If the performance of an elicited item exceeded optimal levels and overdrove the recording gain levels, the researcher adjusted the gain and asked the participant to repeat that particular cue-card.

During set-up procedures, the participants were instructed that each cue-card would normally be performed only once (per hour). However, the participants were notified that a cue-card might be repeated, if noticeable environmental noise occurred or if the participant experienced a disruption in their speech (i.e., sneezing, coughing, laughing, etc.). The participants were encouraged to sip their beverages between sub-decks, or more often, if needed.

Time permitting, the cue-cards of sub-decks 1-8 from the first hour of recording were revisited in order, and a second hour of recording for sub-decks 1-8 was captured. After the recording session was completed, participants were compensated for their time with a gift card worth $25.

3.4 Data Processing and Analysis of the Recorded Data

After the fieldwork capture was completed, the large audio WAV capture files for each sub-deck were re-opened in Adobe Audition and segmented into smaller WAV files for each individual cue-card, which were then labeled and saved separately. Thus, each individual WAV file contained one iteration of the elicitation frame, involving three tokens of item from a cue-card.

After the large capture files were segmented, the individual files were opened in Praat software for acoustic analysis (Praat v.4.5.14 on desktop Mac, or Praat v. 4.4.33 on PC laptop). Whenever possible, the default "standard" setting for each contour in Praat was used (Table 3.6). The standard settings were identical for the PC and Mac versions used in this study.

At the beginning of each Praat session, the standard default settings for each of the analytical tools (Praat Spectrogram, Pitch, Intensity, Formants) were reset to the standards. If any of the settings for a Praat analytical tool were adjusted for a particular token, then the default settings were restored before another token was considered.

If, on occasion, two formants were sufficiently close together that the Praat software merged them together, then the Maximum formant and the Number of Formants (under the Formant settings) was adjusted, until the Praat software was able to nominate separate data-points for all formants in the appropriate ranges, if possible. For instance, if F1 and F2 are close together (as is the case with many tokens containing /o/ or /u/), then the maximum range setting was lowered below 5500 Hz, until Praat was able to separate the energy in the lower frequency range into two distinct formants.

Also if the energy in a particular formant was sufficiently weak that the Praat software did not nominate data-points in the appropriate range, then the Number of Formants (under the Formant settings) was increased, until the Praat software was able to nominate data-points for all formants in the appropriate ranges. Any extraneous data points (created by increasing the number of formants) were deleted during an edit phase.

For this study, the standardized step-interval was 6.25 msec. This interval length is a result of the Praat default settings. The default Formant settings Window length is 25 msec. The Praat software steps through the sound file at an interval that is one quarter of the Window length. Hence, the standarized interval was one quarter of 25 msec.

Table 3.6 Standard Settings for Praat Software Employed in this Research. The only parameter routinely set to a non-standard value was Dot Size, for clearer visibility. This setting is purely a display setting and does not alter the data-values.

Spectrogram Settings:	View range (Hz): 0.0 to 5000.0; Window length (s) 0.005; Dynamic range (dB): 50.0;
Advanced spectrogram settings:	Number of time steps: 1000; Number of frequency steps: 250; Spectrogram analysis settings: Method: Fourier; Window shape: Gaussian; Spectrogram view settings: [checked] Autoscaling; Maximum (dB/Hz) 100.0; Pre-emphasis (dB/oct): 6.0; Dynamic compression (0-1): 0.0;
Pitch Settings:	Pitch Range (Hz): 75.0 to 500.0; Unit: Hertz; Optimize for: [checked] Intonation (AC method); Drawing Method: automatic;
Advanced pitch settings:	Make view range different from analysis range: View range (units): (auto) to (auto); [not checked] Very accurate; Max. number of candidates: 15; Silence threshold: 0.03; Voicing threshold: 0.45; Octave cost: 0.01; Octave-jump cost: 0.35; Voiced / unvoiced cost: 0.14;
Intensity settings:	View range (dB): 50.0 to 100.0; Averaging method: [checked] mean energy; [checked] Subtract mean pressure; the pitch floor is taken from the pitch settings; the time step strategy has its standard value: automatic;
Formant settings:	**Maximum formant** (Hz): 5500.0; **Number of formants**: 5.0; **Window length** (s): 0.025; Dynamic range (dB): 30.0; **Dot size** (mm): 3.0 [non-standard setting];
Advanced formant settings:	Method: [checked] Burg; pre-emphasis from (Hz): 50.0.

If the Window length is increased, a longer time-span of the waveform is accessed to generate the set of formant readings. Using a longer Window length reduces the impact of spurious noise and generates a smoother curve. However, a larger Window length generates fewer data-points, which are further apart, and a longer Window length tends to damp the effects of local, pertinent (non-noise) extrema. Conversely, if the Window length is decreased, a shorter time-span of the waveform is accessed to generate the set of formant readings. Using a shorter Window length increases the impact of spurious noise and generates a more erratic curve. However, a shorter Window length generates more data-points, which are closer together, and a shorter Window length tends not to damp local, pertinent extrema.

From observations in pilot research projects, the status of local extrema and the status of formant readings immediately at the margins of sonorous phonation proved to be pivotal in establishing the behavior of syllable types. Therefore, the strategy of increasing the Window length to generate smoother formant contours was rejected, in favor of generating formant contours which contained un-damped local extrema and multiple data-points in the vicinity of the margins of sonorous phonation.[4]

Each individual WAV file per cue-card was opened and analyzed, using Praat software. During a Praat session, the individual WAV files appeared in the Praat Objects Window. Each WAV file was analyzed in turn, via a Praat Sound Window, created by choosing the Edit option for a WAV file in the Praat Objects Window.

In the Praat Sound Window, the embedded tokens of interest were located by mouse-clicking before and shift-clicking after the expected token, to create a sub-selection of the entire file. The accurate Selection of the desired token was verified by playing the sub-bar at the bottom of the Praat Sound Window, corresponding to the cursor-delimited Selection. Once it was verified that the delimited Selection contained

[4] However, in the future, deviating from the default setting might be warranted. Hopefully, improvements in software packages will reduce the impact of spurious noise. If spurious noise is less of a concern, then establishing a Window length of 20 msec will create a more user-friendly step-interval of 5 msec, without suffering noticeable disruption to the formant contours. If one elects to increase the Window length, it is recommended that one choose a Window length of 40 msec to create a smoothed formant contour, as this will in turn create a less cumbersome step-interval of 10 msec.

the desired token, the option to "Zoom to Selection" was performed, filling the Praat Sound Window with only the cursor-delimited Selection. The procedure of mouse-and-zoom was repeated, to refine the Selection to contain ultimately only two syllables: 1) the final root syllable; and 2) the following "syllable", which was either the suffix of the desired token, the first syllable of the resumption of the elicitation frame, or pause.

Although the entire contiguous duration of the final two syllables of a token was captured, only the formant measurements from the sonorous portions of these syllables were used in statistical comparison. Under the current configuration of input data structure (16-bit, 44K sampling rate for a WAV file) and the default configuration of Praat formant analysis, it was judged that only the formant measurements from the sonorous portions were consistently reliable, due to good signal-to-noise ratio. In the future, with improvements in acoustic analysis software, if formant structure can be reliably identified in non-sonorous portions of the waveform, these additional portions will be included in analysis.

3.4.1 Zones of Phonation Observed During Praat Sessions

During Praat sessions, four levels of phonation are observed in this data:

1) Silence or ambient noise

2) Voicelessness or devoiced frication

3) Voiced phonation

4) Sonorous phonation

Consider Figure 3.1, which depicts a sample token (собаках /sobákax/ 'dogs' prep.pl.) that has a number of zones of differing sonority. Zones 1 and 14 are silence, and contain negligible energy across the entire spectrum. Zones 2, 9, 10, and 13 are voiceless, and contain negligible energy below 1000 Hz. Zone 5 is voiced, and contains negligible energy above 500 Hz. Zones 3, 7, and 11 are sonorous, and contain energy which effectively saturates the spectrum from 0 to 5000 Hz.

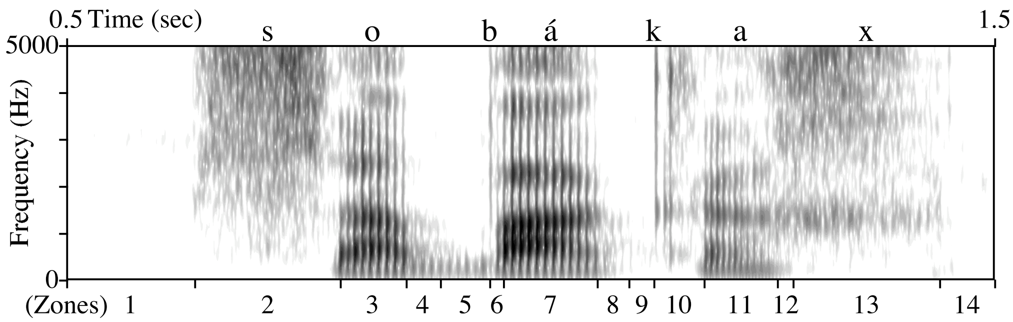

Figure 3.1 Spectrogram of /sobakax/. Zones of varying sonority are denoted on the bottom. The phonemic segments are denoted on the top.

Zones 4, 8, and 12 are composites. They contain approximately 10-15 msec of residual, devoiced energy from the preceding sonorous vowels, which dissipates into the following non-sonorous zones. Except for an overlain waning, partial formant structure below 1500 Hz, zones 4, 8, and 12 bear the same characteristics as zones 5, 9, and 13, respectively. These post-sonorous, devoiced zones were not considered as a separate category of sonority; rather they were considered as an inexact boundary between sonorous and post-sonorous zones; and their durations were considered a portion of the following zone (i.e., zone 4 was considered a portion of zone 5, zone 8 a portion of zone 9, and zone 12 a portion of zone 13).

3.4.2 Use of Praat Contour Tools to Select Zones of Interest

Figure 3.2 represents a complex overlay of three of the diagnostic tools available in the Praat software: Praat Pitch contour, Intensity contour, and Formant contour. Each tool will be addressed separately in turn. Figure 3.2 is provided for purposes of observing simultaneous phenomena.

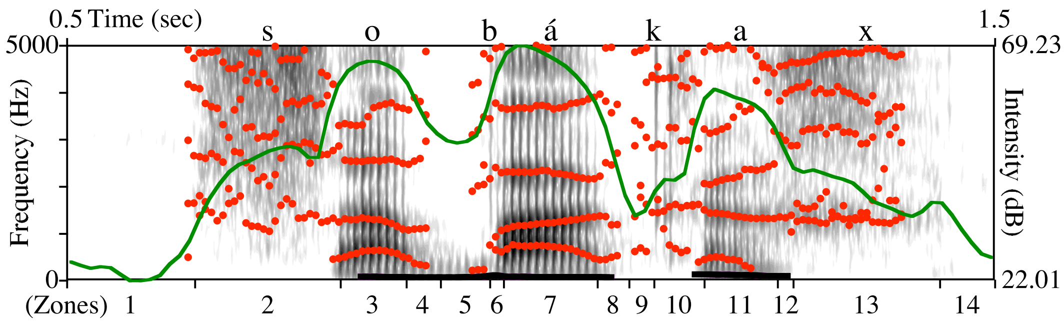

Figure 3.2 Spectrogram of /sobakax/, Including Praat Pitch, Intensity and Formants Contours. Intensity is green. Pitch is black. Formants are red speckles.

Zones 10 and 13 are zones of voiceless frication. These two zones have moderate intensity, contributing to a moderate signal-to-noise ratio, which might enable the Praat software to nominate a continuous formant structure (especially F2); however, the formant structures in zones 10 and 13 are also peppered with speckles from spurious noise. Zone 2 is also a zone of voiceless frication, but the Praat software was not able to nominate a continuous formant structure for this zone. This is likely due to the majority of energy of the /s/ being at a higher frequency than the range of F1 and F2.

The signal-to-noise ratio in silent zones (1 and 14), in voiceless non-fricated zone (9), and in voiced zone (5) is sufficiently weak, that the Praat software is generally unable to identify a continuous formant structure.

3.4.2.1 Use of the Intensity Contour in a Praat Session

Considering only the Intensity contour, Figure 3.3 illustrates the greatest degree of intensity occurs during the sonorous vowels /o á a/. Although there are no sharp edges in the Intensity contour (because it represents a traveling average), the rapid incline or decline of the Intensity at the border of a sonorous zone can be used to help differentiate the boundaries between sonorous zones and the adjacent voiced or devoiced zones. (The boundary between a sonorous zone and a voiceless zone can be accomplished by other means.)

For this study, the Praat Intensity contour was utilized principally as a secondary means of establishing a boundary between sonorous zones and their neighbors.

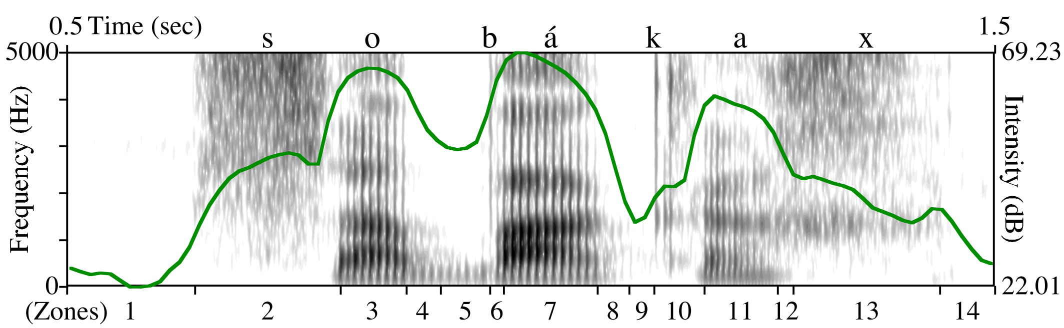

Figure 3.3 Spectrogram of /sobakax/, Including Praat Intensity Contour. Intensity is greatest during the sonorous vowels /o á a/. Voiceless fricatives /s/ and /x/ have a moderate degree of Intensity.

3.4.2.2 Use of the Praat Pitch Contour in a Praat Session

Considering only the Praat pitch contour, Figure 3.4 illustrates that periodicity is detectable by the Praat software in sonorous zones, such as zones 3, 7, and 11. Periodicity may also be detectable by the Praat software in the pre-voicing of a voiced consonant, such as zones 4 and 5, prior to /b/. Periodicity may also be detectable by the Praat software in the residual energy of sonorous vowels, such as in zones 4, 8 and 12. However, a detectable Praat pitch contour was not always present during sonorous, voiced or devoiced zones, because voice qualities which were gravelly or harsh contained characteristics that thwarted the Praat software from identifying sustained periodicity. These types of voice qualities were encountered in the current data, routinely occurring at the leading edge of onsetless vowels, and during brief reduced post-tonic (schwa) vowels. Thus, a detectable Praat pitch contour is an indication of periodicity, and hence voicing; however, the lack of a detectable Praat pitch contour does not necessarily indicate a lack of voicing.

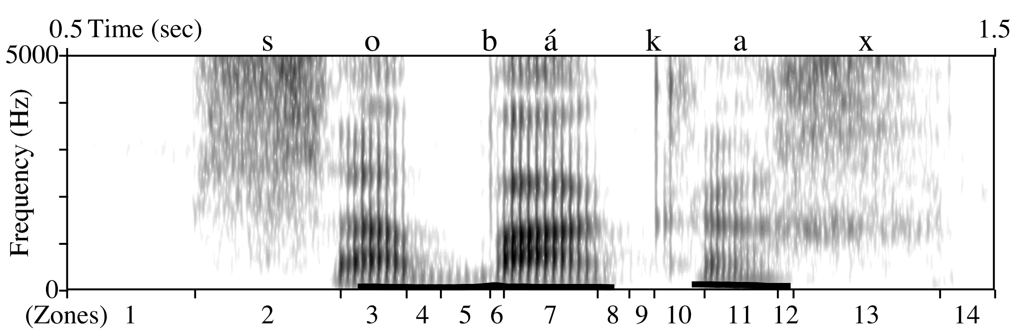

Figure 3.4 Spectrogram of /sobakax/, Including Praat Pitch Contour. The Praat pitch contour has been drawn on the same scale as the spectrogram, thus it appears in the lowest range of the Figure. This Figure is only intended to illustrate where periodicity is detectable by the Praat software.

3.4.2.3 Use of the Formant Contour in a Praat Session

Considering only the Formant contour, Figure 3.4 illustrates that continuous and reliable formant structure is detectable by the Praat software in sonorous zones (3, 7, and 11), in zones of frication (10 and 13, but not 2), and at the release of an obstruent (/b/ or /k/). In general, the Praat software seems to be best able to nominate a replicable formant structure from token to token, during a continuant (i.e., sonorant or fricative), or when the pertinent range of the spectrum has been saturated and the signal-to-noise ratio of the waveform is relatively large (i.e., during a sonorant or briefly at an obstruent release).

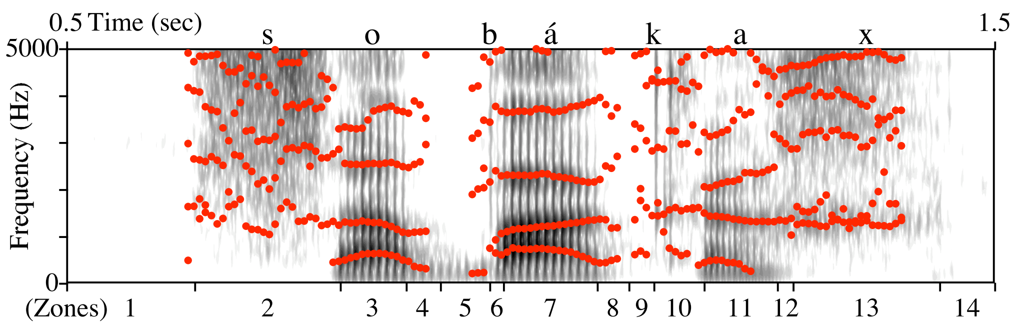

Figure 3.5 Spectrogram of /sobakax/, Including Praat Formant Contour. Note the continuous formant contour in sonorous zones 3, 7, & 11; and in the continuant 13.

However, the Praat software may be unable to establish a continuous formant structure during a continuant, if the continuant characteristically has a paucity of energy in the pertinent range for the lower formants (e.g. zone 2, in which the energy for /s/ is generally greater than the range of F1 and F2). The Praat software may also be unable to establish a replicable formant pattern from token to token during zones of aspiration or frication following the release of an obstruent. These two zones of linguistically relevant noise may be too erratic and unstable for the Praat software to establish a recurring energy pattern from one sampling window to the next.

3.4.2.4 The Pre-eminence of F2 as a Diagnostic Tool

In this study, the formant F2 emerged as the primary means of tracking the behavior of vowels. In most cases, F2 alone was sufficient to establish contrast between minimal pairs of syllables that varied only by nucleus. On occasion, F3 was useful in disambiguating contrastive syllables in which there was no apparent contrast in F1 or F2. In general, F1 was not as useful as F2 in establishing contrast, for two reasons:

1) F1 is similar for vowels with the same specification of vowel height. In particular, there was usually no significant statistical difference in F1 for /i y u/.

2) The Praat software tended to register a decrease in F1 towards the margin of sonorous phonation, whether a decrease in the formant was present or not. This was primarily because the Praat software appeared to be unable to disambiguate F1 and the energy of in the range of F0 at the margins, as the intensity of F1 decreased. The Praat software apparently evaluated the decrease in intensity of F1 at the margins, as a merger of F1 into F0, and nominated data-points which indicated a merger of formants. As such, the Praat-nominated values for F1 effectively indicated a marginal effect in F1 for virtually every syllable, regardless of whether or not the syllable actually exhibited consonantal effects at the margin or a change in vowel formant structure at the margin. This ubiquitous “ghost” marginal effect in F1 reduced the usefulness of F1 as a diagnostic tool for formant behavior at the margins of a syllable.

The formant F2 did not suffer this ubiquitous electronic marginal effect. The range of F2 was sufficiently beyond the normal range of F0. Praat was always able to track F2 accurately through a margin, even if the intensity of F2 diminished.

3.4.3 Levels of Phonation Observed in the Data

Revisiting the complex Figure 3.2 with all three contour tools overlain, the four levels of phonation listed in Table 3.7 can be differentiated based upon a co-occurrence of characteristics from the contour tools. The zones of primary focus in this study are the sonorous zones, because the Praat-nominated formant contours in these zones are judged most likely to be reliable and replicable from token to token. The Praat-nominated formant contours from the non-sonorous zones were only of secondary focus, because measurements from these zones were judged to be less reliable and more susceptible to the effects of spurious noise due to lower signal-to-noise ratio. In the future, with advances in acoustic software that permit more reliable formant contours regardless of sonority, these non-sonorous zones will be considered more fully.

Table 3.7 Characteristics of Four Levels of Phonation in the Data.

Criterion / Phonation	Discernible Intensity Contour	Discernible Periodicity in Waveform	Sustained Pitch Contour	Discernible Amplitude in Waveform	Range of Energy in Spectrogram
Silence	no	no	no	no	no
Voiceless	moderate	no	no	yes	isolated
Voiced	moderate	yes	maybe	yes	isolated
Sonorous	great	yes	yes	yes	saturated and striated

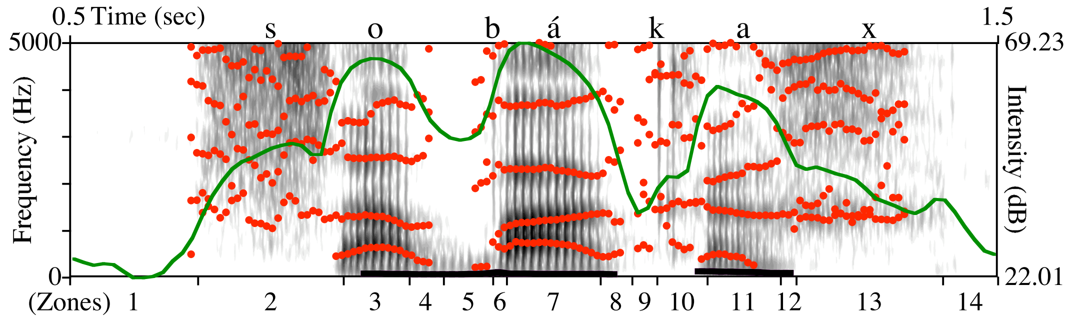

Figure 3.6 Spectrogram of /sobakax/, Including Praat Pitch, Intensity and Formants Contours (3.2 revisited). Intensity is marked in green. Pitch is marked as black. Formants are marked as red speckles. The Figure represents one full sec of speech by speaker pF.

The zones of sonority will now be presented in terms of the data encountered.

The characteristics of silence or ambient noise in the Praat session are: a lack of periodicity (as evident in the raw waveform and lack of identifiable Praat Pitch curve); and negligible amplitude (as evident in the raw waveform and in the Praat Intensity curve). This level of lack of phonation corresponded to either:

1) Silence, or

2) Phonological pause, on the part of the participant.

The characteristics of voiceless zones in the Praat session are: a lack of periodicity (as evident in the raw waveform and lack of identifiable Praat Pitch curve); a lack of amplitude in the Praat Intensity Curve, but a discernible amount of amplitude in the raw waveform; and bands or clouds of energy in isolated tracts of the Praat Spectrogram. This level of voiceless phonation corresponded to one of the following:

1) The partially devoiced or voiceless onglide /j/ as the sole element of the onset

2) The voiceless offglide /j/ after the nucleus of the syllable, before /k/ or pause

3) The onset or coda containing a voiceless consonant (e.g. /p/ or /k/)

4) Aspiration

5) The brief frication after the release of a consonant prior to “zero” suffix

The characteristics of simple voiced phonation are: discernible periodicity (as evident by a simple sine wave in the raw waveform or an identifiable Praat Pitch curve); a lack of amplitude in the Praat Intensity Curve, but a discernible amount of amplitude in the raw waveform; and bands of energy in isolated tracts of the Praat Spectrogram. This level of voiced phonation corresponded to either:

1) The pre-voicing of /b/ in the onset of lexical tokens, or

2) The portion of the offglide /j/ in some syllables, between the preceding sonorous vowel and the point at which the offglide became a voiceless fricative.

The characteristics of sonorous phonation are: a discernible periodicity (as evident by a complex periodic wave in the raw waveform, a sustained Praat Pitch curve, and striated vertical bands in the Praat Spectrogram); a discernible amount of amplitude in the raw waveform and in the Praat Intensity Curve; and energy which effectively saturates the spectrogram from 0 to 5000 Hz. The saturated zone of the spectrogram is organized into vertical striations, corresponding to glottal pulses, and horizontal bands or clouds of energy, corresponding to formants. This level of sonorous phonation corresponded to:

1) Nasals and liquids,

2) Intervocalic sonorants /v/ and /j/, or

3) The vowels in the nuclei of syllables.

Using these definitions, the primary difference between voiced and sonorous phonation is observable in the Praat Intensity Curve and in the amount of organization of energy in the spectrogram. In many cases, the boundary between the isolated energy of voiced phonation and the saturated energy of sonorous phonation is drastic and occurs within the frame of one glottal pulse. In other cases, the boundary is less well-defined and the transition from voiced to sonorous may occur over 15-20 msec. In cases of a more gradual change of sonority, the Intensity Curve and the amplitude envelope of the raw waveform was referenced to establish a boundary.

3.4.4 Establishing the Beginning of the Praat Sound Window Selection

The beginning of the final Selection of a token in the Praat Sound Window was delimited by one of the following criteria:

1) The release burst of the consonant of the onset

2) The local minimum on the intensity envelope, corresponding to the maximum amount of closure for a non-obstruent

3) The beginning of frication of the onset, or

4) 20 msec, in the absence of occurrences of criteria 1 through 3

In the case of onsets of /b p t d k č/, the release burst was readily identified in the Praat Sound Window, as a prominent spike in the raw waveform and/or a vertical column of energy, which saturates the range of 0 to 5000 Hz in the spectrogram. For a few instances of onsets of /v/, a release burst was also detectable. This detectable release burst for /v/ onset corresponded to the local minimum in the intensity envelope of the raw wave, and also roughly to the position of a release burst for /b/ (in similar tokens), prior to the beginning of sonorous phonation of the vowel.

For the remainder of the onsets with /v/, the beginning cursor was set to the location of the local minimum in the intensity envelope of the raw wave (approximately 20 msec prior to the beginning of sonorous phonation of the vowel). For /mozaika/ 'mosaic', which was the only item with contained /z/ in the onset of a syllable of interest, the beginning cursor was set to 20 msec prior to the beginning of sonorous phonation of the vowel /a/.

For onsets involving only the glide /j/, the beginning of the final Selection was set to the beginning of devoiced frication of the glide.

For onsetless syllables, the beginning of the Selection was set to 20 msec prior to the beginning of sonorous phonation of the vowel of the token.

3.4.5 Establishing the End of the Praat Sound Window Selection

The end of the final Selection of a token in the Praat Sound Window was delimited by one of the following criteria:

1) The terminal edge of sonorous phonation of the "suffix"

2) The local minimum in the intensity envelope, which occurred at the end of the "syllable" following the final root syllable of the token, or

3) 100 msec, if the "suffix" was a pause

3.4.6 Timed Landmarks in the Praat Sound Window Selection

In Praat Sound Window, the time-value of the following six points-of-interest were recorded:

(B) The release of the onset of the final root syllable of the token

(I) The beginning of sonorous phonation of the final root syllable of the token

(M) The end of sonorous phonation of the final root syllable of the token

(P) The release of the consonant of the coda of the root syllable of the token

(S) The beginning of sonorous phonation of the “suffix” of the token, and

(T) The end of sonorous phonation of the “suffix” of the token

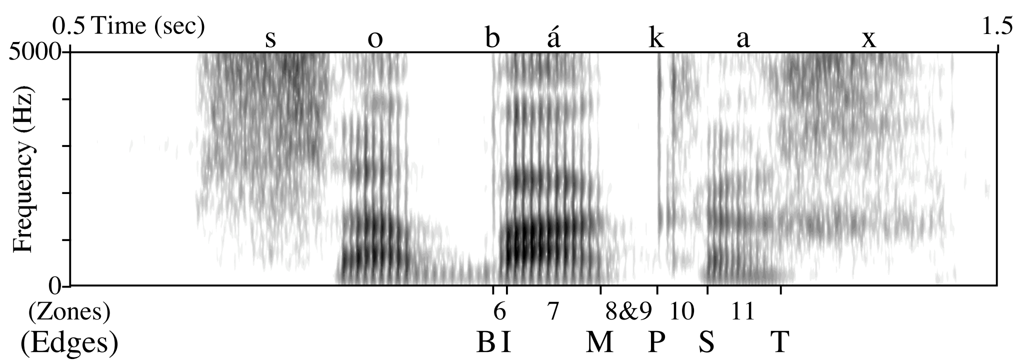

Figure 3.7 Spectrogram of /sobakax/, Including Boundary Points-of-interest for the Final Two Syllables of the Token.

Note: in Figure 3.7, the figure repeats the same portion of the WAV file as shown in previous figures, for purposes of comparison. In an actual Praat session, the option to zoom to the Selection from point B to T would have been performed, and the window would then only display zones 6–11, and would no longer display the portions corresponding to zones 1–5 and 12–14 in previous figures.

These points-of-interest represent the boundaries between zones of differing sonority. From the example in Figure 3.7, point B represents the release of the obstruent /b/, and this point of release is the end of the preceding closure of the obstruent, and is considered the beginning of the final root syllable. Point I represents the initium (the initial edge of the zone of sonorous phonation) of the root syllable, and point M represents the terminus (the terminal edge of the zone of sonorous phonation) of the root syllable. Point P represents the release of the obstruent /k/ in the consonant interlude between the root and the suffix, and again, this point of release is the end of the preceding closure of the obstruent in the interlude. Point S is the initium of the suffix, and point T is the terminus of the suffix.

The criteria for setting the time-value of point B of a token (at the release burst or its equivalent) are discussed in Section 3.4.4. The criterion for setting the time-value of point P is the same as for point B, for tokens with an obstruent between the root and suffix. For tokens with a continuant as the interlude between the root and suffix, point P is set at approximately the same distance from the initium of the suffix, as occurred with other tokens in which point P doe sin fact represent the release burst of an obstruent. The criteria for setting the time-value of the end of the token selection (point T) are discussed in Section 3.4.5. The criteria for setting the time-value at the edge of sonorous phonation (for points I, M, S, sometimes T) are discussed in Section 3.4.6.

As stated previously, once the beginning and the end of the Selection in the Praat Sound Window are established, the "Zoom to Selection" option is performed, filling the Praat Sound Window with only the cursor-delimited span. From the "zoomed" Selection, four data collections are extracted, by using the pull-down menus in the Praat Sound Window:

1) Extract visible formant contour

2) Extract visible intensity contour

3) Extract visible Praat pitch contour, and

4) Extract visible spectrogram

These four menu pulls generated four objects in the Praat Objects Window. Each of the four objects was then saved to disk, using the "Write to text file" menu option in the Praat Objects Window.

In the design of this research, it was originally anticipated that the Praat Pitch contour may possibly contain information that would demonstrate structure of the nucleus or differentiate contrastive segments. Specifically, it was anticipated that the segment /i/ might have an inherently higher fundamental frequency than the back vowels. If it could be shown that the beginning of a nucleus after a soft consonant had the same fundamental frequency signature as the segment /i/, then this would support the conclusion that the nucleus after a soft consonant might be the sequence jV.

However, any fundamental frequency signature inherent to specific segments (if such signatures even exist) was obscured by the widely varying prosodic Praat pitch contours exhibited by the participants. Consider the pitch contours of six tokens performed by speaker uR of the lexical item пике /pikje/ 'spade', as shown in Figure 3.8. The pitch at the initium of the root syllable varies by approximately 250 Hz. Such variability in the pitch on the stressed root syllable of tokens occurred routinely amongst the female speakers, effectively disabling pitch contour as a tool to investigate articulatory specifications of underlying segments. As such, the use of pitch contours to contrast tokens or types was abandoned, and the use of pitch contours was limited to a supportive role of disambiguating the boundaries of sonorous zones within individual tokens.

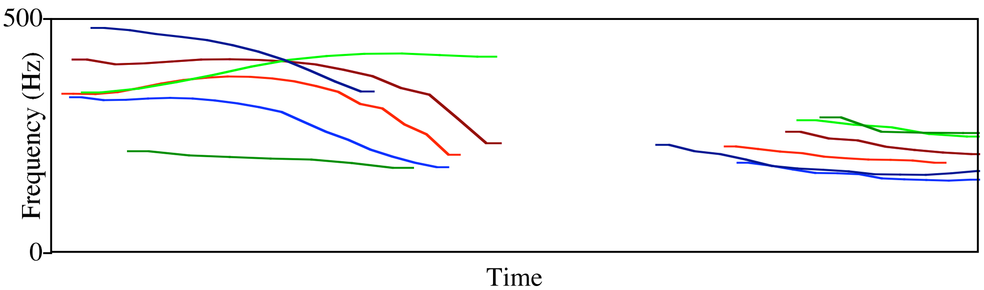

Figure 3.8 Praat Pitch Contours of Six Tokens of пике /pikje/ 'spade', for Speaker uR. Prosodic pitch effects on the root vary greatly. Prosodic pitch effects on the suffix are consistent. The horizontal axis depicts time in general. The scale and units on the Time axis have been removed, because the graphing tool of the Praat software adjusts the proportions of each overlain token to fit within the dimensions of the output window. However, the scale of the six tokens is approximately the same.

Similarly, it was originally anticipated that the Intensity contour might contain information that would demonstrate the structure of the nucleus. Specifically, if the segment /i/ had less sonority than non-high vowels, and there was an increasing Intensity contour in the sequences /je ja jo/, in which the second part of the nucleus had greater intensity than the first part of the nucleus, and the intensity of the first half of the sequence had the same intensity as /i/, then it might be posited that the sequences /je ja jo/ began with a segment similar to /i/.

However, as with the Praat pitch contour, prosodic effects modified the shape and value of the intensity contours of tokens greatly, thus obscuring any nuances that might demonstrate structure (if such nuances even exist). As such, the use of intensity contours to investigate the internal structure of nuclei or contrast nuclei from token to token was abandoned, and the use of intensity contours was limited to a supportive role of disambiguating the boundaries of sonorous zones within individual tokens.

Therefore, the use of the Praat pitch and intensity contours was limited to supportive roles of identifying boundaries during the Praat extraction session, and the extracted Praat pitch and intensity files themselves were archived for future potential research. These two abandonments elevated the role of the formant contours to that of the primary vehicle of investigation for this study.

The last contour tool in the Praat software to be considered is the extracted Formant contour. The extracted data files for formant contours contained a set of summary information, and then a list of frames. Each frame corresponded to the set of data, which was collected at each successive step-interval, from the beginning to the end of the Selection in the Praat Sound Window. This framed set of data for each step-interval included: the number of formants nominated at that interval; and then the frequency, intensity and bandwidth for each formant at that interval.

3.4.7 Importing Praat Output Data to a Spreadsheet

Once the extracted text file containing the formant contour was saved to disk, the text file was converted into a spreadsheet. This conversion involved rearranging the linear presentation of information from the Praat text file into a tabular presentation in a spreadsheet. Once the information was imported a spreadsheet, the interwoven columns of frequency, intensity and bandwidth were separated, and numerous new data columns were inserted, in addition to those columns created by the conversion.

3.4.7.1 The Structure of Praat Data in a Spreadsheet

The final data structure for an individual token from a Praat session includes:

1) A table of data-point records, containing:

a) A reference tag for the individual data-point record consisting of a concatenation of the type + speaker + token (hour and position in the elicitation frame) + step-interval (e.g. sobakaD3b[5] would be the fifth step-interval, for third token of hour b, performed by speaker D, of the type /sobaka/).

b) The absolute time-value of the individual data-point record, expressing the elapsed time from the beginning of the WAV file, calculated by multiplying the duration of the step-interval (6.25 msec) times 1 minus the ordinal of the data-point (e.g. the example in (a) is the fifth record, which is then 5 – 1 = 4 intervals after the origin of the Selection), and adding this to the time-hack of the beginning of the "zoomed" Selection in the Praat Sound Window.

c) The relative time-value of the individual data-point record, expressing the elapsed time from the beginning of "zoomed" Selection, calculated as in (b), except establishing the beginning of the "zoomed" Selection as the origin, as opposed to the beginning of the WAV file.

d) The derived frequency of the formants F2 minus F1

e) The Praat-nominated frequency of the formant F1

f) The Praat-nominated frequency of the formant F2

g) The Praat-nominated frequency of the formant F3

h) The Praat-nominated frequency of the formant F4

i) The Praat-nominated frequency of the formant F5

j) The time-values of the internal boundaries of the "zoomed" Selection.

k) Additional tags for internal points-of-interest within the formant contour (to be discussed more fully in Section 3.5).

2) A table of the durations between points-of-interest.

3) A table of menu settings and notes from the Praat session, so that the file can be re-created in case of data loss, corruption, or suspected mislabeling; and

4) Numerous charts displaying the data from columns A-J of part (1).

Reference tags in column A were generated so that data from disparate files could be extracted and compiled, without losing reference to the originating tokens. The absolute time-value in column B was retained, so that the token could be relocated in an archived data file, in case of data loss or for further inspection. The time-value in column C was calculated, so that multiple tokens could be aligned and compared from perspective of similar points in the course of a token's contours.

Table 3.8. Sample Marked-Up Spreadsheet Data-Structure for Formant Contours. The Points-of-Interest (POIs) are distributed in Column J, and tagged in column K.

A	B	C	D	E	F	G	H	I	J	K
	Time	Time							POI	POI
Ref-Tag Label	Orig	Rel	F2–F1	F1	F2	F3	F4	F5	Time	Tag
soBAKaF1a[01]	0.993	0	565	528	1093	2315	3477	4990	0.992	B
soBAKaF1a[02]	0.999	6.5	562	558	1120	2315	3382	4749	0.999	I
soBAKaF1a[03]	1.006	13	548	609	1157	2325	3379	4756		
soBAKaF1a[04]	1.012	19.5	529	660	1189	2331	3407	4790		
soBAKaF1a[05]	1.018	25	517	698	1216	2331	3416	4777		
soBAKaF1a[06]	1.024	31.5	557	722	1279	2329	3421	4775		J
soBAKaF1a[07]	1.031	38	571	751	1322	2346	3435	4877		
soBAKaF1a[08]	1.037	44.5	572	769	1341	2342	3441	4929		
soBAKaF1a[09]	1.043	50	604	776	1380	2319	3448	4956		
soBAKaF1a[10]	1.049	56.5	575	817	1392	2298	3495	4937		
soBAKaF1a[11]	1.056	63	614	821	1435	2292	3541	5060		K
soBAKaF1a[12]	1.062	69.5	695	792	1488	2284	3598			
soBAKaF1a[13]	1.068	75	733	779	1512	2260	3647			
soBAKaF1a[14]	1.074	81.5	743	767	1511	2222	3676			
soBAKaF1a[15]	1.081	88	845	710	1555	2172	3661	4950		L
soBAKaF1a[16]	1.087	94.5	896	660	1556	2142	3686			
soBAKaF1a[17]	1.093	100	945	598	1544	2112	3707			
soBAKaF1a[18]	1.099	106.5	1037	507	1544	2076	3741	4666	1.099	M
soBAKaF1a[19]	1.106	113	976	548	1524	2108	3746	4623		
soBAKaF1a[20]	1.112	119.5	851	590	1441	2215	3669			
(Units)	sec	msec	Hz	Hz	Hz	Hz	Hz	Hz	sec	

The calculation of F2–F1 in the derived column D was positioned prior to F1 in Column E, in an effort to create adjacency in the spreadsheet, for ease in selecting data for input to charts of vowel-space. Thus, adjacent columns D and E generated F2-F1 vs. F1 vowel-space, and adjacent columns E and F generated F2 vs. F1 vowel-space. Formant F3 in Column G was retained for supportive evidence to the vowel formants F1 and F2 in columns E and F, respectively. Columns H and I were retained for the purposes of establishing criteria for editing the Praat-nominated data.

Columns J and K were created for tags pertaining to points-of-interest in the formant contours. The points-of-interest (B, I, M, P, S, and T) from the Praat session were distributed appropriately through the rows of time-value records in the spreadsheet, as shown in Table 3.8.

Since the dataset of tokens had been constructed to avoid coronal consonants whenever possible, points B and P represented pertinent landmark behavioral changes in non-lingual articulators. Points I, M, S and T represented pertinent behavioral changes in phonation from the vocal cords. Additional points J, K, and L were generated which marked behavioral change-points in the formant structure, and hence, shed light on the behavior of lingual articulator(s).

3.4.7.2 Editing the Praat Data in a Spreadsheet

Editing the Praat-nominated data-points was constrained to aligning the Praat-nominated data into the appropriate formant columns only. No alteration of any numerical value from the Praat-nominated output occurred, other than that which occurred by shifting the data to the left or the right in a table.

In the case of a missing data-point, which occurred if the intensity of a formant was weak, the Praat-nominated data-points were shifted one column to the right (i.e., Praat's F1 becomes actual F2, and Praat's F2 becomes actual F3, etc.), as shown at point "R" in Figure 3.9. This operation created a gap in one of the lower formant tracks, corresponding to the missing data-point.

In the case of an extra data-point, which was caused by localized spurious noise, the Praat-nominated data-points were shifted one column to the left (i.e., Praat's F2 becomes actual F1, and Praat's F3 becomes actual F2), as shown at point "L" in Figure 3.9. The result of this operation removed the extra data-point, and created a gap in one of the higher formant tracks.

In the case of merging formants, for which Praat only nominated one data-point in the frequency range where the two formants had merged, the Praat-nominated data-points were shifted one column to the right, while leaving a copy of the merged data-point behind, as shown at point "D" in Figure 3.9. This operation copied the value at formant Fn, and generated a duplicate data-point at formant Fn+1, while shifting the higher formants over one column to the right. Merging formants were usually encountered in this data between F2 and F3 at the end of a syllable as a velar pinch, or between F1 and F2 for the vowels /o u/ experiencing a fundamental frequency contour.

While editing the Praat-nominated data, the higher formants F3, F4 and F5 were consulted collectively to determine if a systematic shift in formant assignment was caused by missing or extra data-points. Editing in the spreadsheet was accomplished quickly and successfully by Copy-and-Paste operations. After the Copy-and-Paste operations, obsolete data-points were removed by entering the appropriate cell and deleting the datum, or by copying-and-pasting an empty cell onto the obsolete datum.

The Cut-and-Paste operation and the Insert-Cell or Delete-Cell operations were avoided, as these operations caused undesirable results, since the spreadsheet attempts to re-assign links and references to accommodate the adjustment in Cell arrangement. In contrast, the Copy-and-Paste sequence of operations does not sever links or references within the spreadsheet, nor does it cause a re-arrangement of cells within the spreadsheet.

Table 3.9 Examples of Pre-Edited Data in the Spreadsheet. The Praat-nominated data is missing a datum for F1 at [06]; has an extra datum (currently at F2) at [13]; and is missing a series of data for F3 (because of formant merger) at [18]-[21]. The Praat software has correctly identified activity at these points, but mis-assigned them to the incorrect columns. The disrupted continuity of contours caused by these issues is depicted in the left-hand pane of Figure 3.9. Post-Edited Data is listed in Table 3.10.

Ref-Tag Label	Time Orig	Time Rel	F2–F1	F1	F2	F3	F4	F5	Edit Shift
BYK_F2a[01]	2.228	0	875	454	1329	2801	3991	4710	
BYK_F2a[02]	2.234	6.5	818	484	1302	2519	3140	5050	
BYK_F2a[03]	2.241	13	882	491	1373	2328	3139	5099	
BYK_F2a[04]	2.247	19.5	950	485	1435	2256	3161	5109	
BYK_F2a[05]	2.253	25	1053	476	1528	2243	3162	5083	
BYK_F2a[06]	2.259	31.5	630	1642	2273	3198	5069		Right
BYK_F2a[07]	2.266	38	1321	447	1767	2299	3261	5210	
BYK_F2a[08]	2.272	44.5	1460	422	1881	2320	3322	5324	
BYK_F2a[09]	2.278	50	1591	401	1991	2354	3393		
BYK_F2a[10]	2.284	56.5	1687	373	2060	2390	3441		
BYK_F2a[11]	2.291	63	1749	347	2095	2473	3474		
BYK_F2a[12]	2.297	69.5	1816	319	2135	2540	3500		
BYK_F2a[13]	2.303	75	703	302	1005	2165	2547	3512	Left
BYK_F2a[14]	2.309	81.5	1824	354	2179	2531	3528		
BYK_F2a[15]	2.316	88	1847	353	2200	2479	3554		
BYK_F2a[16]	2.322	94.5	1915	340	2255	2358	3588	5242	
BYK_F2a[17]	2.328	100	1914	332	2246	2258	3540	5332	
BYK_F2a[18]	2.334	106.5	1883	317	2200	3515			Dup
BYK_F2a[19]	2.341	113	1857	363	2220	3507			Dup
BYK_F2a[20]	2.347	119.5	1822	374	2197	3472			Dup
BYK_F2a[21]	2.353	125	1758	413	2172	3479	4887		Dup

Table 3.10 Examples of Post-Edited Data in the Spreadsheet. The Praat-nominated data at [06] has been shifted one column to the right to account for the missing datum. The extra datum at [13] has been overwritten by the process of shifting the columns to the left. The missing series of data at [18]-[21] has been copied into the adjacent column and the higher formants have been shifted one column to the right. In the right-hand pane of Figure 3.9, the continuity of contours has been restored.

Ref-Tag Label	Time Orig	Time Rel	F2–F1	F1	F2	F3	F4	F5	Edit Shift
BYK_F2a[01]	2.228	0	875	454	1329	2801	3991	4710	
BYK_F2a[02]	2.234	6.5	818	484	1302	2519	3140	5050	
BYK_F2a[03]	2.241	13	882	491	1373	2328	3139	5099	
BYK_F2a[04]	2.247	19.5	950	485	1435	2256	3161	5109	
BYK_F2a[05]	2.253	25	1053	476	1528	2243	3162	5083	
BYK_F2a[06]	2.259	31.5	1642		1642	2273	3198	5069	Right
BYK_F2a[07]	2.266	38	1321	447	1767	2299	3261	5210	
BYK_F2a[08]	2.272	44.5	1460	422	1881	2320	3322	5324	
BYK_F2a[09]	2.278	50	1591	401	1991	2354	3393		
BYK_F2a[10]	2.284	56.5	1687	373	2060	2390	3441		
BYK_F2a[11]	2.291	63	1749	347	2095	2473	3474		
BYK_F2a[12]	2.297	69.5	1816	319	2135	2540	3500		
BYK_F2a[13]	2.303	75	1863	302	2165	2547	3512		Left
BYK_F2a[14]	2.309	81.5	1824	354	2179	2531	3528		
BYK_F2a[15]	2.316	88	1847	353	2200	2479	3554		
BYK_F2a[16]	2.322	94.5	1915	340	2255	2358	3588	5242	
BYK_F2a[17]	2.328	100	1914	332	2246	2258	3540	5332	
BYK_F2a[18]	2.334	106.5	1883	317	2200	2200	3515		Dup
BYK_F2a[19]	2.341	113	1857	363	2220	2220	3507		Dup
BYK_F2a[20]	2.347	119.5	1822	374	2197	2197	3472		Dup
BYK_F2a[21]	2.353	125	1758	413	2172	2172	3479	4887	Dup

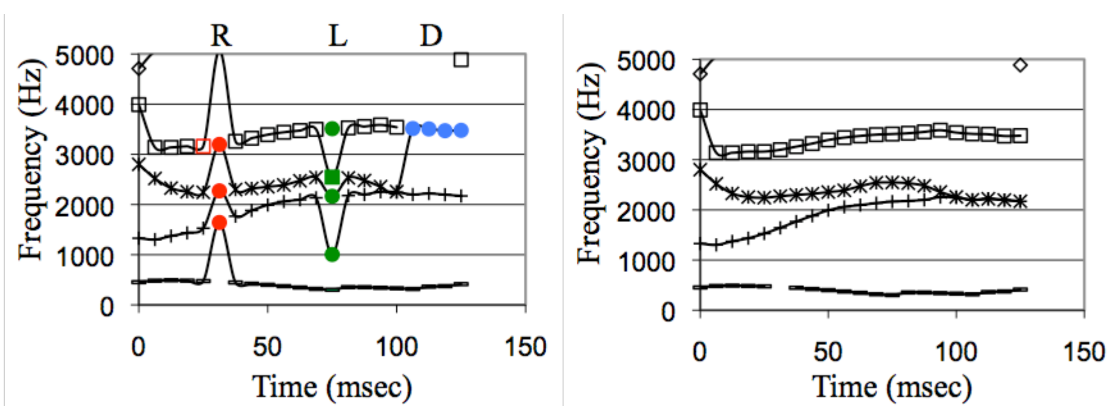

Figure 3.9 Pre-Edited and Post-Edited Data in the Spreadsheet. The left-hand pane represents a disrupted state of Praat-nominated formant contours, prior to editing. The right-hand pane represents a restored continuous state of formant contours, after editing.

3.4.8 Establishing the Value of a Formant at a Point-of-Interest

Once the Praat-nominated data-points had been edited to ensure the measurements for individual formants had been assigned to the appropriate columns, then comparison of formant tracks could begin.

Originally, it was intended that three successive data-points would be extracted in the vicinity of each point-of-interest on a formant track. The collection of three data-points for each of six tokens of a specific type would generate a set of 18 data-points. It was anticipated that a low degree of variability in any such set of 18 data-points would indicate three simultaneous conditions:

1) That each token of the set was consistently on-target at the point-of-interest.

2) That each individual token was static at the given point-of-interest; and

3) That the impact of spurious noise was low for the specific set of 18 points.

In contrast, it was anticipated that a high degree of variability in any set of 18 data-points would indicate discord in one or more of the preceding conditions, namely:

1) That one or more the tokens of the set was not consistently on-target at the given point-of-interest.

2) That one or more of the tokens was not static at the given point-of-interest, but rather was experiencing substantial dynamic transition; or

3) That substantial spurious noise was affecting one or more of the tokens.

However, establishing 18 data-records for only 6 tokens created a numerical disparity in N for statistical considerations, and therefore, the set of 18 data-points per type per point-of-interest was reduced to 6. This was accomplished by averaging the three successive data-points for an individual point-of-interest within a token and creating a composite data-point at that point-of-interest for that token.

The averaging of three successive data-points damped the impact of spurious noise, but also potentially obscured any localized dynamism in the token on the scale of approximately 10 msec. The viewport to observing dynamism within the token's formant track would have to be expanded to a larger scope of observing successive points-of-interest on a scale of 20-100 msec.

Averaging three successive data-points also damped the impact of local extrema on the vertical axis. However, averaging three successive data-points was judged to be a positive step, since it protected from error in measurement of mis-identifying the temporal location on the horizontal axis for the point-of-interest on a scale of approximately 5 msec, and also protected the data set from instances in which the actual temporal location of a point-of-interest fell between step-intervals.

Once the value of a formant at a point-of-interest was recorded as a composite triad, then a record of each token could be constructed as a series of composite triad-averaged frequencies for a sequence of points-of-interest. The six tokens of a specific type could be compared at each point-of-interest, and one type of syllable could be compared to another type of syllable.

The temporal value of a point-of-interest is either the boundary of zones of sonority, which were manually established in the Praat session, or points in time at which a change in behavior occurred within the formant, as nominated by mathematical models.

3.5 Mathematical Models of Formants

The purpose of applying mathematical models to the contiguous curve of a formant pattern was to nominate points-of-interest along the time axis at which the formant pattern exhibits a change of behavior. In some cases, nominating these points-of-interest was accomplished easily, employing features native to a spreadsheet (or other data management software) without applying mathematical models. In other cases, employing tools, which are native to a spreadsheet, was inadequate to the task.

In many instances, nominating a change-point, which was a local extremum in a formant track, was accomplished successfully with function calls or algorithms native to the spreadsheet, by employing a method such as:

1) Within the data-table for a particular formant, locate the extremum using a macro, min()/max() function, or some other algorithm.

2) Then note the time-coordinate related to that extremum.

3) Locate this time-coordinate on the plotted formant curve.

4) Visually verify that the extremum selected by algorithm at this time-coordinate is indeed a behavioral extremum representative of the curve (and not an outlier data-point influenced by jitter or spurious noise).

Thus, successful identification of local extrema on a plotted curve can be accomplished natively in the spreadsheet without engaging additional tools.

However, locating other useful change-points on a contiguous formant curve becomes increasingly more complex. Other change-points of interest are the inflexion points near the middle of an S-curve (for instance, where a curve ceases acceleration and begins deceleration), and points at which a curve effectively becomes asymptotic (where linear behavior ceases and acceleration begins, or where deceleration ceases and linear behavior begins). Nominating these non-extremum change-points with min()/max() function calls or by means of visual inspection can be tenuous and likely to produce inconsistent results. The use of mathematical models to nominate the locations is intended to produce meaningfully useful, consistent, reliable and replicable results. To this end, a variety of mathematical models for a curve were applied to formant patterns.

3.5.1 Specific Mathematical Models

A number of mathematical functions were used to model the formant patterns of selected syllables. Modeling permitted global descriptions of syllable shapes, and facilitated categorization of syllables by similar behavior. Curve-fitting also helped to nominate points in time, along the duration of the syllable, at which measurements could be taken, so that meaningful comparisons between contrastive syllables could be made.

The mathematical functions that were used in this effort are: linear functions; polynomial functions; and trigonometric and other sigmoid functions. Linear estimations were useful in describing isolated steady-state vowels. Trigonometric and sigmoid curves were useful is describing two adjacent steady-state vowels and the transition between them. Polynomials were useful is handling marginal consonantal effects on the formants of a vowel near its initium and terminus.

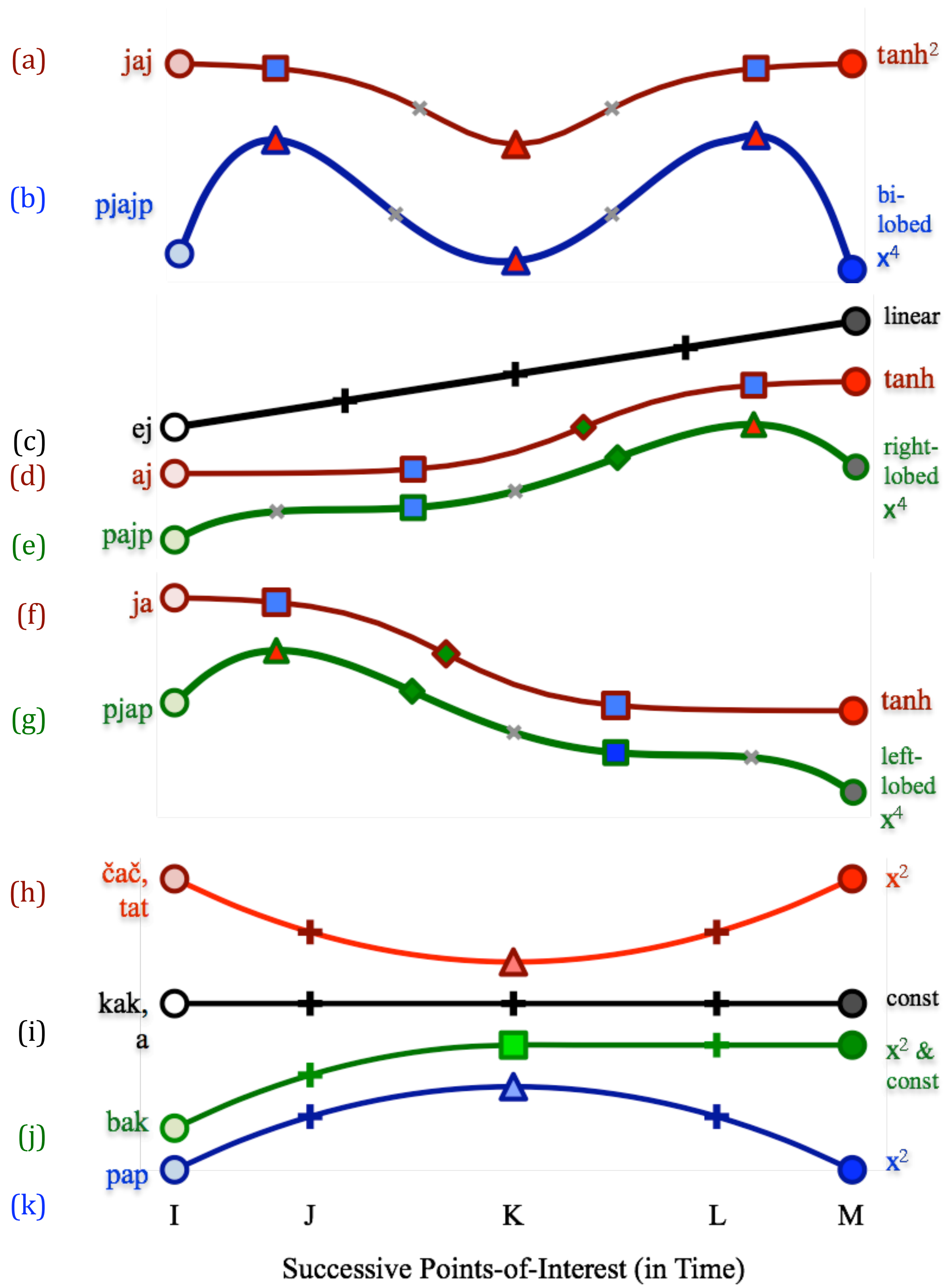

Figure 3.10 Sampled Tracks of F2 for Monophthongs, Diphthongs and Triphthongs. For comparisons, all syllables were sampled at five points. All syllables were sampled at initium and terminus (●). Other points-of-interest are local extrema (▲), points of inflexion (◆), and pseudo change-points (■) where the curve "obtains" the asymptote. If the curve contains less than five points-of-interest, then additional points were sampled (✚). If the number of points-of-interest of a curve exceeds five (as with quartic x^4-polynomials and $\tanh^2$), then change-points designated with (✖) were discarded.

3.5.2 Linear Models

The simple linear models employed in this study fall into two categories: constant functions and non-constant functions. Constant linear functions have a slope of zero, and were suitable to model monophthongs without discernible marginal consonantal effects, such as /a/ or /kak/ (line (i) of Figure 3.10). Non-constant linear functions have a fixed non-zero slope, which can either be increasing or decreasing, and these functions were suitable to model the sonorous portions of diphthongs involving the kernel /e/, as in the increasing linear function for /ej/ (line (c) of Figure 3.10).

3.5.3 Curvilinear Models

When modeling a contour, mathematical models of curvilinear functions were used to identify points in time at which the behavior of the line categorically changed behavior. The following points-of-interest of curvilinear functions were identified for a specific curve: 1) points-of-inflexion, 2) critical points, 3) pseudo critical points, and 4) the margins of the sonorous portion of the token curve.

In calculus, points-of-inflexion are points on the curve at which the slope of the curve changes from increasing to decreasing, or vice versa. Points-of-inflexion are located on the curve at a point at which the second derivative of the curvilinear function is zero. This indicates that the slope of the curve has reached a local extremum at that point. Thus, the vicinity of a point-of-inflexion can also be identified in the sampled data by locating the local extremum in the running difference between successive data-points. Thus, in practice, identifying a point-of-inflexion can be accomplished either by solving the second derivative of a best-fit curve of the observed data, or by using the min()/max()

function native to a spreadsheet, operating on a column of data that is the running difference between two successive measurements in the observed data of a particular formant.

The next category of points-of-interest is critical points. In calculus, critical points are points on the curve at which the slope of the curve changes from positive to negative, or vice versa. Critical points occur at a point at which the first derivative of the curvilinear function is zero. This indicates that the curve itself has reached a local extremum, i.e., the critical point is either a local maximum or local minimum. Thus, the vicinity of a critical point can also be identified in the sampled data by locating the local extremum in the list of data-points. Thus, in practice, identifying a critical point can be accomplished either by solving the first derivative of a best-fit curve of the observed data, or by using the min()/max() function native to a spreadsheet, operating on a column of data that is the original succession of measurements of the particular observed formant.

The next category of points-of-interest is pseudo critical points. In this study, pseudo critical points are classified as points on the curve at which the slope of the curve effectively becomes zero, especially as the curve approaches a horizontal asymptote. In strict mathematical terms, no such change-points exist, because the absolute value of the slope of the curve continues to change, as it approaches zero, although the changes in the slope may become infinitesimally small. However, for practical use, these pseudo critical points can be established by setting a parameter at which the slope is accepted as being zero, or by setting a parameter at which the curve is accepted to have effectively reached the value of the asymptote. In this study, this latter method was used for sigmoid curves.

In this study, the final category of points-of-interest includes the left and right margins of the sonorous portion of the observed token. In strict mathematical terms, these margins do not represent any particular change in behavior of the underlying mathematical model of the formant structure of the token. However, they do represent changes in behavior of the acoustics of the token.

3.5.3.1 Parabolic x^2-Polynomials

The first curvilinear function considered was a quadratic curve. Mathematically, the quadratic curve has a single change-point, which is the local extremum at the vertex of the parabola. The quadratic curve is suitable to model a formant of monophthongal vowels with marginal consonantal effects that create a single trough in the formant, such as /tat/ (line (h) of Figure 3.10), or a single arch in the formant, such as /pap/ (line (k) of Figure 3.10).

3.5.3.2 Cubic x^3-Polynomials

While a quadratic curve has only one mathematical change-point (a critical point), cubic curves have up to three mathematical change-points: a point-of-inflexion, and potentially a pair of critical points. The central portion of a vertically-oriented cubic curve is suitable to model a formant of diphthongal vowels that have marginal consonantal effects on the basic S-curve of a formant in transition from one frequency plateau to another. However, a portion of the observed data of a formant may have to be discarded or temporarily ignored to achieve a best-fit of a vertically-oriented cubic function, since the cubic function is suitable to model symmetrical (but opposite) behavior on either side of its central point-of-inflexion. The suitability of a cubic function as a model of a transitional formant diminishes if the consonant effects at opposite margins of the vowel are not mirror images of one another.

3.5.3.3 Quartic x^4-Polynomials

The suitability of a quartic x^4-polynomial is an improvement over the limited use of a cubic best-fit curve. The quartic curve can contain up to three critical points and two points-of-inflexion. This greater number of change-points allows the quartic function to overcome some of the limitations associated with symmetry in the cubic (and quadratic) curves. A quartic curve can be symmetrical, as in the bi-lobed quartic curve suitable to model the triphthong of a syllable such as /pjajp/ (line (b) of Figure 3.10). A quartic curve can also be asymmetrical, as in the left-lobed quartic curve suitable to model /pjap/ (line (g) of Figure 3.10), or the right-lobed quartic curve suitable to model /pajp/ (line (e) of Figure 3.10).

Furthermore, since quadratic x^2-polynomials and cubic x^3-polynomials are subsets of quartic x^4-polynomials, the specific separate application of quadratic or cubic best-fit curves can be eliminated, in favor of more flexible quartic curves to model formant contours which exhibit marginal consonantal effects.

3.5.4 Sigmoid Models

For this study, the properties of certain horizontally-oriented sigmoid curves are sutiable to modeling formant contours without discernible marginal consonantal effects, but rather stabilize to asymptotic plateaus at the margins. Two particular sigmoid curves (the hyperbolic tangent and the Gompertz function) possess properties that are especially suitable to modeling the formant contours encountered in this study.

3.5.4.1 The Hyperbolic Tangent

The particular form of the hyperbolic tangent curve which was considered is:

$$freq = a * \tanh(\mu * (t - \phi)) + k$$

where t = time, a = amplitude, μ = slope modifier at the central inflexion point, ϕ = the phase offset of the central inflexion point, and k = the frequency offset of the central inflexion point.

This curve has a single central point-of-inflexion in the Time vs. Frequency domain at the coordinate (ϕ, k). The location of the upper asymptote is at (a + k), and the location of the lower asymptote is at (a – k). Thus, the range between the upper and lower asymptotes is 2*a. The slope of a line tangential to the curve through the central inflexion point is $4\mu e / \left(e^{\mu x} + e^{-\mu x}\right)^2$, where the hyperbolic tangent function is approximated by the function $\left(e^{\mu x} - e^{-\mu x}\right) / \left(e^{\mu x} + e^{-\mu x}\right)$. The curve effectively becomes asymptotic (having achieved 99% of the range form the point of inflexion to the asymptote) at time-value of k ± e/μ. Thus, 2e/μ is effectively the width (and hence the duration of the transition) of the central curvilinear S-curve.

This form of the hyperbolic tangent is suitable to model formant contours such as /aj/ (line (d) of Figure 3.10) and /ja/ (line (f) of Figure 3.10. Furthermore, the square of this form is suitable to model symmetrical triphthongal formant contours such as /jaj/ (line (a) of Figure 3.10). The success of this form of the hyperbolic tangent (either the original form or the squared form) to model formant transitions diminishes when marginal consonantal effects are encountered. Furthermore, the hyperbolic tangent in limited by the property that it is symmetrical, which always places the point-of-inflexion arithmetically between the upper and lower asymptotes. The limitation of symmetry is eliminated by using another sigmoid curve: the Gompertz curve.

3.5.4.3 The Gompertz Curve[5]

The standard form of the Gompertz curve is:

$$y(t) = ae^{be^{ct}}$$

where t = time, e = Euler's Number (2.71828…), a = the upper asymptote, b affects the phase offset, c = the growth rate, and b and c are negative numbers. However, for this study, a modified version of the Gompertz is more useful:

$$freq = ae^{-e^{\phi}e^{-\mu t}} + k$$

where t = time, e = Euler's Number (2.71828…), a = amplitude, μ = growth rate, e^{ϕ} = the phase offset of the inflexion point, and k = the lower asymptote.

The requirement in the standard form of the Gompertz function that coefficients b and c must be negative has been permanently encorporated into the modified formula. In the standard Gompertz function, there is an exponential relationship between the coefficient b and the resulting phase offset. Therefore, the role of the coefficient b in the standard form has been replaced with the expression e^{ϕ} in the modified version. This will cause ϕ to behave as the coefficient of phase offset, permitting a unit change in ϕ to behave directly as a unit change in the phase shift.

One advantage of the Gompertz curve over the hyperbolic tangent is that the Gompertz curve is not symmetrical around its point-of-inflexion. Applying the Gompertz curve as a best fit to the observed shape of a formant track makes it possible to discern

[5] http://en.wikipedia.org/wiki/Gompertz_function, viewdate January 21, 2009.

whether the actual point-of-inflexion of an observed formant track is skewed towards one steady-state or the other. If one believes that part of a transition between steady-states belongs to the domain of its attached steady-state, then establishing unequal “halves” of the transition will permit separate observations as to which steady-state controls the majority of the transition.

However, the point-of-inflexion in the Gompertz curve is still in a fixed position in the curve. In order to determine whether the actual formant curve is better modeled with a point of inflexion to the right-of-center or to the left-of-center, the best fit must be performed twice: once in normal forward-time-order, and once in reverse-time-order.

In addition, the Gompertz curve can only successfully model an increasing function, such as the formant track of F2 of /aj/. Fortunately, changing the sign of the amplitude coefficient a to be negative will permit a successful fit to a decreasing function, such as the formant track of F2 of /ja/. Unfortunately, double application of the best-fit of the Gompertz curve to forward and reverse time-coding of the formant track will only reveal whether the actual point of inflexion of the transition is skewed more to the first target or to the second target. As stated previously, the point-of-inflexion of a Gompertz curve is in a fixed position off-center, and the Gompertz curve will not successfully locate the actual point-of-inflexion.

The advantage that the Gompertz curve is asymmetrical causes a simultaneous disadvantage, being that two pseudo critical points between the transition zone and the asymptotic wings must be calculated separately.

Since the Gompertz curve is always positive if it is increasing or always negative if it is decreasing (depending on the sign of amplitude coefficient), squaring the function does not substantially change its overall shape. Therefore, while the Gompertz curve is suitable for modeling a diphthong, the squared Gompertz curve is not suitable for modeling a triphthong.

3.6 Comparing Modeled Syllable Types

Once the change-points of an individual token have been identified, the individual token is modeled as a series of points-of-interest, noting the frequency of each point-of-interest and its time-value as a proportion of the duration of its token syllable. Then, each point-of-interest, in turn, is averaged with the corresponding point-of-interest of the other tokens of a syllable type, creating a series of composite points-of-interest. So, if each separate token is modeled as a series of points-of-interest I through M, then the frequency of the composite point-of-interest L is the average of the frequency for each individual token at point L, and the time-value of composite point-of-interest L is an average of the proportional durations of each individual token at point L. This series of composite points-of-interest represents the collective behavior of the tokens within the syllable type across the duration of the utterance, which the type represents.

A comparison of the composite tokens for contrastive syllable types can be viewed in a single graphic. For example, Figure 3.11 depicts the /bók/ peer group of syllable types. This peer group is comprised of the fixed root бок /bók/ 'side' inflected with the variety of suffixes /-i -je -a -om -u/ and "zero" suffix. That is, the /bók/ peer group is comprised of the types: /bóki bókje bókØ bóka bókom bóku/. Six tokens for each types were elicited. Thus, Figure 3.11 represents 36 tokens, with the root /bók/ (i.e., six tokens for each of the six types).

The upper pane of Figure 3.11 depicts the composite behavior of the six types: /bóki bókje bókØ bóka bókom bóku/. The three panes (I, M and S) in the lower tier of the figure represent expanded views of the six syllable types within the peer group, at each of the syllable edges: the initium of the root, the terminus of the root, and the beginning of the suffix, respectively. Within each expanded view, the central tendencies of the multiple tokens which comprise each syllable type are displayed. Each syllable type is represented by a mean value of F2 and one standard deviation on either side (top and bottom) of the mean. The plots for central tendency are color-coded to the F2 tracks.

In Figure 3.11, the number and membership of homogeneous subsets of a univariate ANOVA test for the value of F2 at the syllable edges are labeled beside the appropriate pane, in the second tier of the Figure. The types within the peer group are labeled with their contrastive element, below each expanded pane on the second tier. The full form of the syllable type is presented below the contrast labels.

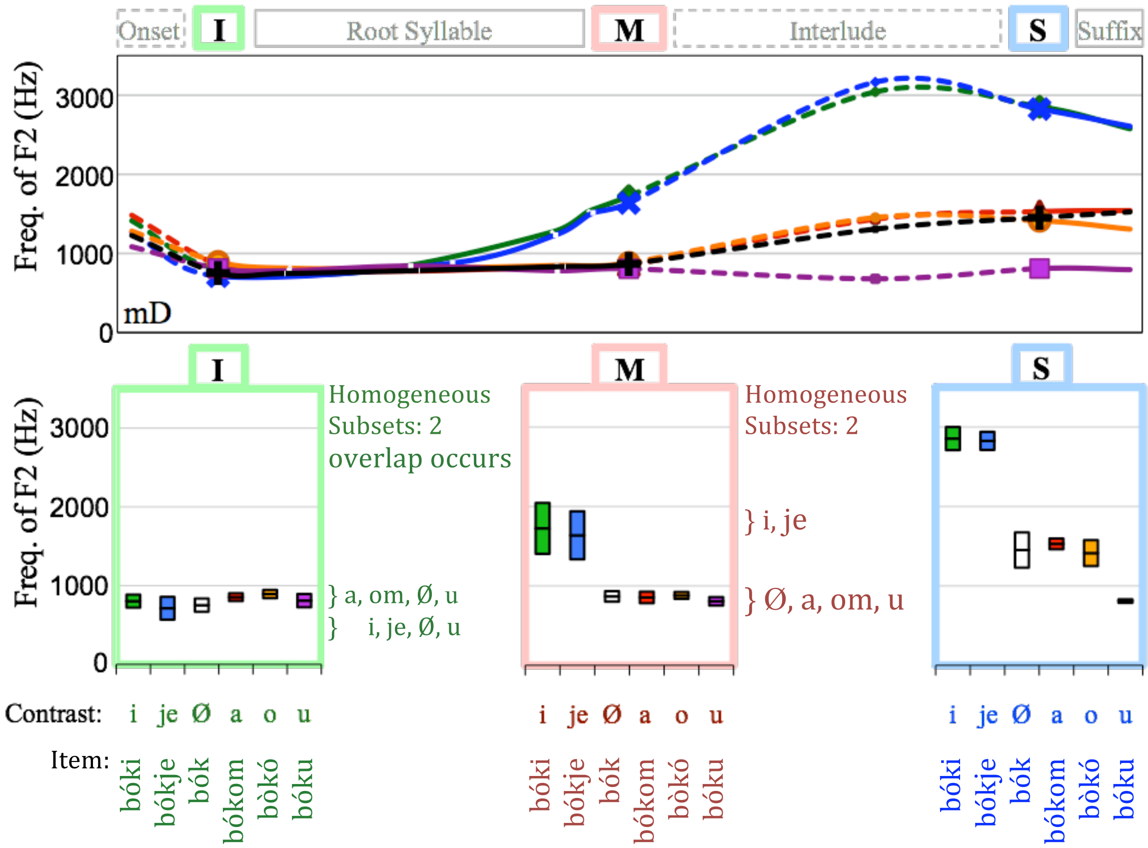

Figure 3.11 Sample Comparison of Composite Tokens for бок /bók/ ‘side’. Each track in the upper pane represents a normalized composite of six tokens. The three lower panes (I, M and S) represent expanded views of the instantaneous behavior at the edges of sonorous phonation, and they display the central tendencies of the individual tokens, which form each composite track in the upper pane.

Figure 3.11 has been duplicated in Figure 3.12, with tutorial labeling and mark-up. In Figure 3.12, Group (1) represents the types of the peer group at the initium of the root. In the upper pane, all types appear to behave similarly. However, in the expanded pane I, slight variations between the types, and differing degrees of variability within the types are revealed. To the right of pane I, the homogeneous subsets of the ANOVA test are identified. Although two homogeneous subsets are nominated, there is no scheme of systematic differentiation at the initium.

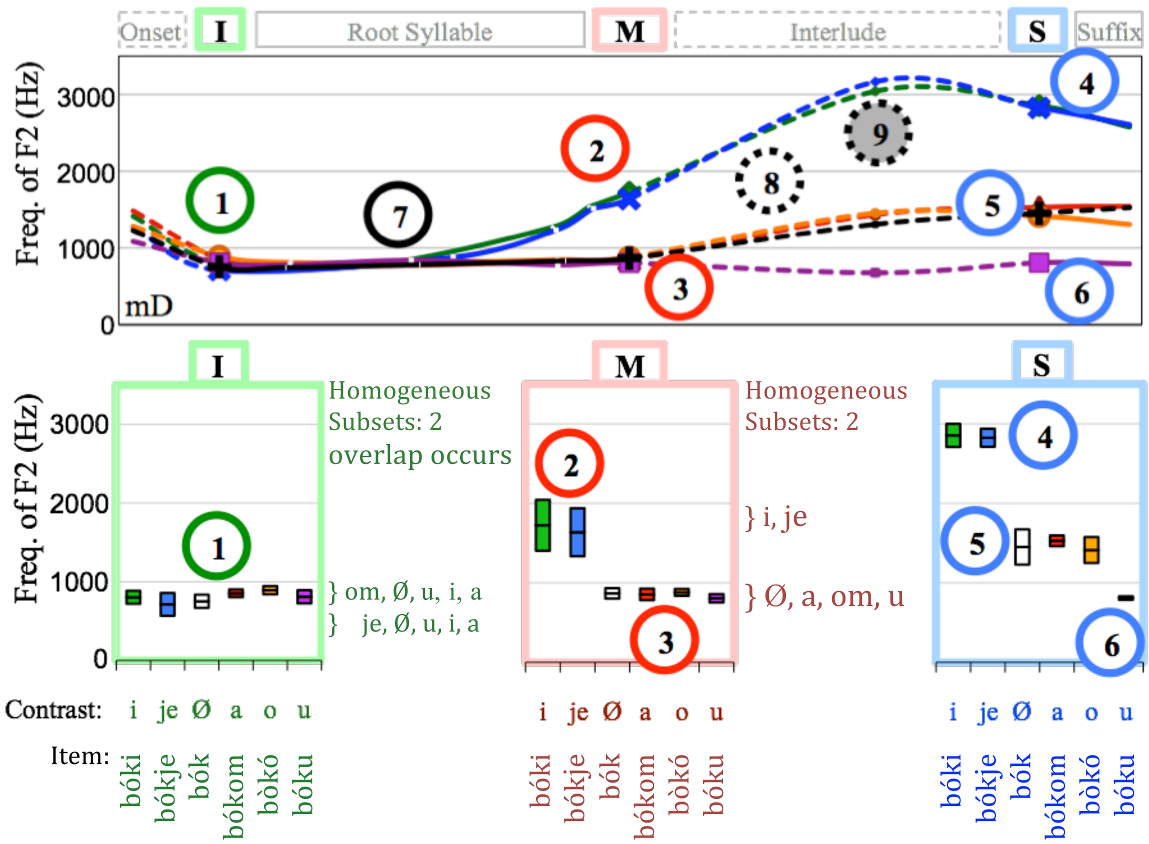

Figure 3.12 Duplicate of Figure 3.11, With Tutorial Mark-up.

Groups (2) and (3) represent two subsets within the peer group at the terminus of the root. In pane M, Point (2) represents the termini of the root before front vowel suffixes /i je/. The high degree of variability of the /i je/ types in group (2) is revealed: one standard deviation for /i/ is 320 Hz, and /e/ is 302 Hz. On the other hand, the variability in group (3) is considerably less: one standard deviation is less than 75Hz, for all of the types in group (3).

Groups (4), (5) and (6) represent the leading edge of the suffixes. Three subsets arise: front /i je/, centralized schwa-like post-tonic positions /Ø a o/ and back /u/. The variability of /u/ in group (6) at the leading edge of the suffix is extremely low (one standard deviation is 22 Hz).

Group (7) in Figure 3.12 represents the contiguous composites of the syllable types in the peer group. The connected lines from I to M for the root syllable in the upper pane are drawn as solid lines, denoting that reliable data-points were collected for the entirety of the duration. However, the contiguous data-point was reduced to composite change-points, and the solid lines in the figure actually represent simple connection of the composite change-points.

In contrast, group (8) represents the non-sonorous interlude, between the root and suffix syllables. The Praat-nominated data-points for this region were not reliable, due to low signal-to-noise ratio. The tracks of F2 for this duration of the utterances have been drawn with dashed lines, denoting that the tracks are estimations, based upon a paucity of data-points. These lines are generated by connecting three instantaneous points in time, at which reliable readings were nominated by the Praat software: the terminus of the root, the burst release of the obstruent /k/ in the interlude (at point (9)), and the leading edge of the suffix.

The portion of the composite tracks prior to the initium of the root are also drawn with dashed lines, denoting that these pre-sonorous zones may also contain unreliable data-points or extraneous phenomena. Likewise, the final portion of the composite track for a “zero” suffix syllable type is always drawn with a dashed line, denoting that the suffix is not sonorous, and hence, the Praat-nominated data-points may be unreliable.

CHAPTER 4

OBSERVATIONS AND ANALYSIS

In this chapter, the selected syllables from the basic design will be compared quantitatively and qualitatively, based upon instrumental measurements extracted from the digital recordings of native speakers of Modern Standard Russian. The syllables will be compared, by focusing on the contiguous formants tracks, especially F2.

In the first section, the formant structure of nonsense syllables will be analyzed, to establish prototypical behavioral baselines for the various nuclei. In the second section, allophonic behavior and the impact of tonic stress on lexical items containing these nuclei will be analyzed. In the third section, the impact of suffixation on lexical items with tonic and pre-tonic nuclei will be analyzed. In subsequent sections, additional considerations for selected syllables will be observed.

4.1 The Systematic Behavior of Nonsense Syllables

In this section, the behavior of nonsense syllables will be analyzed by type. The following nuclei types will be observed with and without obstruent onset and coda:

1) Single-target nuclei.

2) Diphthongs with j-offglide.

3) Diphthongs with soft onset.

4) Triphthongs with soft onset and j-offglide.

Table 4.1 The Features of Prototypical Vowels in Modern Standard Russian. The most salient feature(s) for a vowel is shaded. The glide /j/ is included in the table, because it is the stance of this study that the onglide /j/ occupies the pre-kernel position in a bifurcated nucleus. The back jer-u is also included in the table for completeness. The vowel "V" represents a maximally underspecified vowel, applicable to a reduced kernel.

Vowel	Round	Back	High	Low	Constricted	Targets	Dynamism
j	–	–	+	–	–	(2)	(dynamic)
í	–	–	+	–	–	1	static
é	–	–	–	–	–	1	static
á	–	+	–	+	–	1	static
ó	+	+	–	–	–	1	static
ú	+	+	+	–	–	1	static
ý	–	+	+	–	+	2	dynamic
ъ	–	–	–	–	–	1	static
V	○	○	○	○	○	1	static

From comparisons of the vocalic nuclei in bare vowels syllables and in syllables of the shape pVp, the set of contrastive features for the phonemic vowels of Modern Standard Russian is listed in Table 4.1. The features, which are posited from the observed data using the current method, conform to the features established by the "Dual Consonant Tradition" (DCT) (Halle 1959: 45). The most salient feature(s) is shaded.

Thus, /a/ is readily distinguished from all other vowels in that /a/ is the only low target. As such, a moderate degree of directionality from front-to-back, or back-to-front, or additional lowering due to jaw movement does not effectively change the contrastive quality of /a/, as long as the entire sonorous portion of the syllable remains [+low].

The vowels /i e/ are primarily unrounded, and distinguished form one another based upon height. The vowels /u o/ are primarily rounded, and are also distinguished form one another based upon height. Since the feature of roundedness has a high degree of salience, /u o/ can be distinguished from /i e/, respectively, even if considerable fronting occurs (as will be encountered later in the presentation with fronted [ü ö]).

In contrast with the other vowels, /y/ is the only nucleus which is [+constricted]. This feature distinguishes /y/ from the other vowels, regardless of the exact location of its initial and terminal targets, or the amount of forward travel through vowel-space that the nucleus /y/ exhibits.

The nucleus /y/ did not conform to the behavior of monophthongal /i e a o u/, in that /y/ is not static. The nucleus /y/ did not conform to the behavior of the offglide diphthongs /ij ej aj oj uj/, in that /y/ proceeds forward on a schedule which is approximately one mora earlier than the diphthongs, and /y/ did not exhibit a voiceless coda containing /j/. The nucleus /y/ did not conform to the behavior of the onglide diphthongs /je ja jo ju/, in that /y/ travels forward in vowel-space, while the onglide diphthongs travels backwards.

However, the nucleus /y/ does conform to the targeting schedule of the onglide diphthongs, in that /y/ is usually in transition at the initium (as are the onglide diphthongs), and F2 of /y/ becomes asymptotic circa mid-syllable, in parallel with some onglide diphthongs, which may become asymptotic in F2 well before the terminus.

The triphthong /yj/ did not conform to the behavior of the symmetrical triphthongs /jej jaj joj juj/, in that /yj/ is asymmetrical. However, the triphthong /yj/ conform to the targeting schedule of the symmetrical triphthongs, in that /yj/ is in transition at the initium, /yj/ obtains the allophone of its kernel target circa mid-syllable, and /yj/ exhibits a voiceless coda containing /j/.

4.1.1 Simple Nuclei of the Shape V

The current method of analyzing contiguous formant patterns yielded results for the monophthongs of Modern Standard Russian that are consistent with *The Sound Pattern of Russian* (SPR). A comparison of the vowel-space of the five primary speakers of m-Group and p-Group and subject SPR-D[6] from SPR is displayed in Figure 4.1. Although the specific positions of phoneme targets (/i e a o u/ as bare vowel syllables) vary from speaker to speaker, the overall geometry of a speaker's vowel-space is similar for all five of the primary speakers of this research and for subject SPR-D. From speaker to speaker, the primary difference in vowel-space is the overall dimension.

Two of the five primary speakers for the current study, namely pF and mD, will serve as the main sources of examples in this presentation. Of the five primary speakers who were raised within the borders of Russia proper, speaker pF exhibited the greatest degree of consistency from token to token for any given elicited syllable type, and speaker mD exhibited the greatest degree of contrast from syllable type to syllable type (especially for effects such as suffixation), which will be pivotal to the conclusions of this research study. Except where otherwise indicated, the examples presented for speakers pF and mD are representative of the behavior exhibited by all speakers in this study.

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[6] Formant measurements for subject SPR-D were extracted from Appendix I of SPR. Of those subjects in SPR, subject D was chosen, because data for all of the phonemes of interest to this research study could be gleaned from SPR for subject D, whereas the data listed for subjects J and K of SPR presented numerous gaps, with regard to the interests of this research study.)

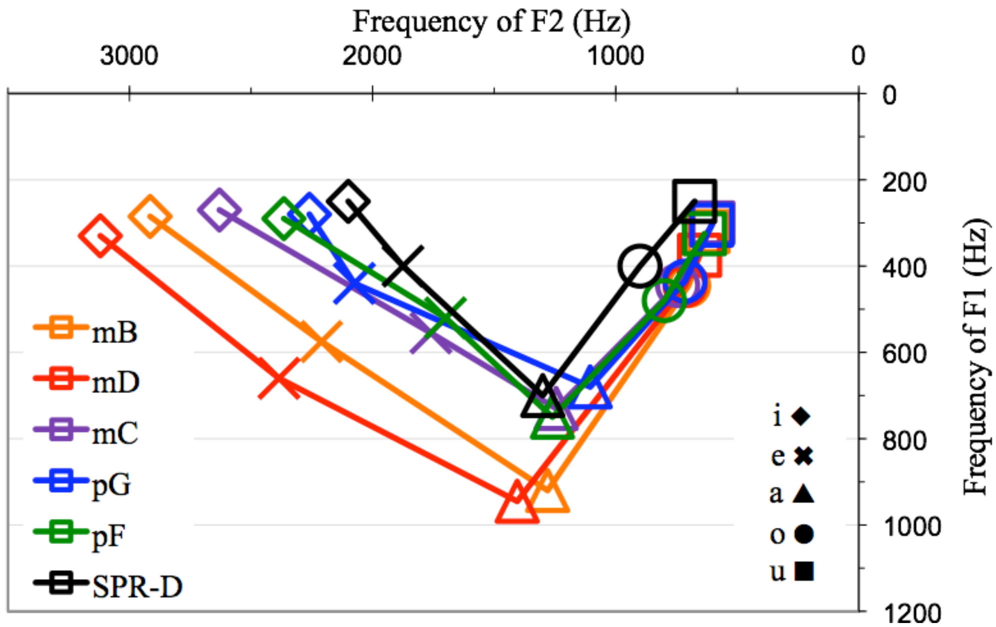


Figure 4.1 Comparison of Vowel-space for m-Group, p-Group, and Subject SPR-D. Note the two groups: the first with a more expansive vowel-space (mD and mB), and the second with a more compact vowel-space (mC, pG, pF and SPR-D).

4.1.1.1 Monophthongs as Bare Vowel Syllables

A number of recurring behaviors for the five bare vowel syllables /u o a/, e i/ are observed. These recurring behaviors include: static formant structures across the normal duration of the syllable; static positions in vowel-space associated with these formant patterns; and a lack of variability of the selected vowel targets at the initium of the syllable. Bare vowel syllables also exhibit a general lack of marginal consonantal effects, except where caused by interaction with /p/ at juncture 4 of the elicitation frame. Syllables with the obstruent /p/ as an onset and coda exhibit marginal consonantal effects, if the nuclei vowel is posited as unrounded.

All five vowels remain confined to their respective regions of vowel-space, with little or no overlap, as shown in Figure 4.2. In general, the values of F2 at the loci of the five vowels were significantly different from one another (with the exception of the contrast between /o u/, which statistically was not significantly different for some speakers). While the high and mid vowels did not exhibit systematic directionality, the low vowel /a/ exhibited directionality for some speakers, attaining its maximum low/back position circa mid-syllable, before becoming more centralized again at the terminus. The likelihood that /a/ exhibited directionality decreased as the overall dimension of vowel-space decreased, from speaker to speaker.

Consider the comparison of the behavior of /u o a e i/ as bare vowel syllables, for speakers pF and mD, in Figures 4.2&4.3 and 4.4&4.5, respectively. As shown in Figure 4.2, speaker pF performs bare vowel syllables as virtually ideal steady-state vowels, with negligible dynamism and little or no overlap in vowel-space. As shown in Figure 4.3, the system of F2 for the five vowels consists of parallel, horizontal lines across the duration of the syllable. Speaker pF also allowed sufficient pause after the performance of bare vowel syllables, so as not to produce terminal marginal effects associated with the /p/ at the resumption of the elicitation frame at juncture 4.

Multiple tokens of bare vowel syllables for speaker mD create a slightly more complicated version of vowel-space. As shown in Figure 4.5, speaker mD does maintain virtually ideal steady-state vowels for the first half (the first 150 msec) of a syllable, after which non-high vowels tend to gravitate towards a more centralized location before the terminus.

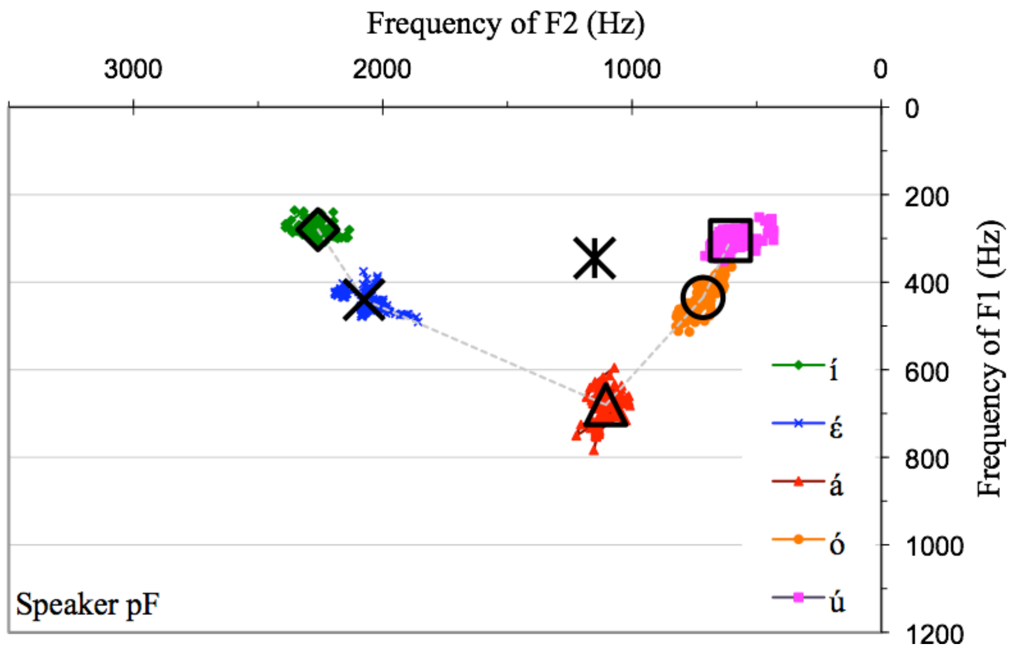


Figure 4.2 The System of Bare Vowel Syllables in Vowel-space, for Speaker pF. The locus of each phoneme is in a unique position, and the entire durations of six tokens of a particular phoneme remain clustered around their locus, with little or no overlap. The clusters did not reveal any specific directionality of movement within vowel-space.

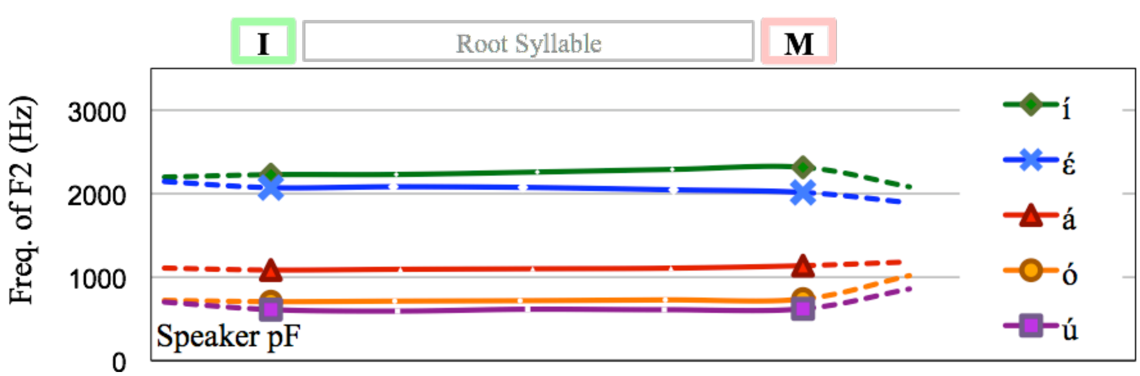


Figure 4.3 Composite F2 Tracks for Bare Vowel Syllables, for Speaker pF. Each track of F2 represents a composite of six tokens. The composites have been normalized for duration, between the initium I and the terminus M. For speaker pF, most bare vowel syllables did not gravitate towards a neutral tongue position until after the terminus.

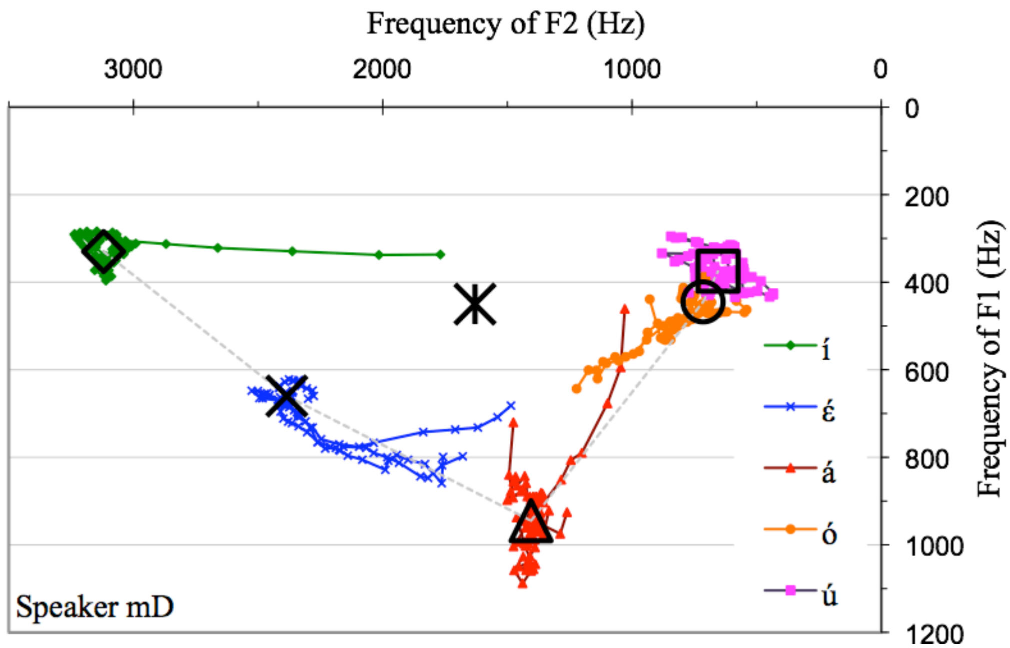


Figure 4.4 The System of Bare Vowel Syllables in Vowel-space, for Speaker mD. The locus of each phoneme is in a unique position, and the entire durations of three tokens of a particular phoneme remain clustered around their locus, with little or no overlap. Some bare vowel syllables (/e a o/) began to gravitate towards a neutral tongue position prior to the terminus. Some tokens of unrounded vowels (/i e a/) exhibit labial consonantal effects, caused by the /p/ at juncture 4 in the elicitation frame.

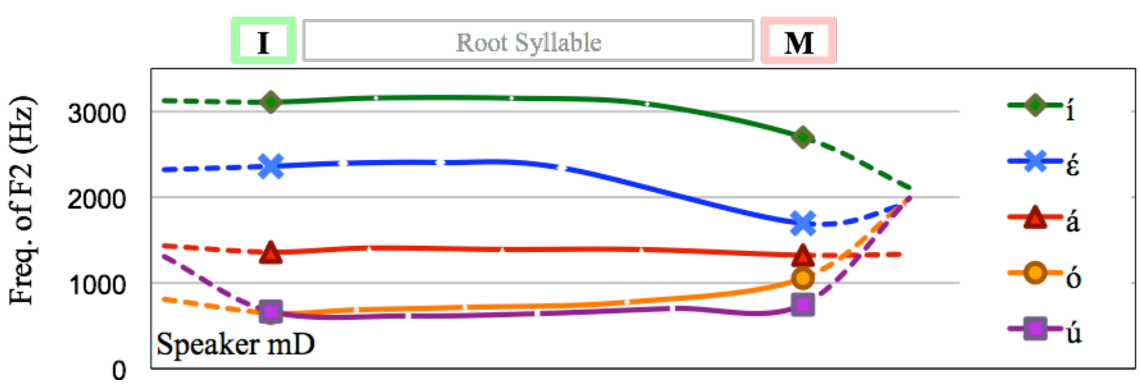


Figure 4.5 Composite F2 Tracks for Bare Vowel Syllables, for Speaker mD. Each track of F2 represents a composite of three tokens. The composites have been normalized for duration, between the initium I and the terminus M. In this figure, the first half of the syllable represents approximately 150 msec, which is the scale of a normal stressed monophthong in a closed syllable. Notice that the first half (the first 150 msec) of a syllable closely resembles an ideal steady-state vowel.

In addition, speaker mD did not provide sufficient pause before juncture 4, and the sententially-embedded tokens for unrounded vowels /i e a/ exhibited marginal labial damping at the terminus. Both effects (gravitation to centralized vowel-space, and the labial damping) are expressed as a change in F2 near the terminus.

In general, for all five primary speakers, all five vowels (/u o a e i/) behaved like single-target monophthongs, when produced as bare vowel syllables. All five vowels exhibited static formant patterns well beyond the normal duration of comparable closed.

Those tokens of bare vowel syllables, which did not exhibit static formant patterns from initium until terminus, gravitated to a more centralized, neutral tongue position, after the initial static formant pattern was maintained well beyond the normal duration of a comparable closed syllable. This gravitation towards neutral vowel-space occurred after a partial syllable break, as indicated by a decrease in the intensity contour.

For the monophthongs which exhibited little or no variability over the duration of the syllable, the entire syllable was recorded for comparison with other syllables encountered later in the research, and the averages of both F1 and F2 for all data-points over the duration of the syllables was posited as the coordinate of the prototypical locus for the vowel in vowel-space.

For the monophthongs which exhibited a discernible degree of directionality over the duration of the syllable, the entire syllable was recorded for comparison with other syllables encountered later in the research; however, the averages of both F1 and F2 for only the data-points at the mid-syllable extremum were posited as the prototypical locus for the vowel in vowel-space.

4.1.1.2 Monophthongs as Nuclei of pVp Syllables

As shown in Figure 4.7, the obstruent /p/ produced labial damping on the unrounded vowels /i e a/. There are no discernible labial damping observed with the vowels rounded /o u/. On occasion, for /o u/, the Praat software would nominate data-points for F2, which registered a decrease at the terminus, regardless of the feature of roundness for the consonant. For /o u/, these terminal effects are associated with the Praat software's inability to disambiguate waning bands of formant energy, concentrated at low frequencies, from the energy of the fundamental frequency.

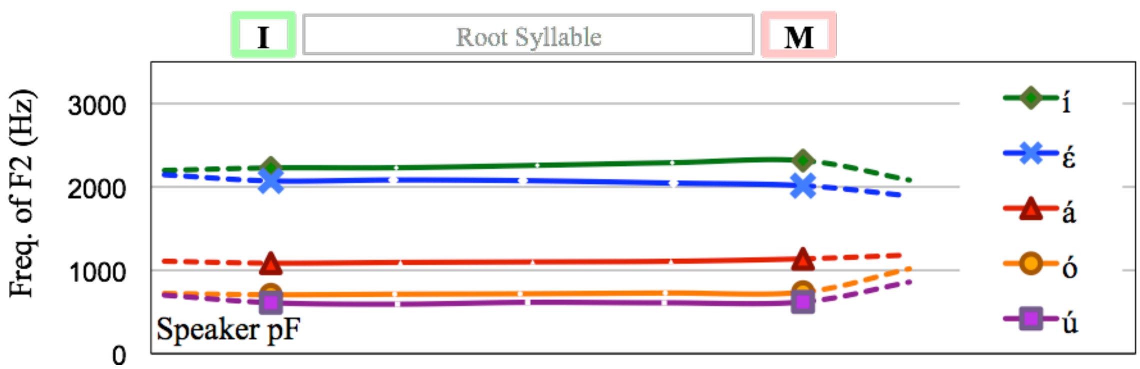


Figure 4.6 Composite F2 Tracks for Bare Vowel Syllables, for Speaker pF (4.3 revisited).

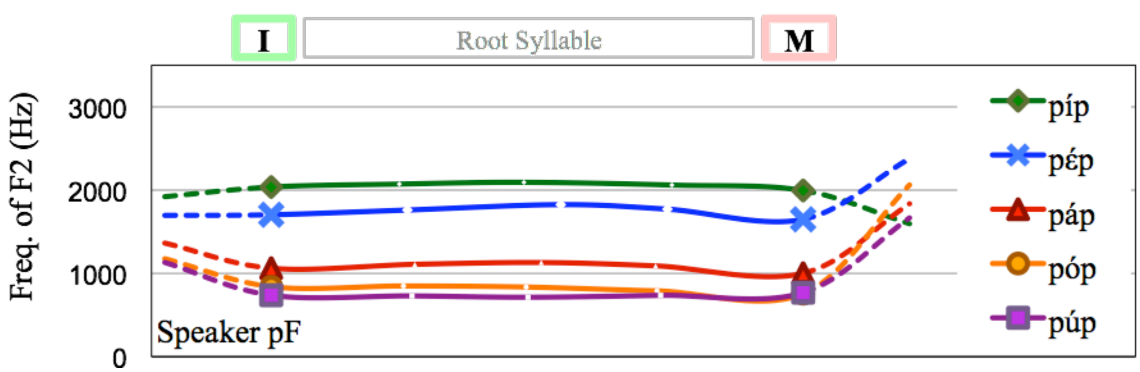


Figure 4.7 Comparison of F2 of Monophthong Nuclei of Nonsense pVp Syllables.

4.1.1.3 The Contrast between /y/ and the Monophthongs

The onsetless syllable /y/ did not behave like a single-target monophthong. The track of an onsetless syllable /y/ did not remain confined to a localized region of vowel-space, across the duration of the syllable; instead, /y/ travels from a close, central/near-back initial locus, forwards to a close, front/near-front locus, as shown in Figure 4.8.

Lexical items that contain onsetless /y/ do not occur in Modern Standard Russian, except for the syllable /y/ itself, as the name of the Cyrillic symbol <ы>. As such, the behavior of /y/ exhibited in Figure 4.9 might be considered anomalous. However, this is not the case. The behavior of onsetless /y/ exhibited in Figure 4.9 was repeated in onsetful environments, as shown in Figure 4.10.

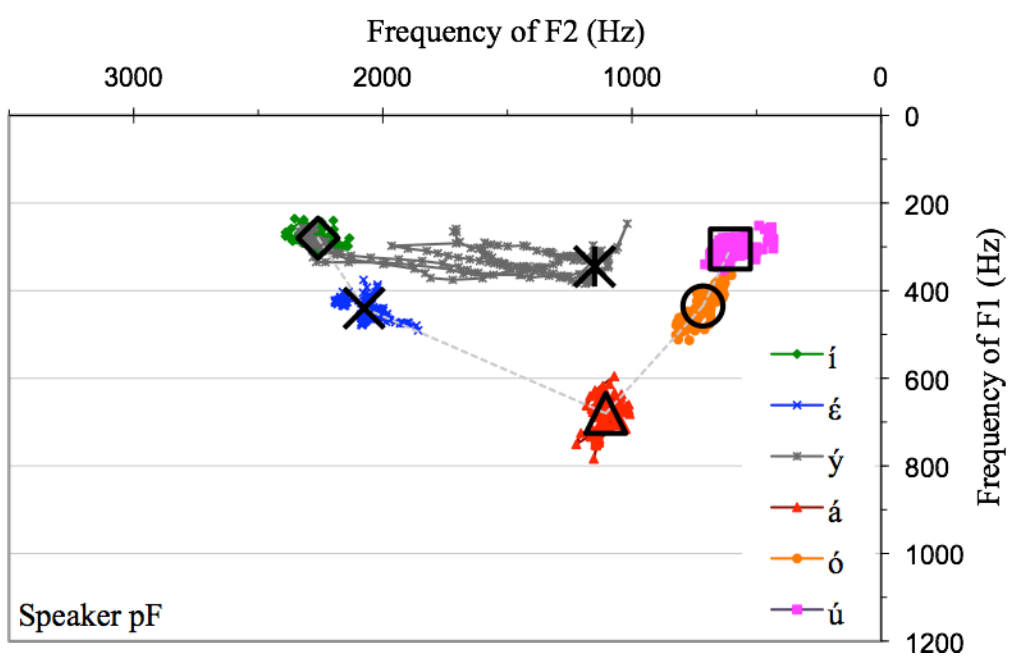


Figure 4.8 Comparison of Static Bare Vowels and the Nucleus /y/ in Vowel-space. In contrast to the static vowels, the nucleus /y/ is dynamic.

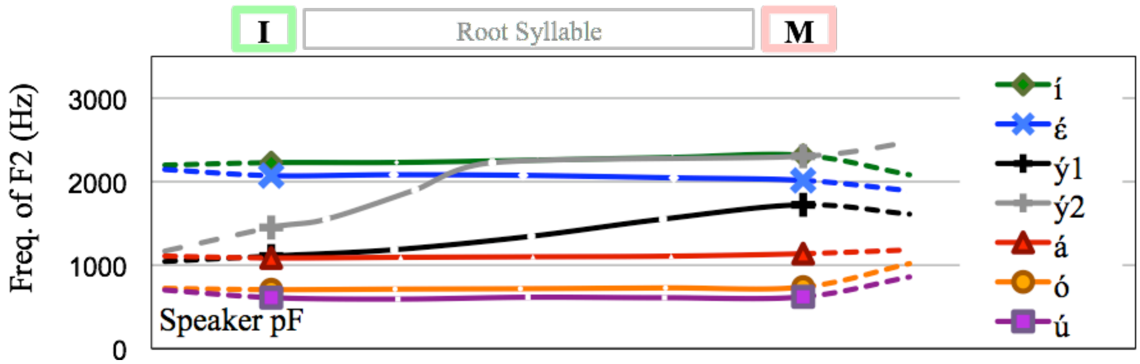


Figure 4.9 Composite F2 Tracks for Bare Vowel Syllables and /y/. The vowels of the periphery (/u o a e i/) remain static. For this speaker, the composite tracks for the three tokens of /y/ of hour 1 and of hour 2 of the recording session exhibit different schedules of dynamic movement.

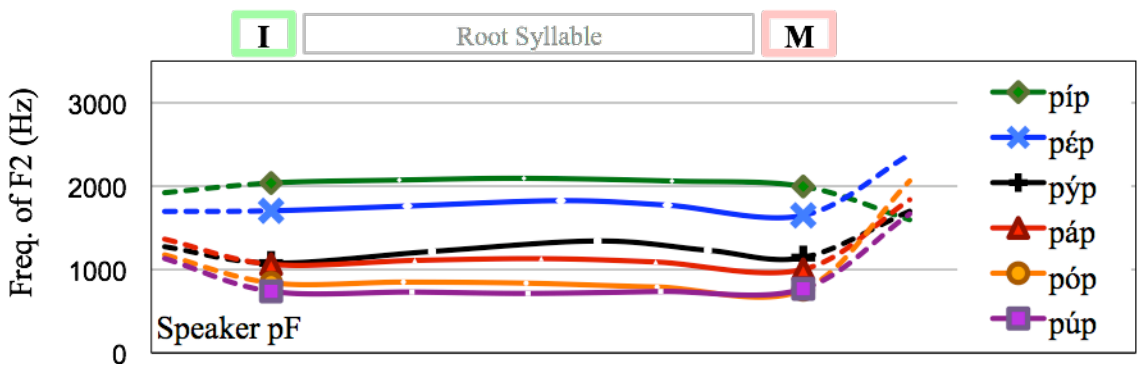


Figure 4.10 Comparison of F2 of Monophthongs and /y/ as the Nuclei of Nonsense pVp Syllables. Marginal effects to the monophthongs represent labial consonant effects. The nuclei /u o/ did not exhibit marginal labial effects.

The initial and terminal locus of the onsetless syllable /y/ varied greatly, from token to token, and from speaker to speaker, making the nucleus /y/ the least consistent nucleus observed in this research study. In Figure 4.9, the three tokens of the onsetless syllable /y/ from the first hour of recording (y1 in gray) behaved differently from the three tokens of bare vowel syllable /y/ from the second hour of recording (y2 in black).

The most unusual cases of /y/ were performed by speakers pG and kK, in which /y/ was performed as a static, doubly-articulated, two-target vowel. The close/front point of closure and close/near-back point of closure were both maintained throughout the duration of the syllable. The effect of "forward movement" was apparently achieved by minute alterations in tongue height at these two simultaneous points of closure.

At the initium, the back point of closure (at approximately 1200 Hz) received more closure than the front, and thus the back point was nominated as the prominent point of closure. By mid-syllable, prominence begins to shift, and the front point of closure (at approximately 2300 Hz) was nominated as most prominent at the terminus.

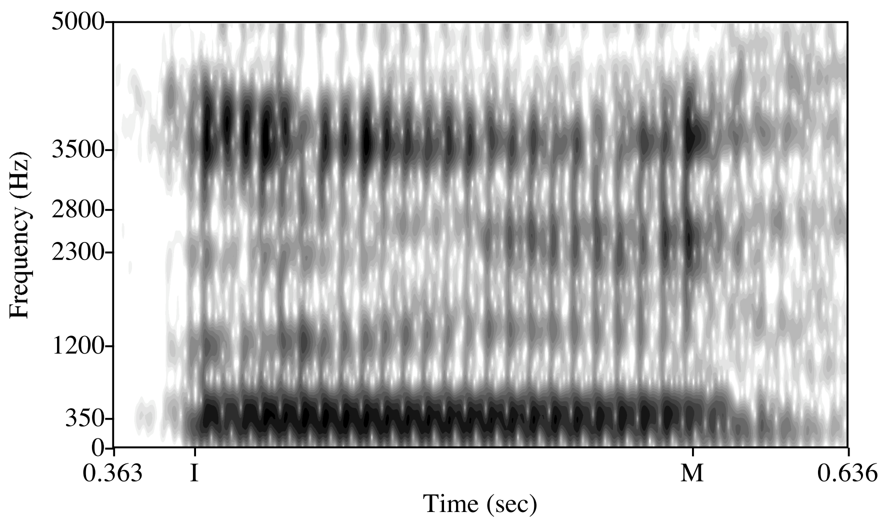


Figure 4.11 The Double Articulation of /y/, performed by Speaker pG. This spectrogram illustrates the effect of "fronting", even though virtually no forward movement has occurred, between the two prominent targets at I and M. At the initium I, the prominent F2 occurs at 1200 Hz. At the terminus M, the prominent F2 occurs at 2300 Hz. Fronting is accomplished by a shift in prominence between the two concurrent formants of F2. Prominence is likely controlled by minute adjustments in the height of the tongue tip, which is registered in F1.

4.1.2 Diphthongs of the Shape Vj

A number of recurring behaviors for the diphthongs /uj oj aj ej ij/ were observed: the transition of formant structure from the kernel target to the offglide; the coordination of obtaining the selected nuclei target and the initiation of the sonorous phonation; two zones of sonority; and consonant effects caused by interaction with the elicitation frame. In some respects, the sequence /yj/ did not conform to the behavior of the diphthongs.

4.1.2.1 Offglide Diphthongs as Intact Syllables

All four diphthongs for which the kernel targets and offglide were contrastive (i.e., /ej aj oj uj/) behaved as double-target diphthongs. In contrast, the sonorous portion of /ij/ behaved as a single-target monophthong, and exhibited a static formant pattern for its entire duration. However, the syllable /ij/ is still posited to be a structural diphthong, because of a change in sonority at the terminus, between the high front kernel [i] and the high front glide [j] of the coda.

The diphthongs beginning with back vowel targets (/aj oj uj/) exhibited static asymptotic formant patterns for approximately the first quarter of the sonorous portion of the syllable, before transitioning to the offglide target. In contrast, /ej/ never exhibited a static formant pattern during sonorous phonation, but rather, /ej/ was dynamic for the entire sonorous portion of the syllable. The entire track of F2 for /ej/ was dynamic, albeit at a shallow slope. The degree to which /ej/ is dynamic was more discernible in F1, which was also dynamic for the entire sonorous portion of the syllable.

The initial loci of diphthongs beginning with back vowel targets were reliably on-target with their prototypical bare vowel counterparts. Conversely, the initial loci of diphthongs beginning with front vowel targets were not on-target with their prototypical targets, but rather the initial target of these diphthongs originated higher than their prototypes, further forward than their prototypes, or both.

As shown in Figure 4.12, the diphthongs beginning with back vowel targets (/aj oj uj/) exhibited distinct and separate trajectories through vowel-space, with no overlap until the terminus of the diphthong, at which point all three diphthongs converged in vowel-space at the target of the offglide. The trajectory of /uj/ remained high for its entirety, and thus remained on the high periphery of vowel-space. The trajectory of /oj/ did not remain on the periphery, but travels through the middle of vowel-space. The trajectory of /aj/ remained on the lower periphery of vowel-space, passing sequentially through the allophonic loci of [æ], [ɛ], [e], until [i].

The trajectory of /ej/ was not usually disparate from that of /aj/; instead, the trajectory of /ej/ was often a short trajectory, sharing the same path through vowel-space as the final sub-portion of the trajectory of /aj/. In the same way, the "trajectory" of /ij/ was essentially a fixed point, and hence, shared a "stationary path" with the endpoint of all trajectories that terminated in the j-offglide.

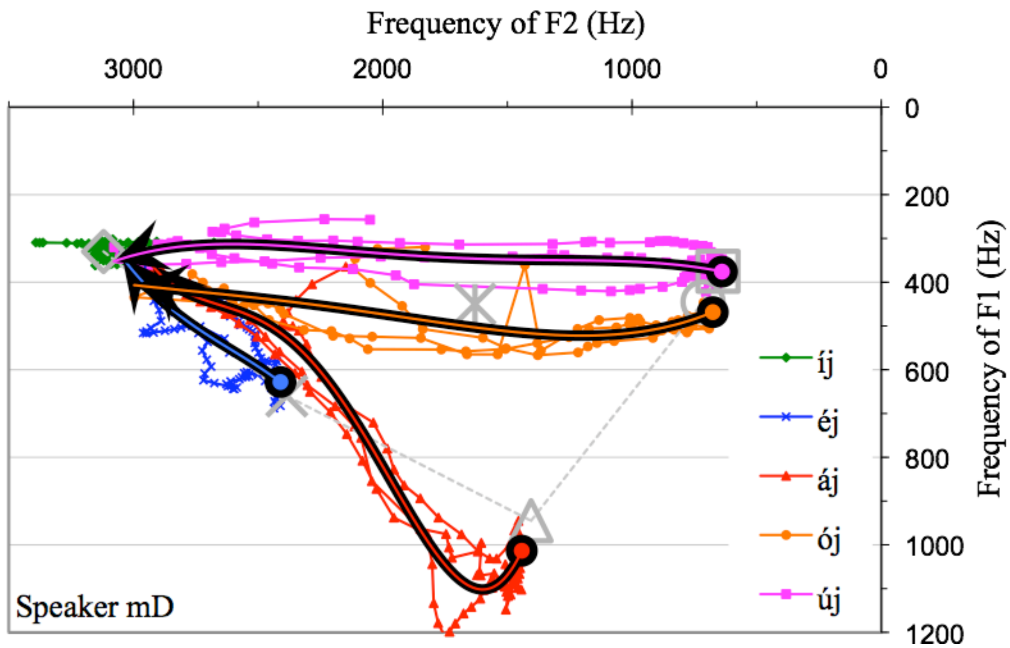


Figure 4.12 Comparison of Trajectories Through Vowel-space for Offglide Diphthongs. The trajectories for /uj oj aj/ begin at their respective back vowel loci, and travel forwards to the locus of [i]. The trajectory of /ej/ is not distinct from a sub-path of the trajectory of /aj/. The "trajectory" of the sonorous portion of /ij/ is static at the locus of [i].

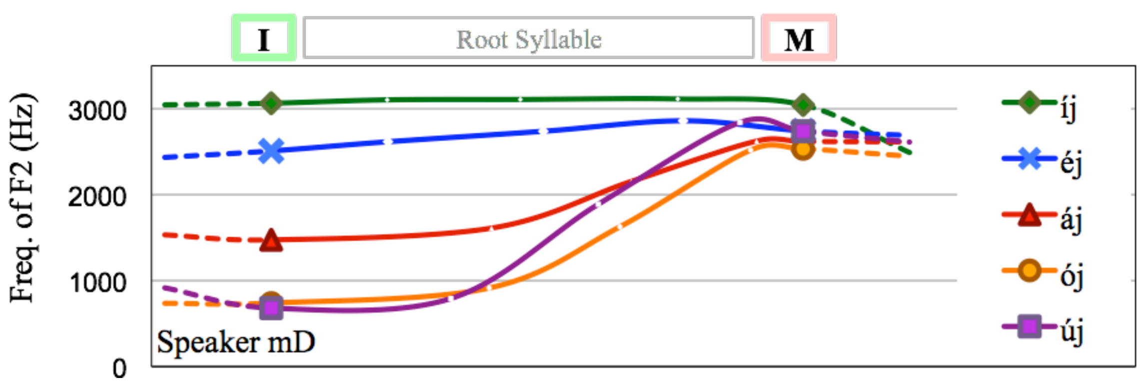


Figure 4.13 Comparison of F2 Tracks of Offglide Diphthongs as Vocalic Syllables. The tracks of /aj oj uj/ are asymptotic at the initium, are on-target with their respective prototypical loci, and become asymptotic to a second target (in the vicinity of the offglide) circa the terminus; however, the further back the initial target is, the less likely that the target of the offglide will be fully obtained. The sonorous portion of /ij/ behaves as a steady-state vowel, and hence, it is static at both the initium and the terminus. The diphthong /ej/ is not asymptotic at the initium; however, the rate of change of F2 is slight. (The dynamism of /ej/ at the initium is strongly exhibited on F1, which is not shown).

All five diphthongs exhibited two zones of sonority: a zone of sonorous phonation, followed by a zone voiceless frication. Although /ij/ had uniformly static formant structure, it also exhibited these two zones of sonority, and therefore, /ij/ will be classified as a double-target diphthong, since the two targets were contrastive for sonority, but not for point of articulation.

In most cases, the majority of final asymptotic plateaus of the offglide occurred after the terminus, and was contained in the post-vocalic zone of voiceless frication. In some cases, this post-vocalic zone was omitted for the sententially-embedded tokens. It was common for speakers of the m-Group to omit the post-vocalic zone for these embedded tokens, but it was uncommon for the p-Group speakers to do so.

All five diphthongs terminated in high front offglide, which is unrounded. As such, all diphthongs exhibited labial damping prior to the phrase {po russki} ‘in Russian” at juncture 4 of the elicitation frame. If sufficient pause was not afforded before the resumption of the elicitation frame, the labial damping was registered on the final zone of the embedded token. The final zone of the syllable was either the sonorous portion of the syllable (if the voiceless frication was omitted), the voiceless frication of the coda, or the word-final schwa (when the diphthong was performed as a disyllabic sequence [ij.jə] by speaker pF). Since the speakers of m-Group were most likely to omit the voiceless coda of the embedded token, the speakers of m-Group were most likely to register the labial damping on the sonorous portion of the syllable.

4.1.2.2 Offglide Diphthongs as Nuclei of pVjp Syllables

The obstruent /p/ was expected to produce labial damping at the initium of the unrounded vowels of /ij ej aj/. Yet, evidence of initial labial effects on /ej aj/ was not strikingly apparent in the data, since the labial effects would be registered as a damping of the formant frequencies towards the exterior of the syllable. At the initium, this would normally be seen as an increase in formant frequencies towards the interior (forwards in time). However, the overall nature of F2 for the offglide diphthongal syllables is to increase over time. As such, considering F2 alone, it was not obvious that the diphthongs /ej aj/ have initial labial damping, since the entire track of F2 was already increasing.

However, a difference between onsetless /ej aj/ and the respective diphthongs with /p/ onset was apparent. In Figure 4.15, the diphthong in /pejp/ began at a lower value of F2, than did the onsetless diphthong /ej/ in Figure 4.14. Also, the diphthong in /pajp/ did not begin with asymptotic behavior, as the onsetless diphthong /aj/ did in Figure 4.14. The lower value of F2 at the initium and the replacement of the initial asymptotic plateau with an initial incline might suggest that the expected labial damping at the initium was being registered in /pejp pajp/.

However, labial damping was not expected to be registered at the initium of /pojp pujp/, since the nuclei vowels of these syllables is rounded. Yet, the same shortening of the initial asymptotic plateau in F2 (as in /pajp/) was also registered on /pojp pujp/. It is possible that the initial asymptotic behavior of the syllables /aj oj uj/ was an artifact of either their being onsetless syllables or being nonsense syllables.

Although the terminal labial damping was registered only on the sententially-embedded tokens in Figure 4.14 by speakers of m-Group, the terminal labial damping was registered on all tokens by all speakers, when the diphthongs contained the obstruent /p/ in the coda, as in Figure 4.15.

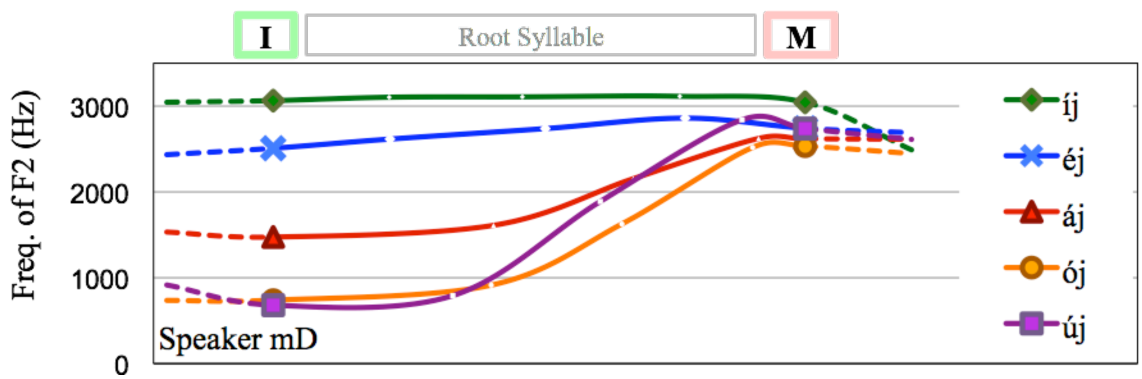


Figure 4.14 Comparison of F2 of Offglide Diphthongs as Vocalic Syllables (4.13 revisited).

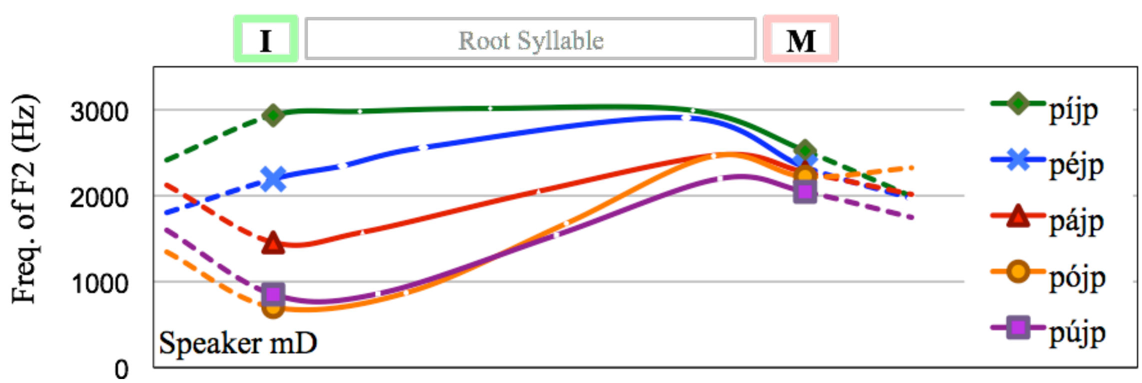


Figure 4.15 Comparison of F2 of Offglide Diphthongs as the Nuclei of Nonsense pVjp Syllables. The tracks of diphthongs with obstuent onsets were less likely to sustain asymptotic behavior for any appreciable duration after the initium, than comparable onsetless diphthongs. All diphthongs with offglides exhibited terminal labial damping.

In addition to the labial damping at the terminus for pVjp syllables, the degree to which the target of the offglide was attained prior to the terminus, as exemplified by Figure 4.15, is representative of all speakers. The degree to which the target of /j/ was attained appears to be conditioned by the diphthong's nucleic vowel.

In /pojp pujp/, it is possible that the labial rounding of /o u/ was carried across the offglide, into the labial /p/ in the final coda position. As such, the failure of F2 of these tokens to obtain the prototypical value of the offglide could be viewed as a result of labial damping. However, the contour of F2 for /pajp/ also failed to obtain the prototypical value for the offglide, and since the kernel vowel /a/ is unrounded, then labial damping could not have been carried from the nucleus, across the offglide, into the final obstruent. Thus, to some extent, the backness of the kernel vowel affected the degree of frontness that the offglide attained.

In the nonsense syllables depicted in Figure 4.15, there was a strong tendency for the tongue to return to a centralized position during the gesture of the final obstruent /p/ of the coda. Since the obstruent in the coda was not a lingual gesture, the offglide, which was a lingual gesture, was essentially intervocalic, between the kernel vowel of the syllable and the neutral schwa position of the tongue after the syllable. With this in consideration, and with the observation that suffixes beginning with front vowels permit the offglide to be fully obtained, it can be posited that the locus of the offglide will be fully obtained if (and only if) the offglide is part of a sequence of two successive front lingual gestures. In other words, the offglide will only be fully obtained if either the preceding vowel or the following vowel is a front vowel.

4.1.2.3 The Contrast Between /yj/ and the Offglide Diphthongs

The sequence /yj/ behaved differently from the other diphthongs in some respects. However, the difference is not readily apparent when the sequences are viewed in vowel-space, since all of the sequences appear to travel from their kernel targets, forward towards the locus of the offglide, as shown in Figure 4.16.

For diphthongs /uj oj aj/, F2 was likely to be asymptotic at the locus of kernel vowel for the first quarter syllable, and asymptotic at the high front offglide for the last quarter. In contrast, the sequence /yj/ was seldom asymptotic at the initium, and more likely to become asymptotic to the offglide as early as mid-syllable, as shown in Figure 4.17. As such, the sequence /yj/ was judged to be a triphthong, consisting of a pre-kernel near [ɨ], a kernel at [i], and a voiceless approximant /j/ in the coda.

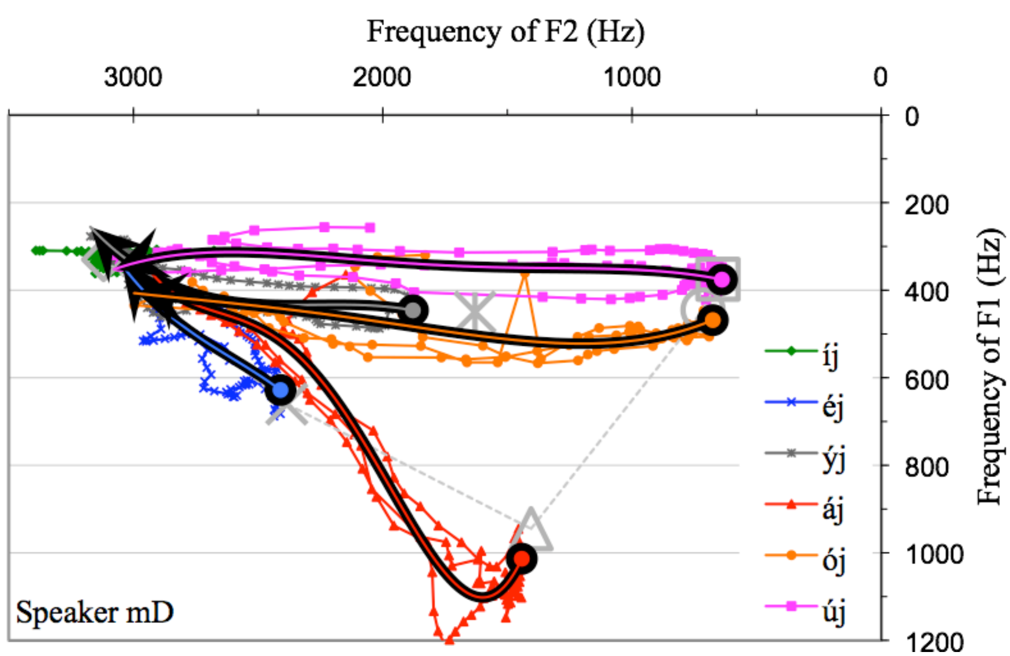


Figure 4.16 Comparison of Offglide Diphthongs vs. /yj/, in Vowel-space. All sequences begin at their initial targets and travel forwards to the locus of the offglide /j/.

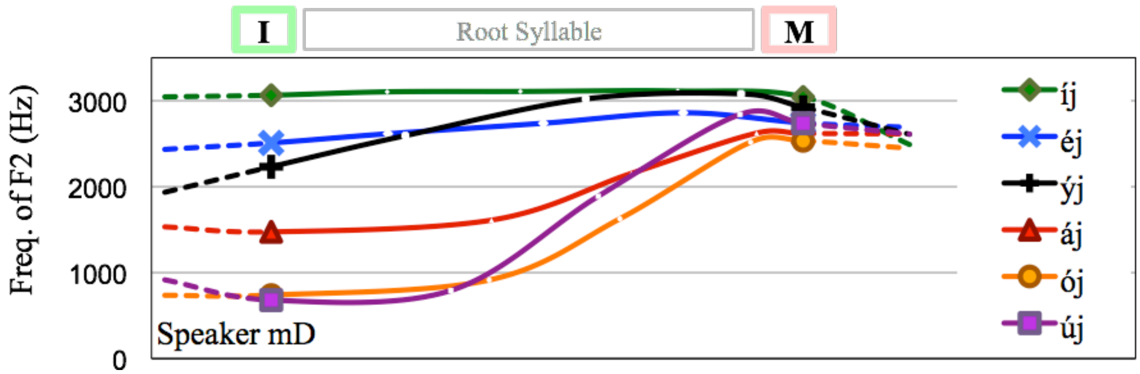


Figure 4.17 Comparison of F2 for Offglide Diphthongs vs. /yj/. The scheduling of asymptotic and transitional behavior for /yj/ appears to be a quarter-syllable earlier than the diphthongs /uj oj aj/. Each track represents a composite of three tokens for speaker mD.

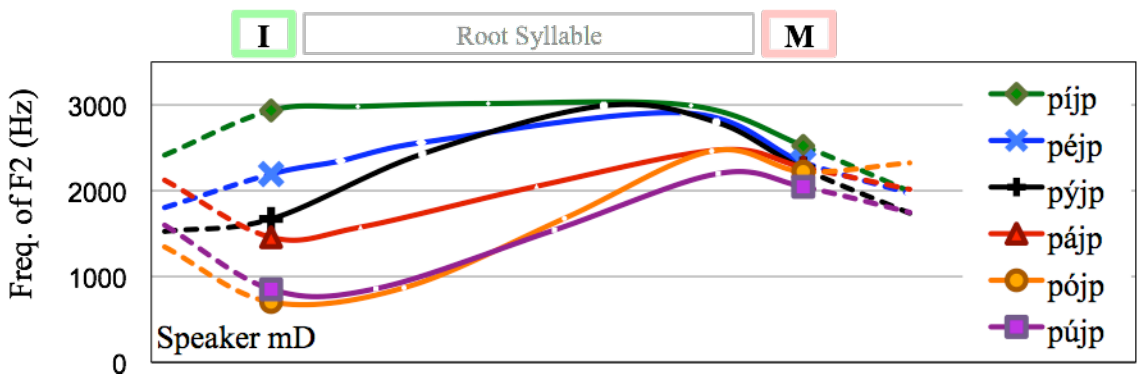


Figure 4.18 Comparison of F2 for Offglide Diphthongs vs. /yj/, in pVjp Syllables. The scheduling of asymptotic and transitional behavior for /yj/ appears to be a quarter-syllable earlier than the diphthongs /uj oj aj/. Each track represents a composite of six tokens for speaker mD.

Lexical items which begin with /yj/ do not exist either. As such, the behavior of /yj/ exhibited in Figure 4.17 might seem be anomalous. However, this is not the case. The behavior of onsetless /yj/ exhibited in Figure 4.17 is repeated in onsetful environments, as shown in Figure 4.18 and with the lexical item бык /byk/ 'bull.'

4.1.2.4 A Discontinuity in Formant Tracks with Offglide Diphthongs

An unexpected phenomenon occurred with some offglide diphthongs. Some diphthongs performed by speakers mC, pF and pG did not exhibit smooth gradual transitions forwards; rather, they exhibited abrupt jumps forward in vowel-space of approximately 500-800 Hz in F2, circa mid-syllable, as shown in Figure 4.19. In contrast, for speakers mB and mD, all offglide diphthongs exhibited the anticipated behavior of smooth gradual transitions from the kernel target to the high front offglide, as shown in Figure 4.20.

This discontinuity was judged to be a variant of the expected smooth, gradual transition, which was exhibited regularly by speakers mB and mD. All instances of this type of discontinuity can be viewed as an abbreviated sigmoid curve, which is asymptotic both on the left and on the right. From either direction, as the curve approaches the center, the tracks begin the normal S-curve towards the central point of inflexion. However, the centermost portion of the S-curve, including the point of inflexion, is missing, and the right half of the sigmoid curve is concatenated immediately onto the left.

This discontinuity was judged to be categorically different from the doubly-articulated /y/ exhibited by speakers pG and kK. In instances involving the doubly-articulated /y/, the separate formant tracks of F2 for the back target and the front target generally did not exhibit any appreciable curvature in F2, which would be associated with a sigmoid function, which in turn would indicate movement towards a more centralized, intermediate tongue position. Instead, the shift of prominence from the back target to the front target of /y/ was registered primarily in the formant F1.

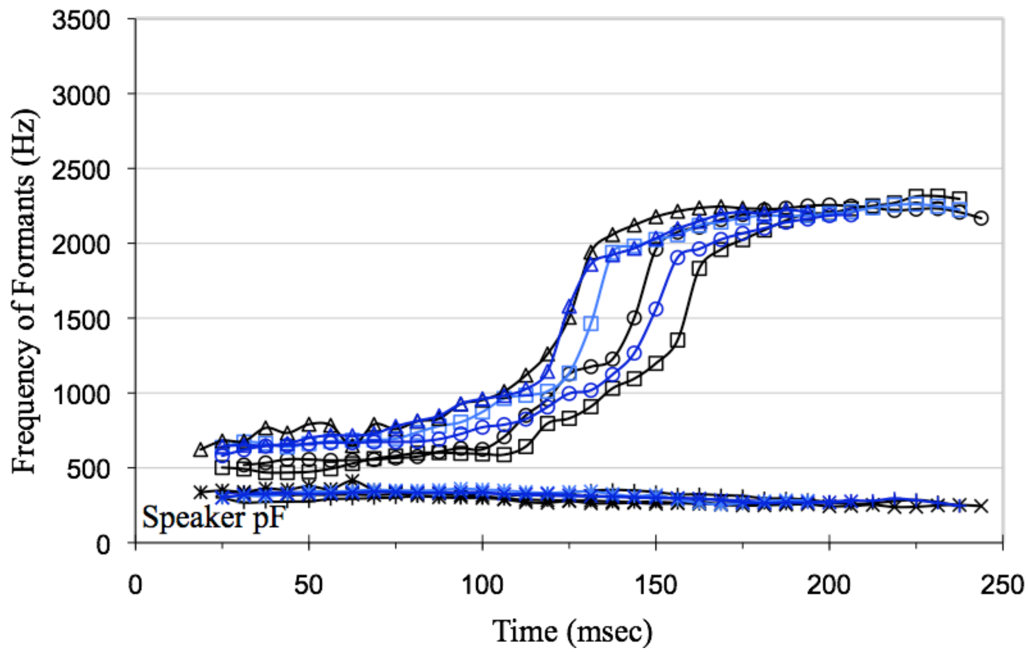


Figure 4.19 Six Tokens of the Syllable /uj/, for Speaker pF. All tokens exhibit an abrupt up-step of approximately 500-800 Hz in F2, at mid-syllable.

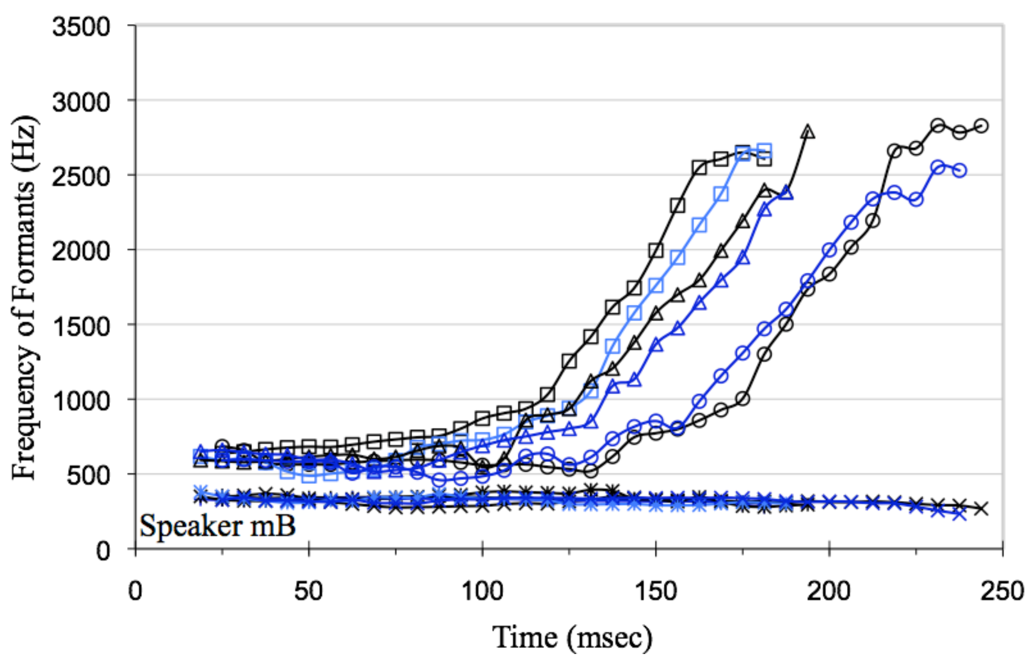


Figure 4.20 Six Tokens of the Syllable /uj/, for Speaker mB. All tokens exhibit a smooth, gradual transition in F2, from /u/ to /j/.

The occurrence of this type of sigmoid discontinuity was predictable, based upon the overall dimensions of a speaker's vowel-space. Speakers with more limited vowel-space were more likely to exhibit an abrupt up-step in F2 at mid-syllable, during the transition from a back kernel target to the high front offglide, as shown in Table 4.2 (which is organized by the overall dimension of the speaker's vowel-space). Also, the higher the back vowel was, the more likely that the up-step will occur.

It was judged that all speakers were performing the offglide diphthongs in the same manner. However, for speakers with more limited vowel-space, as the tongue moved forward, the tongue blade would create a closure in the front of the oral cavity which qualified as a point of closure, before the tongue body had fully departed from the back of the oral cavity, disengaging the initial point of closure. Circa mid-syllable, the Praat software would abruptly abandon the track leading away from the initial target, in favor of the waxing prominence of the track leading into the terminal target.

Table 4.2 Abrupt Up-step in F2 during Transition from Back Target to Front Target. Speakers with broader vowel-spaces are more likely to perform a full smooth, gradual transition. Also, diphthongs involving lower first targets are more likely to be performed with a full smooth, gradual transition.

Diphthong / Speaker	F2 (Hz)	F1 (Hz)	/ij/	/ej/	/aj/	/yj/	/oj/	/uj/
pF	2260	680					yes	yes
pG	2365	750				yes	yes	yes
mC	2630	730			yes			yes
mD	3120	945						
mB	2915	920						

4.1.2.5 Targeting and Scheduling Behavior of Offglide Diphthongs

Back vowels were more likely to be reliably on-target (with regard to the prototypical loci of the kernel vowels), as shown in Table 4.3, and were more likely to be asymptotic at the initium of an offglide diphthong, as shown in Table 4.4. Front vowels were likely to initiate at a locus which was higher and/or further forward than the prototypical target. The diphthong /ij/ was asymptotic initially by default, since the loci of the kernel and the offglide were not contrastive in terms of point of articulation.

Table 4.3. On-target Behavior of F2 for the Initial Target of Offglide Diphthongs. Back vowels are more likely to be on-target at the initial target of the diphthong than front vowels. The diphthongs /ej ij/ are often likely to originate at a location that is higher and/or further forward than the prototypical locus of their kernel targets.

Diphthong / Speaker	F2 (Hz)	F1 (Hz)	/ij/	/ej/	/aj/	/yj/	/oj/	/uj/
pF	2260	680	on	on	on		on	on
pG	2365	750	off	off	on	on	on	on
mC	2630	730	off	off	on		on	on
mD	3120	945	off	off	on	on	on	on
mB	2915	920	off	off	on	on	on	on

Table 4.4. Asymptotic Behavior of F2 for the Initial Target of Offglide Diphthongs. Diphthongs with kernel back vowels are asymptotic at the initium. The diphthong /ej/ is already in transition at the initium. The diphthongs /ij/ is always “asymptotic” by default.

Speaker	F2 (Hz)	F1 (Hz)	/ij/	/ej/	/aj/	/yj/	/oj/	/uj/
pF	2260	680	+	–	+	–	+	+
pG	2365	750	+	–	+	+	+	+
mC	2630	730	+	–	+	+	+	+
mD	3120	945	+	–	+	–	+	+
mB	2915	920	+	–	+	+	+	+
Asymptote abandoned:	“–” before the initium			“0” circa the initium		“+” after the initium		

The high nuclei of /i y u/ were more likely to obtain the high front offglide asymptote before the terminus, as shown in Table 4.5. For the back kernel targets /a o/, the speakers with more limited vowel-space were more likely to obtain the offglide asymptote before the terminus. For all five primary speakers, the diphthong /ej/ was never static during the sonorous portion of the syllable. The diphthong /ej/ was already in transition at the initium, and continued forward and upward until the terminus. In the time domain, the slope of F2 for the diphthong /ej/ was often extremely shallow. If the loci of /i e/ were similar in F2, then for any given speaker, the continuous transition of /ej/ was more evident in F1.

Table 4.5 Timing of Offglide Asymptote with Regard to Terminus. The diphthong /ej/ did not become asymptotic before the terminus. The diphthong /ij/ is usually performed in two portions: sonorous nucleus and voiceless coda. The feature specifications of the two portions are non-contrastive, and the vowel is static. Therefore, the diphthong /ij/ is "asymptotic" from beginning to end by default.

Speaker	F2 (Hz)	F1 (Hz)	/ij/	/ej/	/aj/	/yj/	/oj/	/uj/
pF	2260	680	–	+	–	–	–	–
pG	2365	750	–	+	–	–	–	–
mC	2630	730	–	+	–	–	0	–
mD	3120	945	–	+	+	–	+	–
mB	2915	920	–	+	0	–	+	+
Asymptote obtained:	"–" before the terminus			"0" circa the terminus		"+" after the terminus		

4.1.3 Onglide Diphthongs of the Shape jV

A number of recurring behaviors for the diphthongs /ju jo ja je/ were observed: the consistency to obtain the locus of the onglide prior to sonorous phonation; the transition of formant structure from onglide to the kernel target; the failure to obtain the target of the kernel vowel completely; and two zones of contrastive sonority.

4.1.3.1 Onglide Diphthongs as Intact Syllables

All four diphthongs /je ja jo ju/ behaved like double-target diphthongs. As intact syllables, all four diphthongs exhibited a zone of voiceless (or minimally voiced) frication, prior to the initium of sonorous phonation of the syllable. This zone of frication was maintained as a static position in vowel-space, which was equivalent to [i].

As shown in Figure 4.22, the diphthong /je/ often exhibited sustained asymptotic behavior in F2 into the interior of the syllables, after the initium. At the same time, the diphthong /je/ seldom exhibited asymptotic behavior associated with the kernel target, prior to the terminus. In contrast, the remaining diphthongs /ja jo ju/ were less likely to maintain initial asymptotic behavior associated with the onglide, beyond the initium of the syllable. Diphthongs with back vowel kernels often exhibited asymptotic behavior associated roughly with their prototypical targets, prior to the terminus.

The diphthong /je/ usually obtained the locus of its kernel target, and often overshot the locus, continuing backwards and downwards towards /a/. In contrast, the remaining diphthongs /ja jo ju/ usually failed to obtain the loci of their kernel vowels fully, and tended to terminate approximately 200-300 Hz forward of their respective loci, as shown in Figure 4.21.

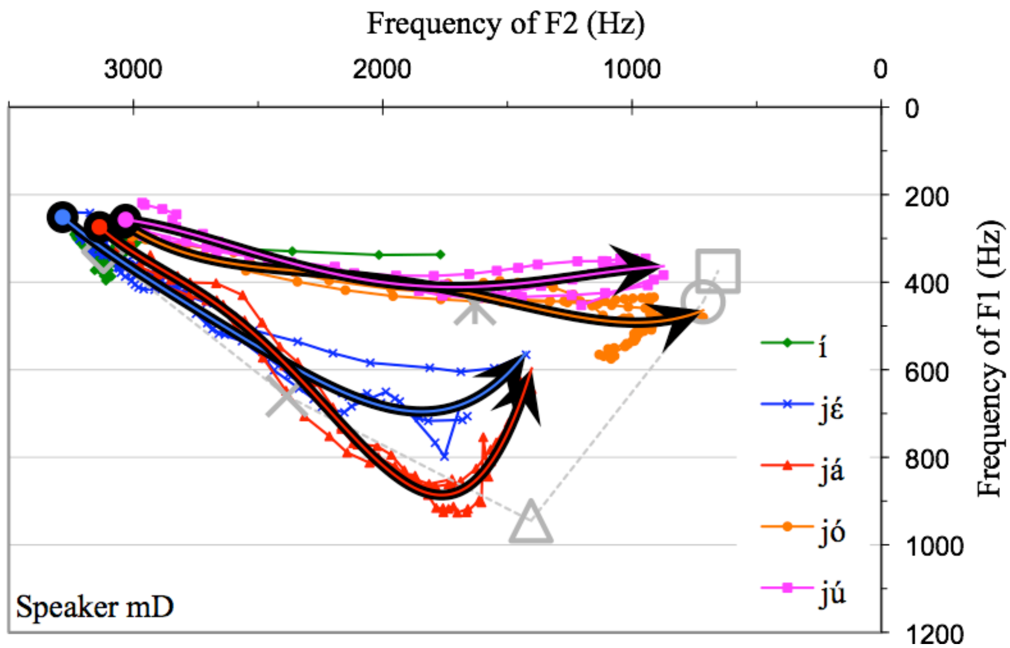


Figure 4.21 Comparison of Onglide Diphthongs in Vowel-space. All sequences begin at the locus of the onglide /j/ and travel towards their kernel targets. The sharp turn of /je ja/ towards central vowel-space is jointly a result of the merger of F1 with F0 at the terminus, and labial damping from the tokens interacting with /p/ at juncture 4 of the elicitation frame. The syllable /i/ is included for comparison of the initial target.

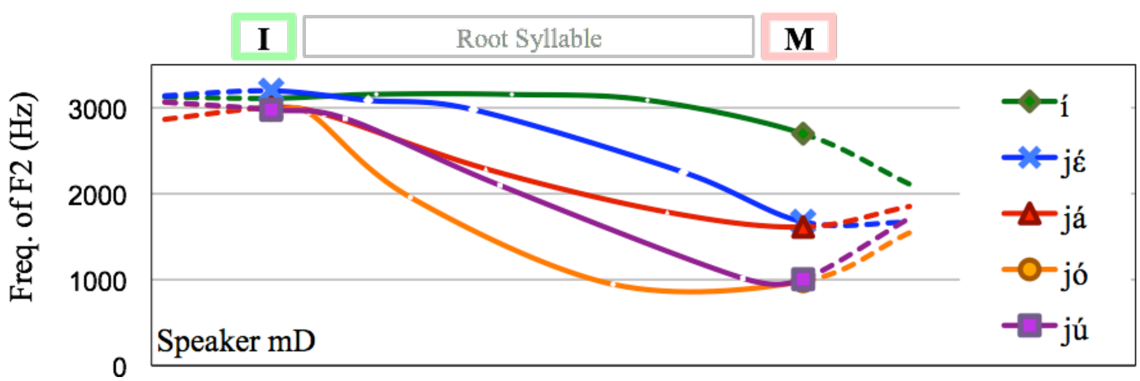


Figure 4.22 Comparison of F2 of Onglide Diphthongs as Vocalic Syllables. Diphthongs terminating in front vowels were more likely to sustain asymptotic behavior at the initium than those terminating in back vowels. The diphthongs typically did not become asymptotic until after the terminus. In most cases, the track of F2 for back vowels failed to obtain the prototypical target of the kernel vowel, and sonorous phonation terminated forward of the prototypical locus by approximately 200-300 Hz.

4.1.3.2 Onglide Diphthongs as Nuclei of pjVp Syllables

Since the obstruent /p/ does not directly involve the tongue as an articulator, soft onsets with /p/ include both a labial component and an independent lingual component. The lingual gesture for the soft labial onset of a syllable of the shape pjV is equivalent to the onglide of an otherwise onsetless syllable of the shape jV. Thus, it was expected that a contrast would be observed between the formant tracks of syllables pjV, which experience labial damping, and syllables jV, which do not experience labial damping.

Comparing Figures 4.23 and 4.24, this contrast was evident. In Figure 4.23, the syllables with only an onglide initiated consistently at a locus equivalent to /i/. In contrast, in Figure 4.24, the syllables of shape pjVp with a labial damping at the onset exhibited behavior at the initium which was not consistent with one another, nor was it always equivalent to the locus of /i/.

The diversity at the initium of syllable types depicted in Figure 4.24 occurred for a number (or combination) of reasons:

1) The loci of the initial tongue position for the pre-kernel onglide for the various syllable types were relatively contrastive; or

2) The loci of the initial tongue position for the pre-kernel onglide for the various syllable types were equivalent (and on-target to /i/), but they were on-target only during the pre-sonorous onset, and the tracks were already in transition, at the initium. Since the formant tracks for the various diphthongs followed different pathways, once the tracks had abandoned any original asymptotic plateau, any data-point taken from a particular pathway should no longer be equivalent with that of another pathway.

3) Since the labial obstruent imparts labial damping, those diphthongs with rounded kernel targets maintained the labial effect across the duration of the onglide, and hence the lowered value of F2 for these diphthongs was a result of (continued) labial effects across the onglide.

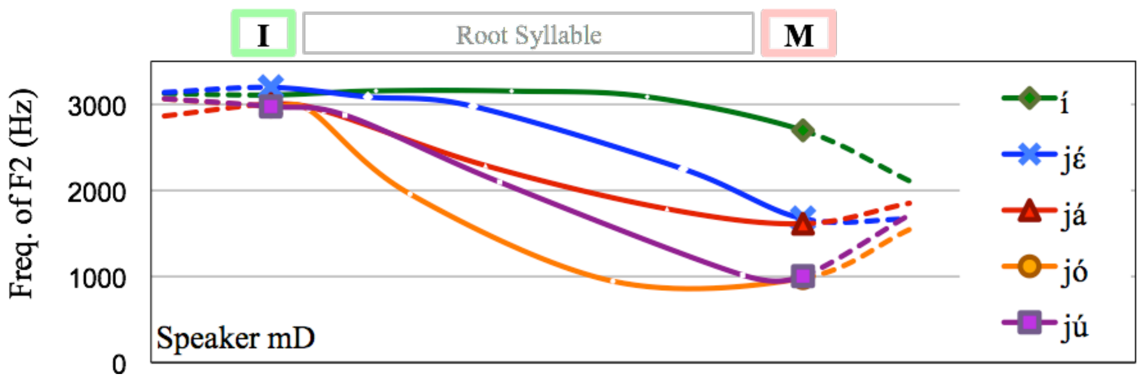


Figure 4.23 Comparison of F2 of Onglide Diphthongs as Vocalic Syllables (4.22 revisited).

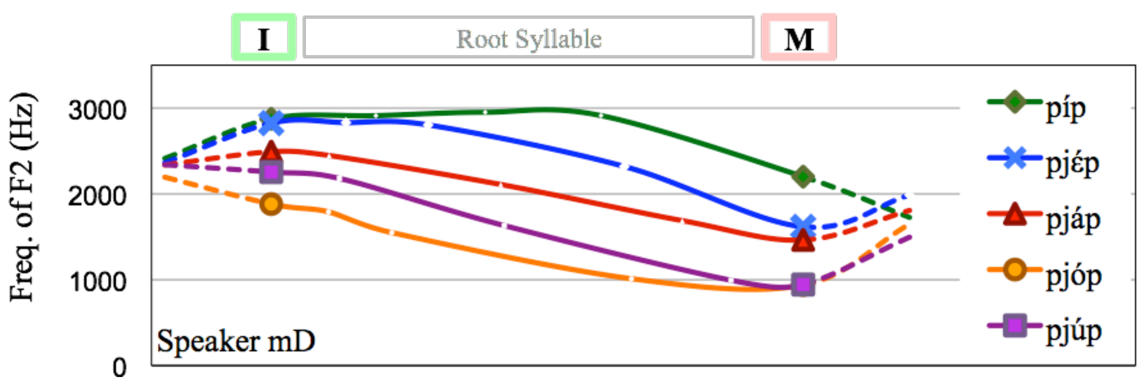


Figure 4.24 Comparison of F2 of Onglide Diphthongs as the Nucleus of Nonsense pjVp Syllables. The value of F2 at the initium is considerably less for back vowels, than for front vowels. Onglide diphthongs in closed pjVp syllables are less likely to become asymptotic before the terminus, than comparable codaless jV syllables.

4.1.3.3 The Contrast Between /y/ and the Onglide Diphthongs

Although the nucleus /y/ was not expected to pattern with the onglide diphthongs, in the interest of thoroughness and the ongoing pursuit to place /y/ in the system of other nuclei, /y/ will now be compared and contrasted with the onglide diphthongs.

In the most obvious sense, the nucleus /y/ behaved differently from the onglide diphthongs in that it traveled forwards in vowel-space towards a terminal locus at /i/; conversely, the onglide diphthongs traveled backwards in vowel-space, away from initial locus at /i/, as shown in Figure 4.25. As such, /y/ did not conform to the behavior of the onglide diphthongs.

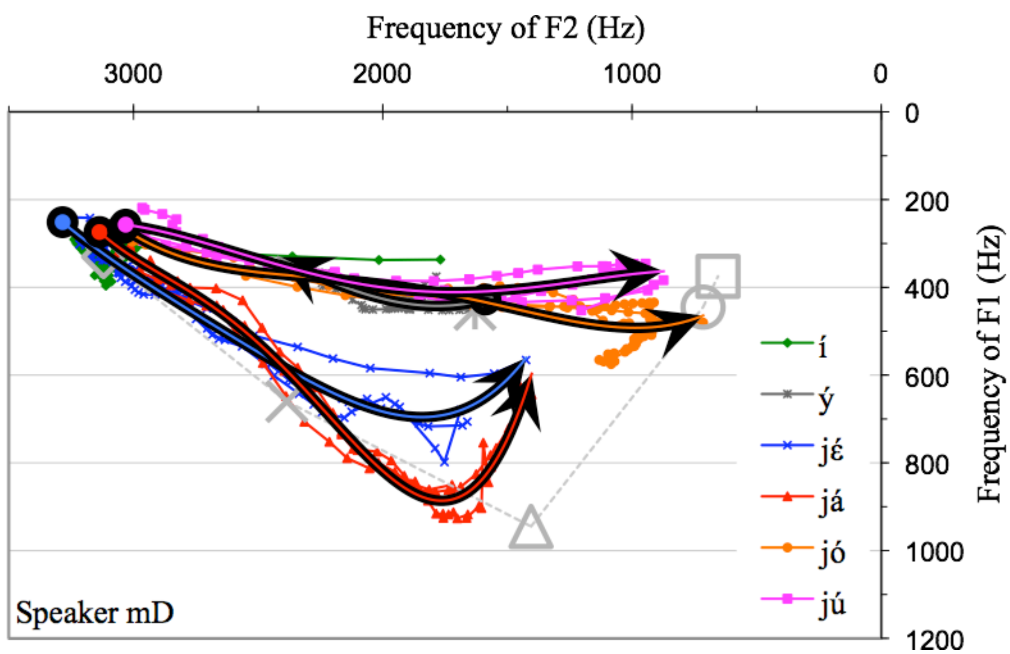


Figure 4.25 Comparison of Onglide Diphthongs vs. /y/, in Vowel-space. While all /j/-onglide diphthongs begin at [i] and travel backwards toward their contrastive kernel targets, /y/ begins at a high, centralized locus and travels forwards towards [i]. (The pathway for /y/ is obscured by the paths of /jo ju/; however, the origin of /y/ (at 1600 Hz) and the terminus of /y/ (at 2400 Hz) are visible.)

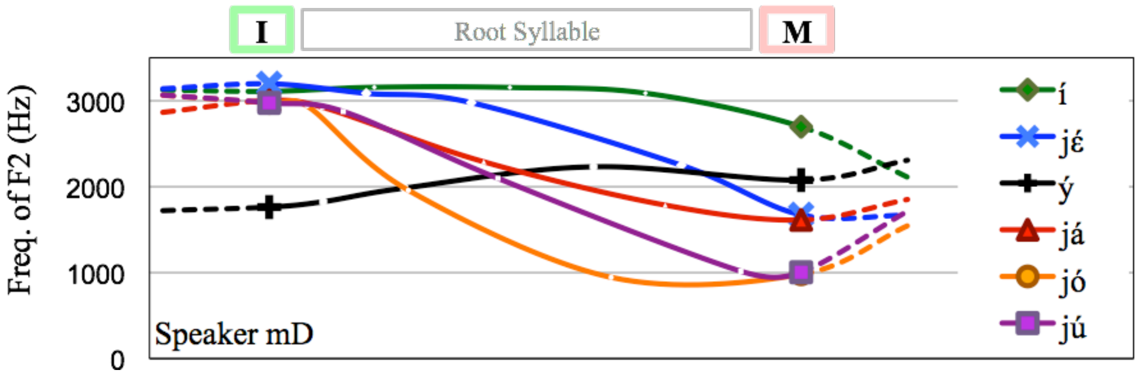


Figure 4.26 Contrast of F2 of OnglideDiphthongs and /y/ as Vocalic Syllables. The element /y/ did not conform to the behavior of syllables with an onglide. The value of F2 for /y/ increases over time, whereas the value of F2 for the onglide diphthongs decreases over time. However, the scheduling structure of /y/ is parallel to that of /aj/ or /oj/, in that they are all in transition at the initium and continue transition for the first two-thirds of the syllable, then they become asymptotic for the final third of the syllable.

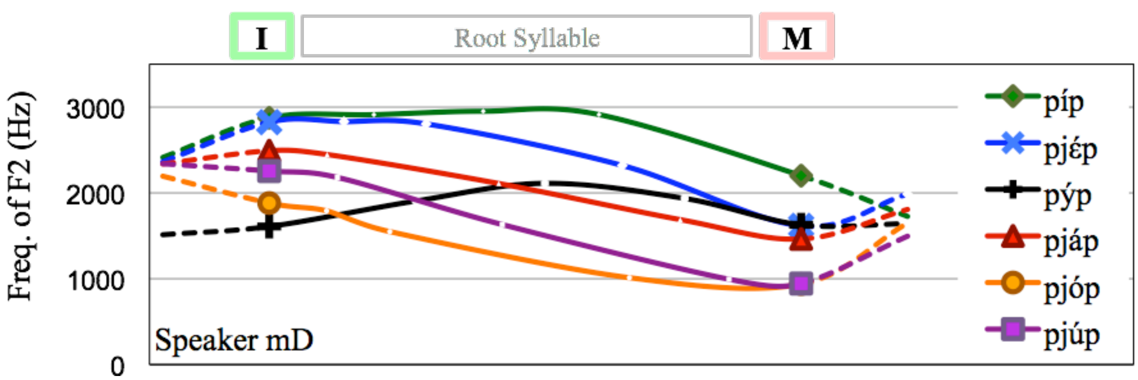


Figure 4.27 Contrast of F2 of OnglideDiphthongs and /y/ as Nuclei of Nonsense pjVp Syllables. The nucleus /y/ did not conform to the behavior of syllables with a soft onset. The nucleus /y/ is moving forwards, while the other syllables are static or moving backwards. /pyp pip/ exhibit similar schedules for terminal labial damping, and it is posited that both contain a kernel vowel /i/. The terminal labial damping for the other syllables was not readily apparent, because the syllables did not have terminal labial damping (for kernels /o u/), or the labial damping of F2 was in distinguishable from the decrease in F2 caused by the backward movement of the diphthong (for kernels /e a/).

There is, however, a potential parallel between /y/ and the onglide diphthongs which is rather subtle. As shown in Figure 4.26, two of the syllables without labial obstruent in the onset (/ja jo/) were in transition at the initium and attained asymptotic behavior associated with the kernel vowel of the nucleus, prior to the terminus. The syllable containing only /y/ exhibited a similar schedule: /y/ was already in transition at the initium, and it became asymptotic before the terminus.

This parallel schedule of initial transition and pre-terminal asymptotes is apparently not duplicated closed syllables of the shape pjVp, as shown in Figure 4.27. It is not clear whether the closed syllables fail to become asymptotic at the terminus because of a consonantal effect which causes the terminal asymptotic plateaus to become inclined, or whether the closed syllables are of shorter duration, and the terminal asymptotic plateaus have been omitted.

4.1.3.4 A Discontinuity in Formant Tracks with Onglide Diphthongs

The abrupt jump in vowel-space, encountered with offglides diphthongs for speakers with a limited overall dimension for vowel-space, was also encountered with onglide diphthongs. However, the instances of abrupt jump in vowel-space for onglide was only evident with onglide syllables /ju jo/ for speaker pG.

Owing to the fact that the formant tracks for /ju jo/ exhibited curvature towards the central S-curve, for both the asymptote associated with the pre-kernel onglide and the asymptote associated with the kernel vowel, it was judged that speaker pG was performing the onglide diphthongs in much the same manner as the other speakers who all exhibited smooth, gradual transition from the onglide to the kernel vowel. As such, the tracks of F2 for speaker pG represented an abbreviated sigmoid curve, with the centermost S-curve and point of inflexion missing. The resulting abbreviated transitional zone permitted speaker pG to obtain the kernel target earlier than the other speakers, as highlighted in blue in Table 4.8.

4.1.3.5 Targeting and Scheduling Behavior of Onglide Diphthongs

In syllables with an onglide, but no obstruent in the onset, all onglide syllables tended to be on-target to the locus of /i/ at the initium. Also, during the voiceless/ devoiced frication of the pre-kernel onglide, the asymptotic behavior associated with the locus of /j/ was often maintained for up to 150 msec, for non-sententially-embedded tokens. In Table 4.6, all onglide syllables for the five primary speakers were initially on-target at /j/.

The nucleus /y/ is included in the tables of this section, in the ongoing effort to place /y/ within the vocalic system. The nucleus /i/ has also been included, since /i/ is often grouped with the onglide diphthongs by DCT, in terms of its association with soft onsets. Furthermore, /i/ is often depicted as the diphthongal [ji] or [jɪ]. And in fact, in the current data set, word final /i/ in the phrase {po russki} ‘in Russian’ was usually performed as [i] by all speakers, in cases when sufficient pause was not afforded before the final token of the frame, and that final token also was /i/-initial. If sufficient pause was afforded, or the third token was not /i/-initial, then the final syllable of {po russki} ‘in Russian” was performed as [skjɪ]. In addition, the post-tonic plural suffix was also often performed as [kjɪ], since all lexical items in this data set were /k/-final. It is unclear whether this diphthong [jɪ] was purely circumstantial, since it was only observed word-finally, and the track of the kernel vowel /i/ might be gravitating to the neutral vowel-space of the following pause. Instances of pre-tonic /i/ were not available in the current data set. Analysis of pre-tonic /i/ (or post-tonic /i/ which is not word-final) would be necessary to determine if unstressed /i/ occurs as [jɪ] with any regularity.

The nucleus /y/ was least likely to be initially on-target, and as such /y/ did not pattern with onglide diphthongs, as shown in Table 4.6. Furthermore, in Table 4.7, /y/ was also less likely to be initially asymptotic than onglide diphthongs (other than /ja/).

In all four tables of this section, the nucleus /i/ was static: /i/ was on-target at the initium and was still on-target at the terminus. Since /i/ was static, it was asymptotic for the entirety of the syllable, and hence, it was static at the initium and terminus by default.

As shown in Table 4.7, onglide diphthongs with front vowel kernels were more likely to maintain asymptotic behavior from the initium into the interior of the syllable; on the other hand, diphthongs with back vowel kernels were more likely to abandon the initial asymptote in F2 circa the initium, or shortly thereafter. Diphthongs with the low vowel kernel /a/ were least likely to maintain the initial asymptote, and in fact, /ja/ was the only onglide diphthong which was likely to abandon the initial asymptote prior to the initium on a regular basis.

It should also be noted in Table 4.7, that the two speakers of St. Petersburg dialect were more likely than the speakers of Moscow dialect to maintain a brief asymptote at the initium of diphthongs with back vowel kernels. It was unclear whether this behavior exhibited by pF and pG was a result of their dialect, or the fact that they had the most limited overall vowel-space, or that they were the only males (or a combination).

The behavior at the terminal edge of sonorous phonation for onglide diphthongs is listed in Tables 4.8 and 4.9. In most cases, the target associated with a back vowel kernel was not fully obtained. The allophonic position which was attained for the back vowels was usually forward of the prototypical locus. In the case of /o u/, the slightly fronted allophonic locus was directly on the trajectory from /i/ to the kernel vowel. In the case of /a/, the attained allophonic locus was not directly on the trajectory from /i/ to /a/.

In terms of targeting and scheduling, the behavior of /y/ tended to be inconsistent, from speaker to speaker, whereas the behavior of the onglide diphthongs tended to be generally consistent from speaker to speaker.

As shown in Table 4.9, the track of F2 for the diphthong /je/ did not tend to ever become asymptotic, and typically did not exhibit any degree of discernible curvature in the vicinity of the terminus to indicate that is might become asymptotic. In contrast, onglide diphthongs, which terminated in back vowels, either became asymptotic well before the terminus, or they exhibited sufficient slowing or braking curvature to indicate that asymptotic behavior would occur circa the terminus or immediately thereafter.

As shown in Figure 4.12, speaker pG was able to obtain the asymptote associated with the back vowel kernels /o u/ approximately three-quarters of a syllable before the terminus. Presumably, the abrupt jump backwards in vowel-space permitted the kernel target to be attained so early.

Table 4.6 On-target Behavior of Onglide at the Initium of Diphthong.

Speaker \ Diphthong	F2 (Hz)	F1 (Hz)	/i/	/je/	/ja/	/y/	/jo/	/ju/
pF	2260	680	on	on	on		on	on
pG	2365	750	on	on	on	dual	on	on
mC	2630	730	on	on	on	on	on	on
mD	3120	945	on	on	on		on	on
mB	2915	920	on	on	on	on	on	on

Table 4.7 Timing of Release of Onglide Asymptote (F2) for Diphthongs with Regard to Initium. Fractions listed are partial syllables (e.g., +1/2 indicates that the asymptote is maintained until after the initium, for approximately one half of a syllable).

Speaker	F2 (Hz)	F1 (Hz)	/i/	/je/	/ja/	/y/	/jo/	/ju/
pF	2260	680	const	+ 1/2	0	–	+	0
pG	2365	750	const	+ 1/4	–	dual	+	+
mC	2630	730	const	0	–	+ 1/2	0	0
mD	3120	945	const	+ 1/4	–	–	0	0
mB	2915	920	const	+	0	+	0	0
Asymptote abandoned:	"–" before the initium			"0" circa the initium		"+" after the initium		

Table 4.8 On-target Behavior at the Terminus of Kernel Target of an Onglide Diphthong. In an onglide diphthong, the kernel target of a back vowel was usually not fully obtained; instead, the track of the syllable through vowel-space terminated approximately 200 Hz forward of the prototypical locus of the kernel vowel.

Speaker	F2 (Hz)	F1 (Hz)	/i/	/je/	/ja/	/y/	/jo/	/ju/
pF	2260	680	on	on	on	on	forward	forward
pG	2365	750	on	on	forward	dual	forward	forward
mC	2630	730	on	on	forward	off	forward	forward
mD	3120	945	on	on	forward	on	forward	forward
mB	2915	920	on	on	forward	on	forward	forward

Table 4.9 Timing of Kernel Asymptote in F2 with Regard to Terminus. Fractions listed are partial syllables (e.g., –1/2 indicates that an asymptote for F2 was obtained approximately one half of a syllable prior to the terminus). For Speaker pG, /jo ju/ experienced an abrupt jump backwards, to the kernel target, before mid-syllable.

Speaker	F2 (Hz)	F1 (Hz)	/i/	/je/	/ja/	/y/	/jo/	/ju/
pF	2260	680	const	+	0	– 2/3	– 1/4	0
pG	2365	750	const	+	– 1/4	dual	– 3/4	– 3/4
mC	2630	730	const	+	– 1/2	–	– 1/2	– 1/4
mD	3120	945	const	+	0	+	– 1/2	0
mB	2915	920	const	+	– 1/2	–	– 1/2	– 1/4
Asymptote obtained:	"–" before the terminus			"0" circa the terminus		"+" after the terminus		

4.1.4 Triphthongs of the Shape jVj

Recurring behaviors for the triphthongs /juj joj jaj jej/ were observed: the consistency to obtain the locus of the onglide prior to sonorous phonation; the transition of formant structure from onglide to the kernel target; the fronting and/or raising of the kernel vowel; the transition from the partially attained kernel target back to the locus of the offglide; and three zones of contrastive sonority.

4.1.4.1 Triphthongs as Intact Syllables

All four triphthongs /jej jaj joj juj/ behaved like triple-target triphthongs. As intact syllables, all four triphthongs exhibited a zone of voiceless (or minimally voiced) frication, prior to the initium. This zone of frication was maintained as a static position in vowel-space, which was equivalent to the locus of /i/. In addition, all four triphthongs exhibited a zone of voiceless frication, following the termination of sonorous phonation.

For purposes of comparison, the sequences /ij yj/ will be presented with the four triphthongs /jej jaj joj juj/. Unlike the symmetrical triphthongs, /ij yj/ did not exhibit voiceless frication prior to the initium; however, /ij yj/ did exhibit frication after the terminus, in parallel fashion with the symmetrical triphthongs.

As shown in Figure 4.28, the trajectories of /jej jaj joj juj/ essentially represent round-trip pathways from a high front position associated with the glide /j/ towards the respective kernel vowels of the triphthongs, and then back again. The allophonic position attained by the kernel of each triphthong was fronted, in relation to the locus associated with the prototypical vowel of the kernel.

The allophonic locus of /e/ was both fronted and raised. The allophonic locus of /a/ was always fronted, and in addition, for some speakers, the allophonic locus of /a/ was raised as well. The allophonic locus of /o/ was always fronted, and in addition, for some speakers was lowered to a more centralized position, particularly for speakers with a more limited overall dimension of vowel-space. Apparently, the centralization of the fronted allophonic /o/ permits more contrast with the fronted allophonic locus for /u/. The allophonic locus for /u/ was always fronted, and remained high in vowel-space.

For /o u/, the allophonic loci are directly on the trajectory from /i/ to the prototypical vowel. For some speakers, the allophonic locus of /a/ may be raised, as well as fronted. In such cases, the allophonic locus for /a/ is more likely to occur on the direct trajectory from /i/ to /a/.

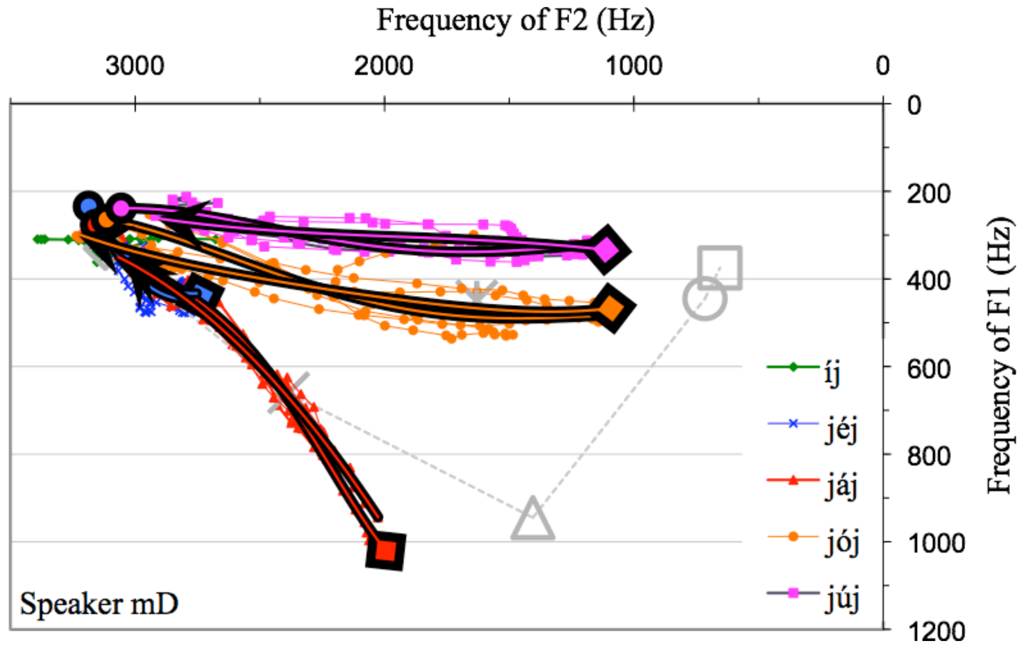


Figure 4.28 Comparison of Tautosyllabic Triphthongs in Vowel-space. All sequences begin at the locus of the onglide /j/ and travel towards their kernel targets, attaining mid-syllable allophonic loci of their kernel targets (represented as diamond icons), before returning towards the high front locus of the offglide.

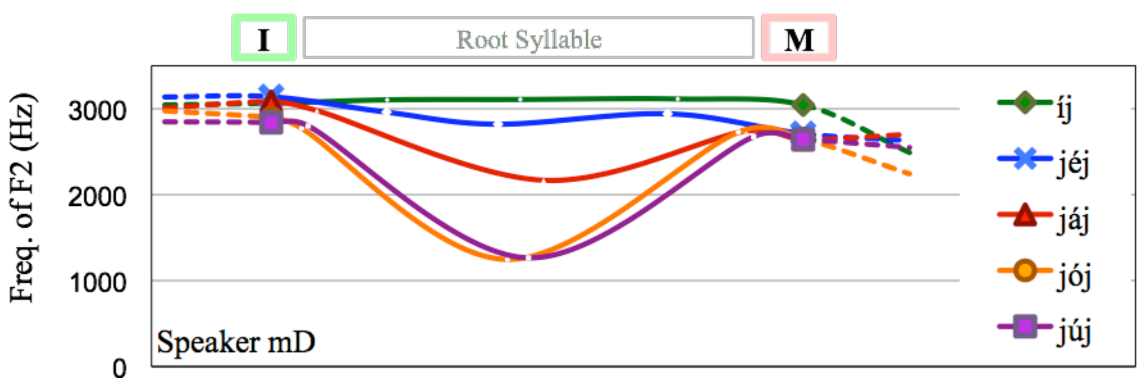


Figure 4.29 Comparison of F2 of Tautosyllabic Triphthongs as Vocalic Syllables. The backness and/or roundness of the kernel vowel affects the value of F2 at both the initium and the terminus: back vowels are more likely to have a lower F2 than front vowels at the margins.

4.1.4.2 Triphthongs as Sequences in pjVjp Syllables

In parallel with the behavior with onglide diphthongs in section 4.1.3.2, the introduction of the labial obstruent /p/ into the onset of the triphthongs produced a separation at the initium between the tracks of F2 for contrastive kernel vowels. This differentiation can be seen by comparing the initium of the triphthongs without onset in Figure 4.29, in which there is general consistency at the initium, regardless of the kernel vowel, with the initium of the triphthongs with /p/ onset in Figure 4.31, in which there is general contrast at the initium, depending on the kernel vowel.

As with the onglide diphthongs, the apparent contrast at the initium in Figure 4.31 could potentially be caused by: contrastive position for the onglide; varying degrees of roundness being carried through the onglide from the labial obstruent of the onset to the rounded/unrounded kernel vowel; or the various partial positions attained at the initium by the tongue pursuing contrastive trajectories through vowel-space. In the latter case, the scheduling of the initium would need to be later for the instances with /p/ onset than for the instances without /p/ onset.

This latter case is indicated by the asymmetry of the formant tracks circa mid-syllable in Figure 4.31. Either the timing of the mid-syllable extremum is located closer to the initium, or the initium is delayed and located closer to mid-syllable. Since the formant tracks in Figure 4.31 were uniformly consistent prior to the initium, this suggests that the pre-initium convergence of Figure 4.31 might correspond to the covergence at the initium of Figure 4.30, and the differentiation at the initium of Figure 4.31 might correspond to post-initium differentiation in Figure 4.30.

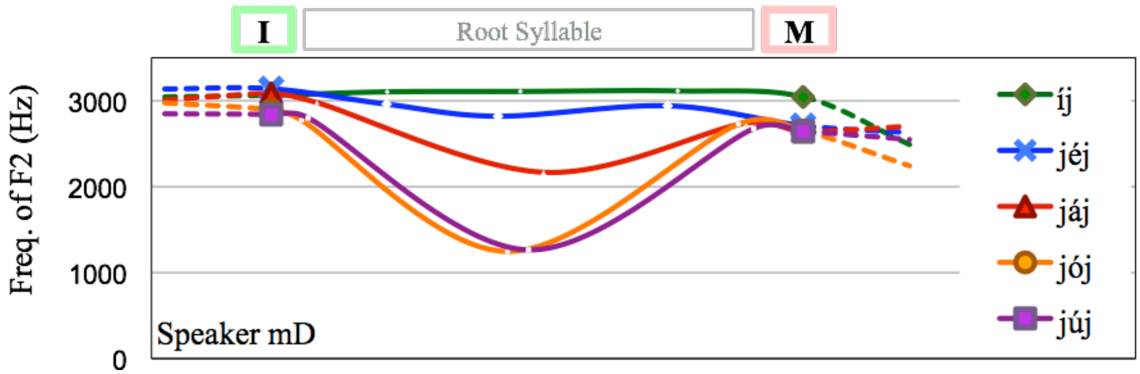


Figure 4.30 Comparison of F2 of Tautosyllabic Triphthongs as Vocalic Syllables (4.29 revisited).

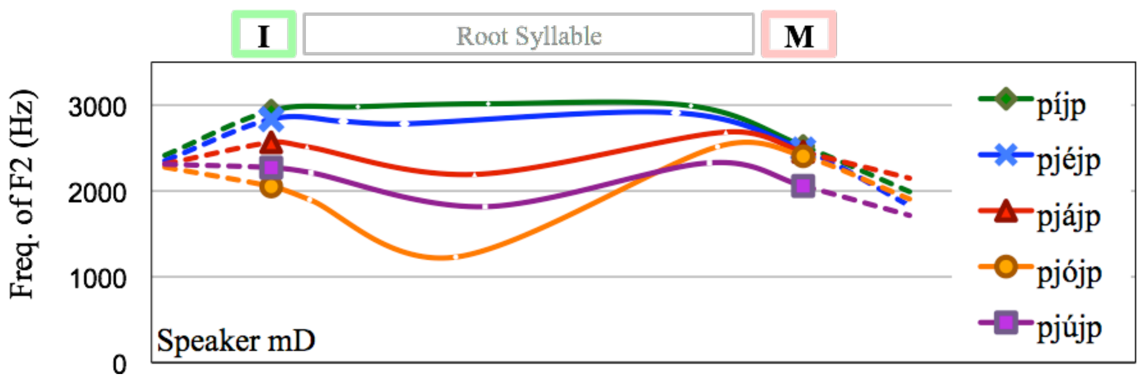


Figure 4.31 Comparison of F2 of Tautosyllabic Triphthongs as the Nuclei of Nonsense pjVjp Syllables. The backness of the kernel vowel affects the value of F2 at both the initium and the terminus: back vowels are more likely to have a lower F2 than front vowels at the margins. The majority of the initial labial effect is registered on the onglide, prior to the initium. As such, the local maximum in F2 occurs prior to the initium. However, at the coda, the local maximum occurs during sonorous phonation, and the terminal labial effect is registered prior to the terminus.

4.1.4.3 The Contrast Between /yj/ and the Symmetrical Triphthongs

Although the sequence /yj/ is not expected to pattern with the other triphthongs, in the interest of thoroughness and the ongoing pursuit to place /y/ in the systematic behavior of other nuclei, /yj/ will now be compared and contrasted with the symmetrical triphthongs.

Firstly, in the most obvious sense, the sequence /yj/ behaved differently from the symmetrical triphthongs, in that the trajectory of /yj/ through vowel-space was uni-directional, and not bi-directional. As such, /yj/ did not conform to the behavior of the symmetrical triphthongs.

Secondly, /yj/ behaved differently from the symmetrical triphthongs, in that /yj/ only exhibited only two zones of sonority: a sonorous vowel, followed by a voiceless offglide. As noted above, the symmetrical triphthongs exhibited three zones of sonority: 1) a voiceless/devoiced onglide, 2) a sonorous vowel, and 3) a voiceless offglide.

However, /yj/ did conform loosely to the behavior of the symmetrical triphthongs in that /yj/ represented a sequence of three targets: pre-kernel /ɨ/, kernel /i/, and an offglide /j/ in the coda. Similarly, the symmetrical triphthongs represented a sequence of three targets: pre-kernel /j/, a kernel vowel (one of /e a o u/), and an offglide /j/.

In addition, as shown in Figure 4.32, the triphthong /yj/ also loosely conformed to the timing schedule of the symmetrical triphthongs, in that /yj/ was in transition at the initium, attained its kernel target circa the mid-syllable mark, became asymptotic at the locus for /j/, and maintained the locus of /j/ into the coda, as a voiceless approximant.

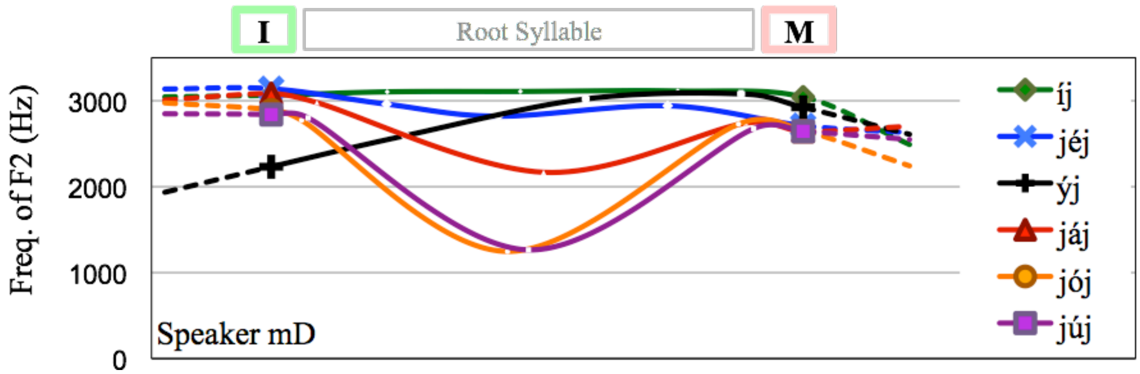


Figure 4.32 Contrast of F2 of /yj/ and Symmetrical Triphthongs as Vocalic Syllables. The triphthong /yj/ was asymmetrical, and did not conform to the behavior of the other triphthongs, with their local extrema centered within the sonorous portion of the syllable.

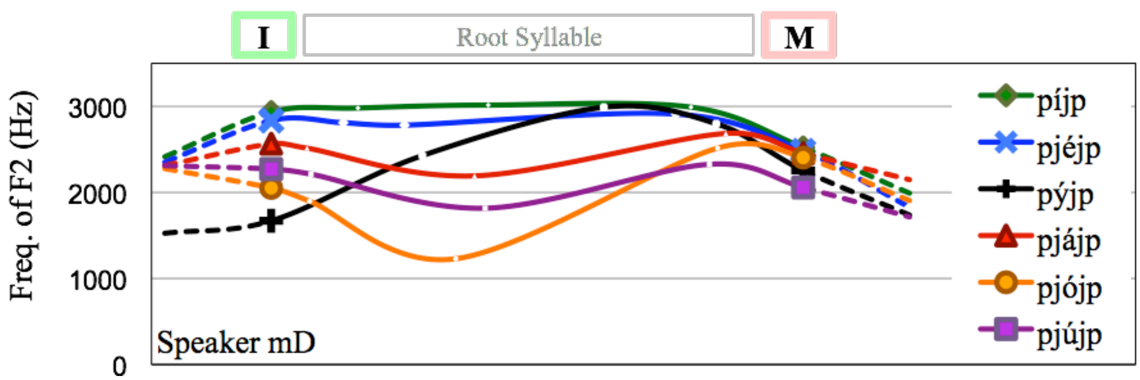


Figure 4.33 Contrast of F2 of /yj/ and Symmetrical Triphthongs in Nonsense pjVjp Syllables. The triphthong /yj/ is asymmetrical, and did not conform to the behavior of the other triphthongs, with their local extrema occurring circa or prior to mid-syllable.

4.1.4.4 A Discontinuity in Formant Tracks with Symmetrical Triphthongs

The triphthongs /joj juj/ performed by speaker pG exhibited abrupt jumps in vowel-space, presumably created by minute alterations in tongue height (particularly of the tongue tip/blade). Speaker pG was the only speaker of the five primary speakers to perform these abrupt jumps with regard to triphthongs, and was the only speaker of the five primary speakers to perform abrupt jumps with onglide diphthongs /jo ju/. However, all three primary speakers with more limited vowel-space (pG, pF and mC) performed this type of abrupt jump through vowel-space with offglide diphthong /uj/. It remains to be seen if the abrupt jumps associated with onglides was similar to that associated with offglides.

4.1.4.5 Targeting and Scheduling Behavior of Triphthongs

In syllables with a symmetrical triphthong and no obstruent in the onset, all onglides tended to be on-target to the locus of /i/ at the initium. Also, during the voiceless/devoiced fricative of the pre-kernel onglide, the asymptotic behavior associated with the locus of /i/ was often maintained for up to 150 msec, for non-sententially-embedded tokens. In Table 4.10, all symmetrical triphthongal syllables for the five primary speakers were initially on-target at /i/.

As shown in Figure 4.15, the asymptotic behavior associated with the onglide of /jej/ was most likely to be maintained beyond the initium for all speakers. In contrast, as the only triphthong containing a low target, the asymptotic behavior associated with the onglide of /jaj/ was likely to be abandoned at the initium for all speakers. For triphthongs containing /o u/, those speakers with a more limited overall vowel-space were more likely to maintain the onglide beyond the initium than speakers with more expansive vowel-space.

Table 4.10 On-target Behavior of Onglide at the Initium of Triphthongs.

Speaker \ Triphthong	F2 (Hz)	F1 (Hz)	/ij/	/jej/	/jaj/	/yj/	/joj/	/juj/
pF	2260	680	on	on	on		on	on
pG	2365	750	on	on	on	on	on	on
mC	2630	730	on	on	on		on	on
mD	3120	945	on	on	on	on	on	on
mB	2915	920	on	on	on	on	on	on

Table 4.11 Timing of Release of Onglide Asymptote (F2) for Triphthongs with Regard to the Initium.

Speaker	F2 (Hz)	F1 (Hz)	/ij/	/jej/	/jaj/	/yj/	/joj/	/juj/
pF	2260	680	const	+	+	–	0	+
pG	2365	750	const	+	0	+	+	+
mC	2630	730	const	+	0	+	+	+
mD	3120	945	const	+	0	–	0	0
mB	2915	920	const	+	0	+	–	0
Asymptote abandoned:	"–" before the initium			"0" circa the initium			"+" after the initium	

As shown in Table 4.12, the allophonic locus attained by the kernel of a symmetrical triphthong was likely to be fronted. For all speakers, the allophonic locus for the kernel /e/ was fronted and raised, in comparison to the prototypical locus of [ɛ]. The allophonic locus for the kernel /a/ was fronted for all speakers, and was also raised for some speakers. The allophonic locus for the kernel /u/ was only slightly fronted for some speakers, while it was greatly fronted (to the point of being a near-front vowel) for other speakers. The allophonic locus of the kernel /o/ always tended to be fronted;

however, for some speakers, the allophonic locus was slightly lowered from the height of prototypical /o/ and slightly below the trajectory from /i/ to /o/. Since /o u/ are the only rounded vowels, this slight lowering might serve to help differentiate /o/ from /u/, given that both vowels experience fronting, as the kernel of a triphthong.

Table 4.12 On-target Behavior of Kernel of Triphthong at Mid-syllable. In a symmetrical triphthong, the kernel target is not fully obtained; instead, the track of the syllable through vowel-space will attain a locus which is fronted (and often raised) from the position of the prototypical locus of the kernel, before returning forwards, in the direction of the offglide. (The symbols ü and ï represent centralized locations, i.e., ï is a close/near-front position, and ü is a close/near-back position. In this case, as allophones of /u/, both ü and ï are rounded.)

Speaker	F2 (Hz)	F1 (Hz)	/ij/	/jej/	/jaj/	/yj/	/joj/	/juj/
pF	2260	680	on	e fronted raised	ɛ to æ fronted raised	i	ø to ɵ fronted (greatly)	ï fronted (greatly)
pG	2365	750	on	e fronted raised	æ fronted	i	ɵ fronted (lowered)	ü fronted
mC	2630	730	on	e fronted raised	ɛ fronted raised	in transit to i	ɵ fronted (lowered)	ï fronted (greatly)
mD	3120	945	on	e fronted raised	ɛ to æ fronted raised	i	ö fronted	ü fronted
mB	2915	920	on	e fronted raised	æ fronted	in transit to i	ö fronted	ü fronted

From Table 4.12, it would appear that speakers with a more limited vowel-space tended to front the kernels /o u/ more greatly than speakers with a more expansive vowel-space. The exception to this trend was speaker pG, who managed to attain a less-fronted locus of [ü], equivalent to that of speakers mD and mB.

However, for triphthongs /joj juj/, it should be noted that speaker pG exhibited abrupt jumps in vowel-space on the trajectory from /i/ to kernel vowel /o/ or /u/ and also an abrupt jump in the trajectory from these kernels, back to the locus of the offglide. As such, speaker pG appears to have articulated the front and the back of the tongue independently, at least in terms of tongue height. As such, speaker pG maintained dual points of closure for both /j/ and the kernel across the entirety of the syllables. Speaker pG could apparently disengage the onglide by lowering the height of the tongue tip/blade, and thus disqualifying it as a point of closure. This shifted the prominence of the vowel track to the tongue position of the back kernel /o/ or /u/. After the kernel position had been afforded sufficient duration to receive its time-on-target, the tongue tip/blade could then be elevated again to shift prominence back to the (off)glide. Therefore, the effect of backwards and forwards movement could be accomplished almost exclusively by dis-qualifying and then re-qualifying the tongue tip/blade as a point of closure, without appreciably modifying the tongue position for the back vowel of the kernel.

As with the timing of asymptotic behavior at the beginning of a triphthong, the timing of the offglide seemed to involve the overall dimension of vowel-space of the speaker. As shown in Table 4.13, speakers with more limited vowel-space tended to obtain asymptotic behavior associated with the offglide prior to the terminus.

Considering Tables 4.11, 4.12 and 4.13 together, the two speakers with more expansive vowel-space attained allophonic loci for the kernels /o u/, which more closely approximated the prototypical locus of the kernel. However, in doing so, these two speakers sacrificed the asymptotic behavior of both the onglide and the offglide, within the durational confines of the sonorous portion of the syllable. In contrast, for the speakers with more limited vowel-space, the allophonic loci of /o u/ were greatly fronted. The failure to approximate the prototypical locus of the kernel permitted time, which might have been devoted to lengthy transitions, to be devoted to the maintenance of the asymptotic plateaus for the glides, at both the initial edge and the terminal edge of the syllable. The exception to this trend was speaker pG, who often tended to articulate the front and back of the tongue independently, and thus eliminated the majority of the transitions, which in turn permitted asymptotic plateaus at both margins to be maintained, and also permitted an allophonic locus of the kernel, which was close to its prototypical locus.

Table 4.13 Timing of Offglide Asymptote in F2 for Triphthongs, with Regard to Terminus.

Speaker	F2 (Hz)	F1 (Hz)	/ij/	/jej/	/jaj/	/yj/	/joj/	/juj/
pF	2260	680	const	–	0	–	–	–
pG	2365	750	const	–	0	–	–	–
mC	2630	730	const	–	0	–	–	–
mD	3120	945	const	–	+	–	0	0
mB	2915	920	const	–	0	–	+	+
Asymptote obtained:	"–" before the terminus			"0" circa the terminus		"+" after the terminus		

4.1.5 Summary of the Systems of Nonsense Syllables

The bare vowel syllables /u o a e i/ behaved as steady-state vowels, and as such had uniform formant structure across the normal duration of the syllable. For some speakers, the stressed bare vowel syllables exceeded the normal duration of a comparable closed syllable, and after 150 msec (which is the normal duration for the monophthong syllable) these bare vowel syllables often gravitated towards neutral vowel-space. For other speakers, the syllables did not gravitate towards neutral vowel-space at the terminus, and the bare vowel syllables were in fact virtually uniform, which is an ideal form of symmetry.

When the phonemes /u o a e i/ were the nuclei of closed pVp syllables, the abnormal duration of an open syllable was avoided, and their formant trajectories were symmetrical.

When the phonemes /u o a e i/ were the kernel vowels of offglide diphthongs of the shape Vj, the formant tracks of the vowels were asymmetrical; however, all syllables /uj oj aj ej ij/ terminated at an equivalent position in vowel-space (the locus of /j/, which was equivalent in vowel-space to the locus of /i/).

When these offglide diphthongs were placed in pVjp syllables, the asymmetry was maintained; however, the terminal equivalence exhibited a degree of differentiation, with the backness (and hence lower value of F2) of the kernel vowel causing a lower local maximum in the value of the offglide before the terminus. It is also possible that the labial rounding of the kernel vowel was carried across the offglide for the syllable /pojp pujp/, which would also effectively lower the local maximum of the offglide at the terminus. With regard to targeting, the initial locus of the kernel vowel in a syllable with an offglide was equivalent to the initial locus of the kernel vowel in an otherwise comparable syllable without the offglide.

When the phonemes /u o a e i/ were the kernel vowels of jV syllables, the formant tracks of the vowels were asymmetrical; however, all syllables /ju jo ja je i/ initiated at an equivalent position in vowel-space (the locus of /j/, which was equivalent in vowel-space to the locus of /i/).

When these onglide nuclei were placed in pjVp syllables, the asymmetry was maintained; however, the initial equivalence was not maintained, and the various tracks of the vowels began to differentiate. The cause of differentiation is likely two-fold. First, sustained labial damping across the onglide for /pjop pjup/ lowered the initial value of F2. Second, local maxima of the tracks of F2 occurred before the initium, and as such, the values of F2 at the initium represented the corresponding point on contrastive pathways in vowel-space, all emanating from the locus of /j/, traveling towards the loci of their respective kernel vowels. With regard to targeting, the terminal locus of the kernel vowel in a syllable with an onglide tended to terminate further forward (approximately 200-300 Hz higher value of F2) than the terminal locus of the kernel vowel in an otherwise comparable syllable without the onglide.

When the phonemes /u o a e i/ were the kernel vowels of jVj syllables, the formant tracks of the vowels were once again symmetrical. All syllables /juj joj jaj jej ij/ initiated at an equivalent position in vowel-space (the locus of /j/, which was equivalent in vowel-space to the locus of /i/). Also, all syllables /juj joj jaj jej ij/ terminated at an equivalent position in vowel-space.

However, when these symmetrical triphthongal nuclei were placed in pjVjp syllables, the symmetry was not maintained. The initial equivalence was not maintained, and the various tracks of the vowels began to differentiate, as was observed with the pjVp syllables. Also, the terminal equivalence was not maintained, and the various tracks of the vowels began to differentiate, as was observed with pVjp syllables.

In addition, symmetry about the mid-syllable maximum was skewed backwards in time, by approximately one-half mora. The local maximum in the onglide occurred in the onset, prior to the initium, and as such, occurred externally to the zone of sonorous phonation. On the other hand, the local maximum in the offglide occurred prior to the terminus, and as such, occurred internally to the zone of sonorous phonation.

In general, syllables containing the nucleus /y/ did not conform to behavior of otherwise comparable syllables containing a nucleus of /u o a e i/. The only two parameters upon which syllables with /y/ did conform to comparable syllables without /y/ were: firstly, syllables with /y/ conformed loosely to the scheduling of on-target behavior as syllables with onglides, if the nucleus /y/ was posited to be the sequence [ɨi]; and secondly, syllables containing the sequence /yj/ attained similar terminal behavior as any syllable with an offglide.

4.2 Allophonic Behavior of the Vowel Phonemes

In this section, the allophonic variants of stressed and unstressed vowels were compared. In addition, the stressed phonemes from Section 4.1 were analyzed with a greater variety of consonant onsets and codas than those previously considered in Section 4.1, in order to determine to what degree the point of articulation of a consonant can create additional allophonic loci.

Results from the current contiguous method indicated that more allophonic variants are warranted, than are noted by DCT (Hamilton 1980: 28-48; Jones & Ward 1969: 29-71). Jones and Ward posited two to five major allophonic loci per stressed phonemic vowel, based upon ÇVÇ vs. non-ÇVÇ contexts. Hamilton only posited two major allophonic loci for stressed kernels, based upon ÇVÇ contexts vs. non-ÇVÇ contexts.

However, the current method indicated that a third major set of allophonic loci is warranted, based upon extracting the ÇVK context from non-ÇVÇ contexts of DCT. This additional sub-division was judged to be warranted based upon the consistent tendency of ÇVK sequences to terminate at loci distinctly different from KVK sequences, from token to token, from type to type, and from speaker to speaker. This sub-division suggested that the allophonic variation caused by the onglide operates as an independent factor, apart from the influence of the offglide.

The current contiguous method also revealed that high vowels can reduce, which is contrary to the DCT convention that high vowels never reduce (Hamilton 1980: 49).

4.2.1 Allophones of the Phoneme /u/

The phoneme /u/ was observed in syllables without obstruents, in syllables with obstruents, and in syllables in which the primary contrast is stress placement. The observed behavior indicated that a modification to DCT's allophonic mapping of /u/ was warranted. The modification entails removing the ÇúK category from DCT's ÇúC set, and establishing a new allophone [u̟] for ÇúK, reserving [ü] for ÇúÇ sequences only.

The allophones of /u/ from three studies is presented in Table 4.14. The new, distinct locus for ÇúK sequences has been highlighted in blue. The table also includes two violations of DCT conventions: 1) separate loci were indicated for KŭK sequences, depending upon the nucleus of the following syllable; and 2) the kernel of ÇŭC exhibited reduction, since they were severely fronted, and de-rounding might have occurred.

Table 4.14 Comparison of Observed Allophones for the Kernel /u/. An additional locus was identified for ÇúK sequences. For KŭK sequences, separate loci for kernel /u/ occurred, depending on the suffix. The mid-syllable extremum of ÇúÇ occurred at a single locus, the location of which varied from [ʉ] to [ÿ], depending on speaker.

	Segment Contrast			Allophonic Loci		
	Pre-Kernel	Post-Kernel	Kernel Stress	Hamilton 1980	Jones & Ward 1969	Current Study
CuC	KuC	KuK	KúK	u	u	u
			KŭK	u	ω	u ʊ
		KuÇ	KúÇ	u	u	u
			KŭÇ	u	ω	ʊ
	ÇuC	ÇuK	ÇúK	u	u	u̟
			ÇŭK	u	ω	ɪ/ʏ
		ÇuÇ	ÇúÇ	ü	ü	ʉ...ÿ
			ÇŭÇ	ü	ω̈	i/ÿ

4.2.1.1 The Phoneme /u/ as the Nucleus of Syllables Without Obstruents

As shown in Figure 4.34, syllables containing /u/ in the kernel position exhibited systematic behavior. In general, syllables that possessed equivalent pre-kernel sequences exhibited equivalent initial behavior, and syllables that possessed equivalent post-kernel sequences exhibited equivalent terminal behavior. If the pre-kernel or post-kernel sequences contained glides, mid-syllable behavior of was seldom equivalent.

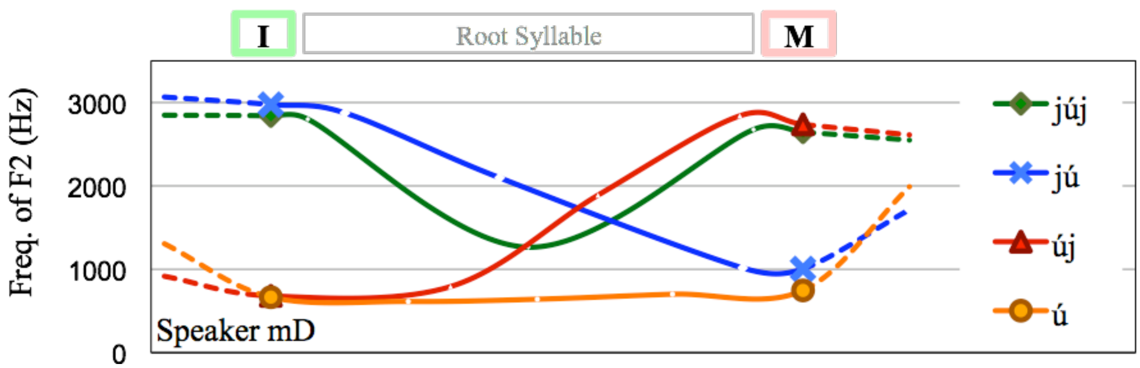


Figure 4.34 Comparison of F2 Tracks of Syllables of the Shape (j)u(j). Each track represents a composite of three tokens. The proportions of all four types of syllables have been normalized to fit within a standard frame. Due to normalization, direct comparison of time-related parameters (such as slope) for dissimilar syllable types may not be valid.

With the behavior exhibited by the bare vowel syllable /u/ posited as the prototypical behavior for the phoneme, the systematic behavior of the syllables with /u/ as the kernel was as follows:

1) The bare vowel syllable /u/ was a steady-state monophthong, and as such, F2 was asymptotic from the initium until the terminus.

2) The onsetless syllable /uj/ conformed initially to the behavior of onsetless /u/. The terminal behavior of the syllable /uj/ conformed to the terminal behavior of /juj/, both of which terminated in the sequence /uj/.

3) The terminal behavior of the syllable /ju/ failed to conform to the terminal behavior of the syllable /u/, even though both syllables terminated in the same target. The syllable /ju/ tended to terminate approximately 200-400 Hz forward of the prototypical locus of /u/, for all speakers. As expected, the initial behavior of /ju/ was categorically different from the initial behavior of onsetless /u/, and the initial behavior of /ju/ conformed to the initial behavior of /juj/, both of which initiated with /ju/.

4) The mid-syllable behavior of /juj/ was fronted, when compared to the mid-syllable behavior for the bare vowel /u/, as indicated by a higher value for F2. The initial behavior of /juj/ conformed to the initial behavior of /ju/, and the terminal behavior of /juj/ conformed to the terminal behavior of /uj/.

4.2.1.2 The Phoneme /u/ as the Nucleus of Syllables With Obstruents

As shown in Figure 4.35, syllables containing /u/ in the kernel position exhibited systematic behavior. As above, syllables that possessed equivalent pre-kernel sequences exhibited equivalent initial behavior, and syllables that possessed equivalent post-kernel sequences exhibited equivalent terminal behavior. If the pre-kernel or post-kernel sequences contained glides or soft consonants, the mid-syllable behavior of different syllable types was seldom equivalent.

With the behavior exhibited by the bare vowel syllable /u/ posited as the prototypical behavior for the phoneme, the systematic behavior of the syllables with /u/ as the kernel was as follows:

1) The bare vowel syllable /u/ was a steady-state monophthong, and as such F2 is asymptotic from the initium until the terminus. Since /u/ is rounded, there was no labial damping registered at the initium nor at the terminus of /pup/, and hence, the formant tracks of /u pup/ were equivalent.

2) The syllable /pujp/, which contained a labial "hard" consonant as its onset, conformed initially to the behavior of onsetless /u/, since /u/ is rounded, and also conformed initially with the syllable /pup/, since both /pujp pup/ initiated with the sequence /pu/. The terminal behavior of the syllable /pujp/ conformed to the terminal behavior of /pjujp/, both of which terminated in the sequence /ujp/.

3) The terminal behavior of the syllables /pjup jup/ was equivalent; however, both failed to conform to the terminal behavior of the syllable /pup/, even though these syllables terminated in the same sequence. The syllables /pjup jup/ tended to terminate approximately 200-400 Hz forward of the terminal locus of /pup/, for all speakers. The initial behavior of /pjup/ was categorically different from that of /jup/, in that /pjup/ initiated at a lower value of F2. Also, the initial behavior of /pjup/, which possessed a soft onset, was categorically different from the initial behavior of /pup/, which possessed a hard onset; however, the initial behavior of /pjup/ conformed to the initial behavior of /pjujp/, both of which initiated with the sequence /pju/.

4) The mid-syllable behavior of /pjujp/ was fronted from that of /pup/, as indicated by a higher value for F2. The initial behavior of /pjujp/ conformed to the initial behavior of /pjup/, and the terminal behavior of /pjujp/ conformed to the terminal behavior of /pujp/.

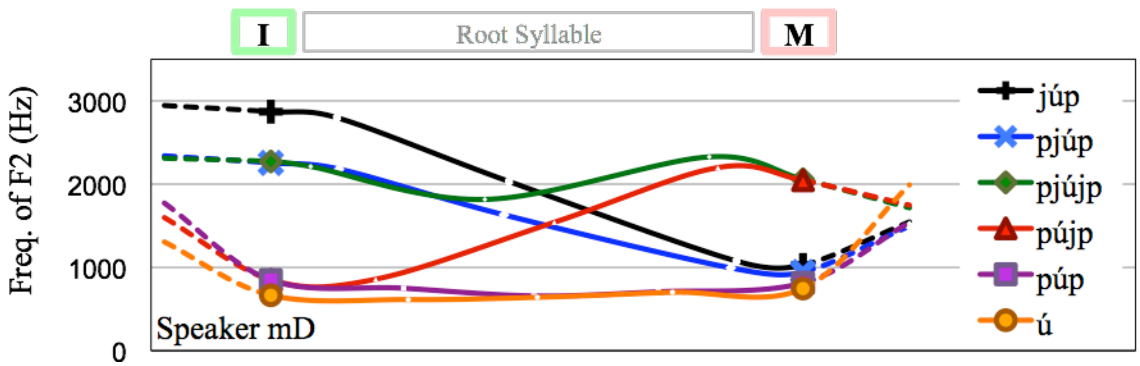


Figure 4.35 Comparison of F2 Tracks of Syllables of the Shape (p)(j)u(j)(p). Syllables containing /u/ often terminated further forward after the soft onset /j/ or /pj/ than syllables with hard onset /p/ or no onset. Each track represents a composite of six tokens. All composites have been normalized to fit in a standard frame, therefore direct comparison of time-related parameters (such as slope) for dissimilar syllable types may not be valid.

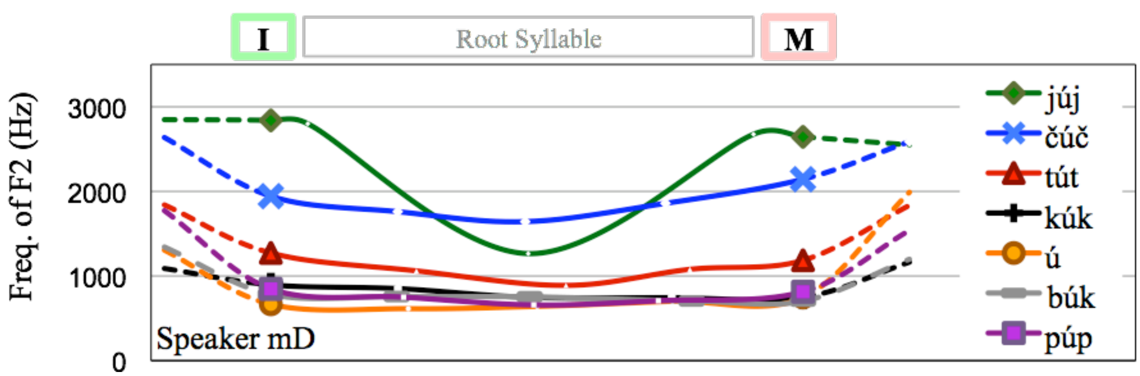


Figure 4.36 Comparison of F2 Tracks of Syllables of the Shape CuC. Each track represents a composite of multiple tokens (6 for /pup/ & /buk/; and 3 for the remainder). Non-coronal consonants attained allophonic variants with lower values of F2 than alveolar consonants, which in turn attained lower values of F2 than palatal consonants.

As shown in Figure 4.36, varying the point of articulation of the consonant(s) of the onset and coda also generated allophonic variants of kernel vowel /u/. According to DCT, the allophonic variants of /u/ for syllables of the shape ÇVÇ, represented in the figure by the syllables /juj čuč/, can be categorically different from the allophonic variant of /u/ for syllables of the shape KVK, represented by /tut kuk pup buk/. A categorical difference did in fact occur; however, the contrast was not simply a binary contrast between ÇVÇ and KVK syllables. Additional replicable differentiated allophonic variants existed within both sets of syllables. Within the ÇVÇ set, syllables which were potentially vocalic sequences (/jVj/) attained a differentiated allophonic variant from syllables which are CVC sequences (/čuč/). Likewise, within the KVK set, syllables with alveolar consonants (/tut/) attained a differentiated allophonic variant from syllables with non-alveolar consonants (/kuk pup buk/).

Since the kernel vowel /u/ is rounded, a labial obstruent in the coda did not impart labial damping to the terminus of /u/, and thus, the syllables /u pup/ terminated at equivalent values of F2. However, the syllables /kuk buk/ also terminated at an equivalent value for F2, as /u pup/. As will be shown later in the presentation, syllables ending in /k/ tended to terminate at equivalent loci in vowel-space (and hence had equivalent values of F2) as comparable open syllables, regardless of the roundness of the kernel vowel. As such, the velar consonant /k/ tended not to impart discernible marginal effects at the terminus of a vowel. This transparent marginal effect will be helpful later in the presentation, when suffixation is encountered, since the root of all lexical items terminated in velar consonants.

4.2.1.3 Allophonic Loci for the Phoneme /u/

The allophonic loci of /u/ were organized along two axes: a fronting axis from the prototypical locus of the kernel vowel /u/ to the locus of the pre-kernel glide /j/; and a centralizing axis from prototypical locus of the kernel vowel /u/ towards the locus of schwa. This centralizing axis did not extend inwards beyond the location of [ʊ].

Within the syllables considered, a nucleus containing the phoneme /u/ behaved like a single-target monophthong /u/, a two-target offglide diphthong /uj/, a two-target offglide diphthong /ju/, or a triple-target triphthong /juj/. In determining the allophonic loci of the kernel /u/ in these nuclei, measurements were collected at local extrema. The mid-syllable extrema represented the kernel of monophthongal /u/ and triphthongal /juj/, the terminal extremum represented the kernel of diphthongal /ju/, and conversely, the initial extremum represented the kernel of diphthongal /uj/.

Thus, in the Figure 4.37, although entire vowel tracks of multiple tokens of the selected syllables are plotted, the allophonic loci for the kernel /u/ were isolated by averaging the appropriate localized extrema for the selected syllables, and these extrema (allophonic loci) of the kernel /u/ have been highlighted with oversized icons.

The extrema of the differing types of syllables varied to some degree. Three categories of extrema were noted, by sequence type:

1) ÇúÇ nonsense item: the kernel of the triphthong /juj/ ceased backward movement at a point which was the furthest forward of all stressed allophones.

2) Çú(K) nonsense item: the kernel of the onglide diphthong /ju/ terminated at a slightly fronted position from the prototypical locus, and

3) KúK/KŭK/KúÇ sequences: the prototypical locus was equally representative of tonic kernel with an offglide in /uj/, of a tonic monophthong kernel in /búku/, and of a pre-tonic monophthongal kernel in /bukú/.

One additional locus was isolated, which does not appear in Figure 4.37. The locus occurred in vowel-space at approximately [ɪ], for the unstressed root syllable of inflected forms of утюг /utjug/ 'flatiron.' This lexical item did not conform to the basic root syllable shape (BWG) imposed on all other lexical items. As such, the allophonic locus associated with /utjug/ potentially contains factors which were not controlled for in the design of the research.

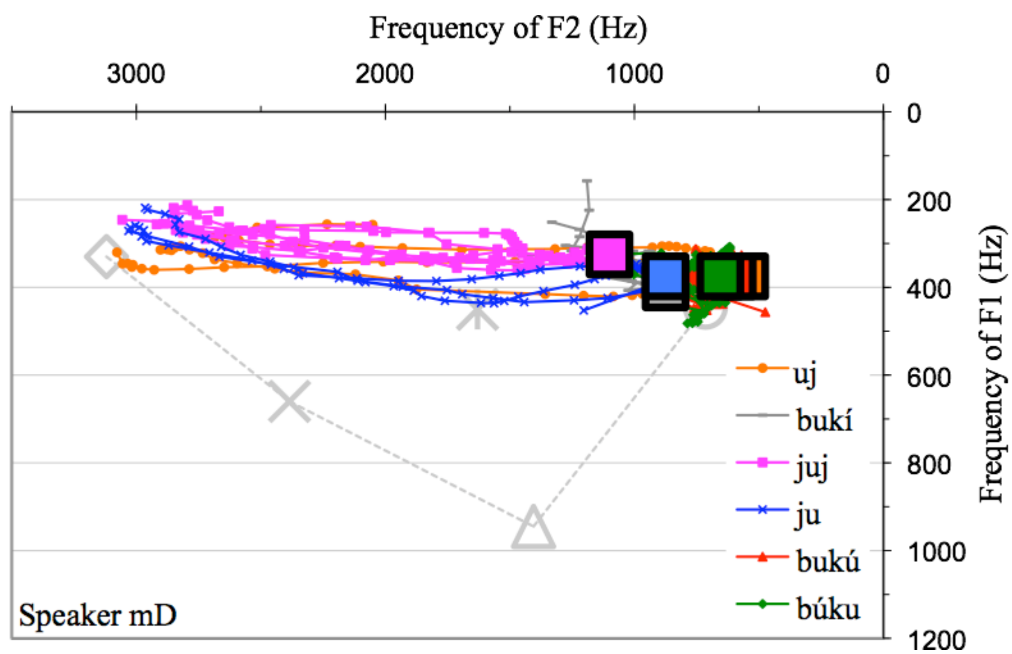


Figure 4.37 Comparison in Vowel-space of Tokens for the Kernel /u/. The figure contains multiple tokens of selected syllables containing the kernel /u/. For suffixed tokens, only the root syllable is depicted. Note: Icons buried beneath the uppermost icons have been tiled to one side to verify that all tokens are represented. Thus, only three loci are depicted, at the magenta, blue and green icons.

4.2.2 Allophones of the Phoneme /o/

The phoneme /o/ was observed in syllables without obstruents, in syllables with obstruents, and in syllables in which the primary contrast is stress placement. The behavior observed in the data indicated that a modification to DCT's allophonic mapping of /o/ was warranted. The modification entails removing the ÇóK category from DCT's ÇóC set, and establishing a separate allophone [o̟] for ÇóK, while applying the previous [ö] allophone only to ÇóÇ sequences.

A comparison of the allophones of /o/ indicated by three studies is presented in Table 4.15. The new, distinct locus for ÇóK sequences has been highlighted in blue. Following a train of logic in Jones and Ward (1969) that the sound /o/ can be written as o or ё/е (p. 58), and that [ɩ] can be written as и, е, э, or я (p. 36), the table includes [ɩ] for ÇŏC sequences, although Jones and Ward did not explicitly state that ё resolves to [ɩ].

Table 4.15 Comparison of Observed Allophones for the Kernel /o/. An additional locus was identified for ÇóK sequences. The mid-syllable extremum of ÇóÇ occurred at a single locus, the location of which varied from [ɵ] to [ø], depending on speaker.

	Segment Contrast			Allophonic Loci		
	Pre-Kernel	Post-Kernel	Kernel Stress	Hamilton 1980	Jones & Ward 1969	Current Study
CoC	KoC	KoK	KóK	o	o	o
			KŏK	a ə	ʌ ə	ɐ ə
		KoÇ	KóÇ	o	o	o
			KŏÇ	a ə	ʌ ə	ɐ ə
	ÇoC	ÇoK	ÇóK	o	o	o̟
			ÇŏK	i	(ɩ)	ɪ
		ÇoÇ	ÇóÇ	ö	ö	ɵ...ø
			ÇŏÇ	i	(ɩ)	ɪ

4.2.2.1 The Phoneme /o/ as the Nucleus of Syllables Without Obstruents

As shown in Figure 4.38, syllables containing /o/ in the kernel position exhibited systematic behavior. In general, syllables which possessed equivalent pre-kernel sequences exhibited equivalent initial behavior. Syllables which possessed equivalent post-kernel sequences exhibited equivalent terminal behavior. If the pre-kernel or post-kernel sequences contained glides, mid-syllable behavior of was seldom equivalent.

With the behavior exhibited by the bare vowel syllable /o/ posited as the prototypical behavior for the phoneme, the systematic behavior of the syllables with /o/ as the kernel was as follows:

1) The bare vowel syllable /o/ was a steady-state monophthong, and as such F2 was asymptotic for the majority of the syllable; however, open syllables terminating in /o/ can gravitate towards a more centralized tongue position for some speakers.

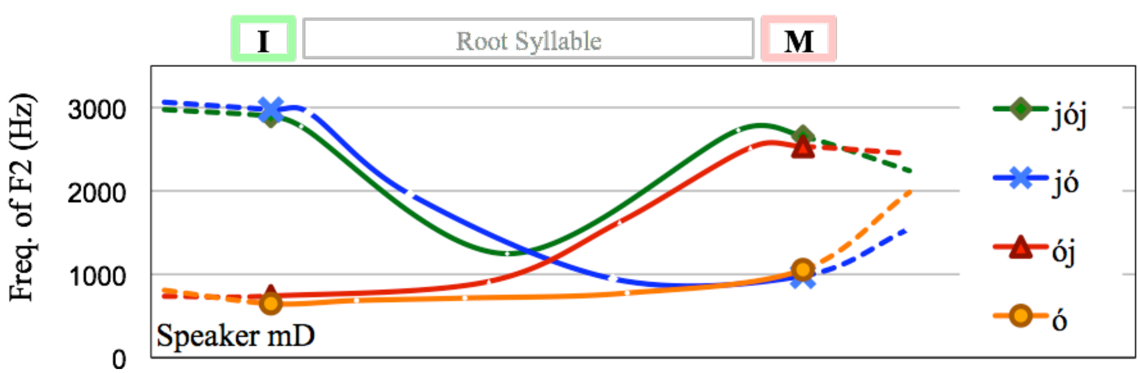


Figure 4.38 Comparison of F2 Tracks of Syllables of the Shape (j)o(j). For this speaker, monophthongal /o/ tended to gravitate towards neutral vowel-space. Even though syllables /o jo/ terminated with similar values of F2, after consulting F1 or observing the tracks in vowel-space, it can be shown that /o/ is traveling towards schwa, and /jo/ is traveling towards /o/. Each track represents a composite of three tokens. All composites have been normalized to fit in a standard frame, therefore direct comparison of time-related parameters (such as slope) for dissimilar syllable types may not be valid.

2) The onsetless syllable /oj/ conformed initially to the behavior of onsetless /o/. The terminal behavior of the syllable /oj/ conformed to the terminal behavior of /joj/, both of which terminated in the sequence /oj/.

3) The terminal behavior of the syllable /jo/ failed to obtain the prototypical locus of /o/. As expected, the initial behavior of /jo/ was categorically different from the initial behavior of onsetless /o/, and the initial behavior of /jo/ conformed to the initial behavior of /joj/, both of which initiated with the sequence /jo/.

4) The mid-syllable behavior of /joj/ was fronted, when compared to the mid-syllable behavior for the bare vowel /o/, as indicated by a higher value for F2. The initial behavior of /joj/ conformed to the initial behavior of /jo/, and the terminal behavior of /joj/ conformed to the terminal behavior of /oj/.

4.2.2.2 The Phoneme /o/ as the Nucleus of Syllables With Obstruents

As shown in Figure 4.39, syllables containing /o/ in the kernel position exhibited systematic behavior. In general, syllables with equivalent pre-kernel sequences exhibited equivalent initial behavior, and syllables with equivalent post-kernel sequences exhibited equivalent terminal behavior. If the pre-kernel or post-kernel sequences contained glides or soft consonants, the mid-syllable behavior of different syllable types was seldom equivalent.

With the behavior exhibited by the bare vowel syllable /o/ posited as the prototypical behavior for the phoneme, the systematic behavior of the syllables with /o/ as the kernel was as follows:

1) The bare vowel syllable /o/ was a steady-state monophthong, and as such F2 is asymptotic for the majority of the syllable. Since /o/ is rounded, there was no labial damping registered at the initium nor at the terminus of /pop/, and hence, the formant tracks of /o pop/ are equivalent. It should be noted that the open syllable /o/ tended to gravitate towards neutral vowel-space for some speakers; however, it tended to do so only after the steady-state behavior of the monophthong has been maintained beyond the normal duration of closed syllables. As such the terminal locus of /pop/ corresponded to the position /o/ at a comparable duration.

2) The syllable /pojp/, which contained a labial “hard” consonant as its onset, conformed initially to the behavior of onsetless /o/, since /o/ is rounded, and conformed initially with the syllable /pop/, since both /pojp pop/ initiated with the sequence /po/. The terminal behavior of the syllable /pojp/ conformed to the terminal behavior of /pjojp/, both of which terminated in the sequence /ojp/.

3) The terminal behavior of the syllables /pjop jop/ was equivalent; however, for most speakers, both failed to conform to the terminal behavior of the syllable /pop/, even though these syllables terminated in the same sequence. The syllables /pjop jop/ tended to terminate approximately 200-400 Hz forward of the terminal locus of /pop/ for some speakers. The initial behavior of /pjop/ was categorically different from that of /jop/, in that /pjop/ initiated at a lower value of F2. Also, the initial behavior of /pjop/, which possessed a soft onset, was categorically different from the initial behavior of /pop/, which possessed a hard onset; however, the initial behavior of /pjop/ conformed to the initial behavior of /pjojp/, both of which initiated with the sequence /pjo/.

4) The mid-syllable behavior of /pjojp/ was fronted from that of /pop/, as indicated by a higher value for F2. The initial behavior of /pjojp/ conformed to the initial behavior of /pjop/, and the terminal behavior of /pjojp/ conformed to the terminal behavior of /pojp/.

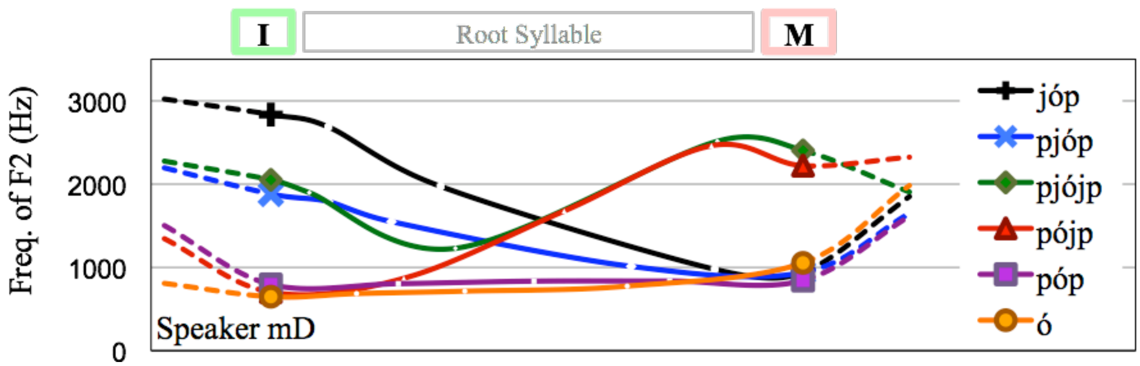


Figure 4.39 Comparison of F2 Tracks of Syllables of the Shape (p)(j)o(j)(p). For this speaker, the syllable /o/ gravitated towards neutral vowel-space. Each track represents a composite of multiple tokens (3 tokens for /o/, and 6 tokens the remainder). All composites have been normalized to fit in a standard frame, therefore direct comparison of time-related parameters (such as slope) for dissimilar syllable types may not be valid.

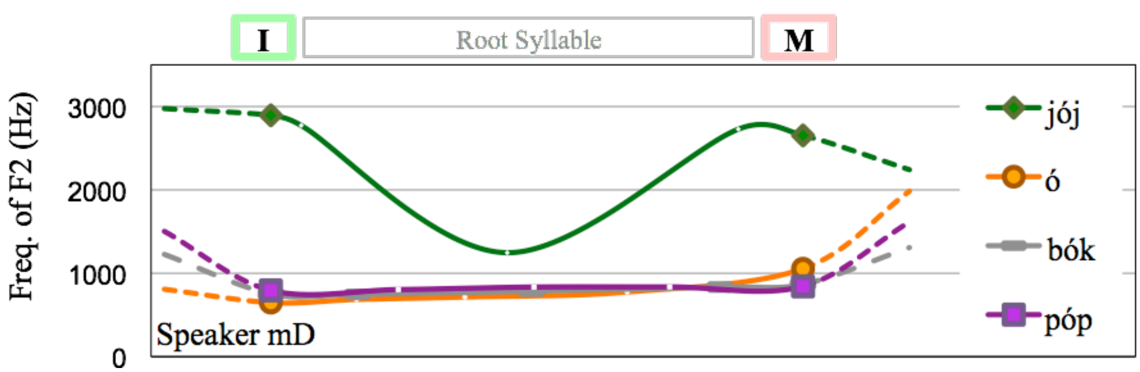


Figure 4.40 Comparison of F2 Tracks of Syllables of the Shape CoC. The labial /p/ did not impart discernible marginal effects on the rounded kernel /o/. In addition, the velar obstruent /k/ did not impart terminal marginal effects. For this speaker, the bare vowel syllable /o/ gravitated towards neutral vowel-space. Each track represents a composite of multiple tokens (6 tokens for /pup buk/, and 3 tokens for /o joj/).

According to DCT, the allophonic variants of /o/ for syllables of the shape ÇVÇ (represented in Figure 4.40 by the syllable /joj/) will be categorically different from the allophonic variant of /o/ for syllables of the shape KVK, represented by /pop bok/. As shown in Figure 4.40, this categorical difference was observed. The current data set did not contain syllables such as /čoč/ or /tot/, to test whether further differentiation within the ÇVÇ and KVK syllable sets occurs, as was observed in Section 4.2.1, with the kernel /u/.

Since the kernel vowel /o/ is rounded, a labial obstruent in the coda did not impart labial damping to the terminus of /o/, and thus, the syllables /o pop/ should terminate at equivalent values of F2. However, for some speakers, the open syllable /o/ tended to gravitate towards neutral vowel-space. In such cases, the terminal value of F2 for /pop/ was equivalent to the mid-syllable value of /o/, before the gravitation to neutral vowel-space begins.

The syllables /pop bok/ terminated at equivalent loci in vowel-space, and hence, at equivalent values for F2. In both cases, the obstruent of the coda did not impart terminal marginal effects on the vowel /o/. In the cases of /pop/, the labial damping associated with /p/ was not registered, because the kernel vowel /o/ is rounded. in the case of /bok/, a terminal marginal effect was not registered, because /k/ tended not to impart discernible terminal marginal effects.

4.2.2.3 Allophonic Loci for the Phoneme /o/

The allophonic loci of /o/ were organized along two axes: a fronting axis from the prototypical locus of the kernel vowel /o/ to the locus of the pre-kernel glide /j/; and a centralizing axis from prototypical locus of the kernel vowel /o/ towards the locus of schwa. For /o/, an additional locus was encountered, which was located on the centralizing axis for /a/ allophones.

Within the syllables considered, a nucleus containing the phoneme /o/ behaved like a single-target monophthong /o/, like a two-target offglide diphthong /oj/ or a two-taret offglide diphthong /jo/, or like a triple-target triphthong /joj/. In determining the allophonic loci of the kernel /o/ in these nuclei, measurements were collected at local extrema. The mid-syllable extrema represented the kernel of monophthongal /o/ and triphthongal /joj/, the terminal extremum represented the kernel of diphthongal /jo/, and conversely, the initial extremum represented the kernel of diphthongal /oj/.

Thus, in the Figure 4.41, although entire vowel tracks of multiple tokens of the selected syllables are plotted, the allophonic loci for the kernel /o/ were isolated by averaging the appropriate localized extrema for the selected syllables, and these extrema (allophonic loci) of the kernel /o/ have been highlighted with oversized icons.

The terminal loci of the differing types of syllables clustered into four categories, by sequence type:

1) ÇóÇ: the tonic kernel of the /(le)pjóxi/ ceased backward movement at a point which was the furthest forward of all stressed allophones.

2) ÇóK: the kernel of the onglide diphthong /(le)pjóxa/ terminated at a slightly fronted position from the prototypical locus.

3) KóK/KóÇ: the prototypical locus was equally representative of tonic kernel with an offglide in /(po)pójka/, which represented KóÇ sequences, and of a tonic monophthong kernel in /bókom/, which represented KóK sequences, and

4) KŏK: the mid-syllable extremum of pre-tonic monophthongal kernel in /bokóv/ was located in mid-open/near-open vowel-space.

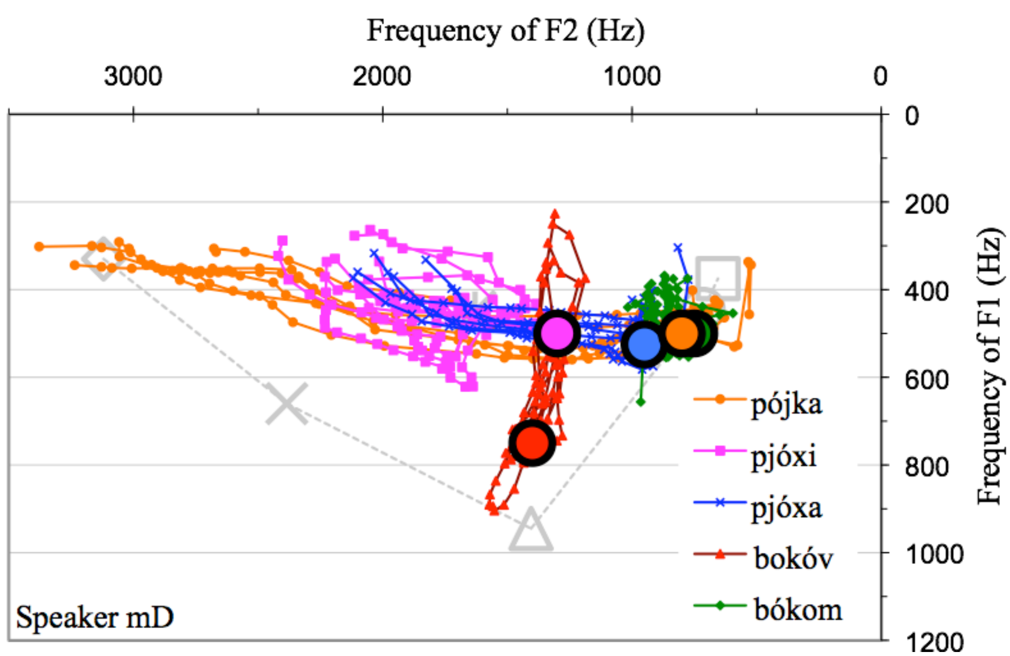


Figure 4.41 Comparison in Vowel-space of Tokens for the Kernel /o/. The figure contains six tokens of each syllable types containing the kernel /o/. For suffixed tokens, only the root syllable is depicted. Note: Icons buried beneath the uppermost icons have been tiled to one side to verify that all tokens are represented. Thus, only four loci are depicted, at the magenta, blue, green and red icons.

4.2.3 Allophones of the Phoneme /a/

The phoneme /a/ was observed in syllables without obstruents, in syllables with obstruents, and in syllables in which the primary contrast is stress placement. The behavior observed in the data indicated that separate loci for KáK and ÇáK sequences are warranted. This separation was previously presented by Jones and Ward (1969). A comparison of the allophones of /a/ indicated by three studies is presented in Table 4.16.

Table 4.16 Comparison of Observed Allophones for the Kernel /a/. The locus for ÇáK sequences was distinctly different from the prototypical locus at [ɑ], encountered in KáK sequences. The mid-syllable extremum of ÇáÇ sequences occurred at a single locus, the location of which varied from [æ] to [ɛ], depending on speaker.

	Segment Contrast			Allophonic Loci		
	Pre-Kernel	Post-Kernel	Kernel Stress	Hamilton 1980	Jones & Ward 1969	Current Study
CaC	KaC	KaK	KáK	a	ɑ+	ɑ
			KăK	a ə	ʌ ə	ɐ ə
		KaÇ	KáÇ	a	ɑ+	ɑ
			KăÇ	a ə	ʌ ə	ɐ ə
	ÇaC	ÇaK	ÇáK	a	a	a
			ÇăK	i	ɩ	ɪ
		ÇaÇ	ÇáÇ	æ	æ	æ...ɛ
			ÇăÇ	i	ɩ	ɪ

4.2.3.1 The Phoneme /a/ as the Nucleus of Syllables Without Obstruents

As shown in Figure 4.42, syllables containing /a/ in the kernel position exhibited systematic behavior. In general, syllables that possessed equivalent pre-kernel sequences exhibited equivalent initial behavior, and syllables that possessed equivalent post-kernel sequences exhibited equivalent terminal behavior. If the pre-kernel or post-kernel sequences contained glides, mid-syllable behavior of was seldom equivalent.

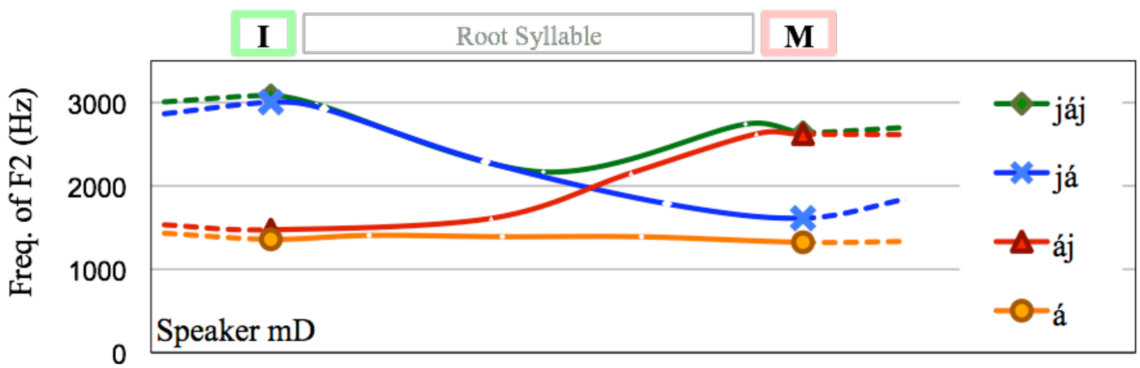


Figure 4.42 Comparison of F2 Tracks of Syllables of the Shape (j)a(j). Each track represents a composite of three tokens. Syllables comprised of /ja/ often terminate further forward than the prototypical locus for /a/.

With the behavior exhibited by the bare vowel syllable /a/ posited as the prototypical behavior for the phoneme, the systematic behavior of the syllables with /a/ as the kernel was as follows:

1) The bare vowel syllable /a/ was a steady-state monophthong, and as such F2 is asymptotic from the initium until the terminus.

2) The onsetless syllable /aj/ conformed initially to the behavior of onsetless /a/. The terminal behavior of the syllable /aj/ conformed to the terminal behavior of /jaj/, both of which terminated in the sequence /aj/.

3) The terminal behavior of the syllable /ja/ failed to obtain the prototypical locus of /a/. As expected, the initial behavior of /ja/ was categorically different from the initial behavior of onsetless /a/, and the initial behavior of /ja/ conformed to the initial behavior of /jaj/, both of which initiated with the sequence /ja/.

4) The mid-syllable behavior of /jaj/ was fronted, when compared to the mid-syllable behavior for the bare vowel /a/, as indicated by a higher value for F2. The initial behavior of /jaj/ conformed to the initial behavior of /ja/, and the terminal behavior of /jaj/ conformed to the terminal behavior of /aj/.

4.2.3.2 The Phoneme /a/ as the Nucleus of Syllables With Obstruents

As shown in Figure 4.43, syllables containing /a/ in the kernel position exhibited systematic behavior. In general, syllables with equivalent pre-kernel sequences exhibited equivalent initial behavior, and syllables with equivalent post-kernel sequences exhibited equivalent terminal behavior. If the pre-kernel or post-kernel sequences contained glides or soft consonants, the mid-syllable behavior of different syllable types was seldom equivalent.

With the behavior exhibited by the bare vowel syllable /a/ posited as the prototypical behavior for the phoneme, the systematic behavior of the syllables with /a/ as the kernel was as follows:

1) The bare vowel syllable /a/ was a steady-state monophthong, and as such, F2 was asymptotic from the initium until the terminus. Since /a/ is unrounded, labial damping was often registered at the initium and at the terminus of /pap/.

2) The syllable /pajp/, which contained a labial "hard" consonant as its onset, exhibited labial damping at the initium. The amount of labial damping at the initium of nonsense syllables beginning with /pa/ varied from speaker to speaker. These nonsense speakers were often performed with a lengthy voice onset time and often a discernible amount of aspiration. As such, the majority of labial damping was contained within the onset, prior to the initium, for these nonsense syllables. Later in the presentation, once actual lexical items are encountered (especially syllables with a voiced onset /b/), the voice onset time of the syllable will decrease dramatically, and labial damping will be more readily discernible at the initium of syllables beginning with labial consonant + /a/. The terminal behavior of the syllable /pajp/ usually conformed to the terminal behavior of /pjajp/, both of which terminated in the sequence /ajp/.

3) The terminal behavior of the syllables /pjap jap/ was equivalent; however, both failed to conform to the terminal behavior of the syllable /pap/, even though these syllables terminated in the same sequence. The syllables /pjap jap/ tended to terminate approximately 200-400 Hz forward of the terminal locus of /pap/ for all speakers. The initial behavior of /pjap/ was categorically different from that of /jap/ in that /pjap/ initiated at a lower value of F2. Also, the initial behavior of /pjap/, which possesses a soft onset, was categorically different from the initial behavior of /pap/, which possesses

a hard onset; however, the initial behavior of /pjap/ conformed to the initial behavior of /pjajp/, both of which initiated with the sequence /pja/.

4) The mid-syllable behavior of /pjajp/ was fronted from that of /pap/, as indicated by a higher value for F2. The initial behavior of /pjajp/ conformed to the initial behavior of /pjap/, and the terminal behavior of /pjajp/ conformed to the terminal behavior of /pajp/.

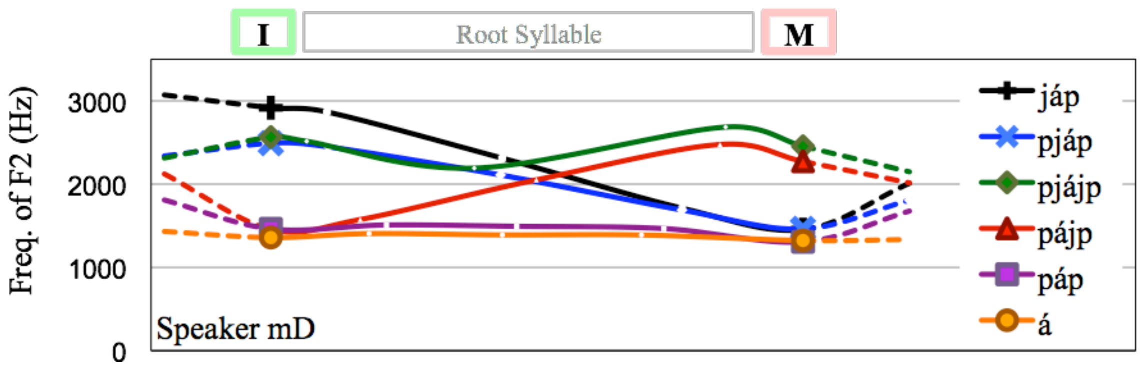


Figure 4.43 Comparison of F2 Tracks of Syllables of the Shape (p)(j)a(j)(p). The track for /a/ represents a composite of three tokens. All other tracks represents a composite of six tokens. All composites have been normalized to fit in a standard frame, therefore direct comparison of time-related parameters (such as slope) for dissimilar syllable types may not be valid.

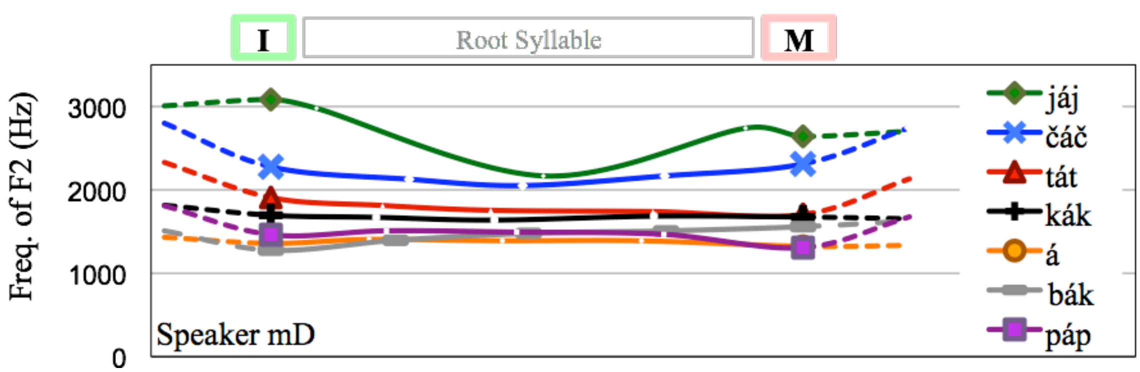


Figure 4.44 Comparison of F2 Tracks of Syllables of the Shape CaC. Each track represents a composite of multiple tokens (6 tokens for /pap bak/, and 3 tokens for the remainder). The labial /p/ imparts discernible marginal effects on the unrounded kernel /a/. However, the velar obstruent /k/ did not impart marginal effects.

As shown in Figure 4.44, varying the point of articulation of the consonant(s) of the onset and coda also generated allophonic variants of kernel vowel /a/. According to DCT, the allophonic variants of /a/ for syllables of the shape ÇVÇ, represented in the figure by the syllables /jaj čač/, can be categorically different from the allophonic variant of /u/ for syllables of the shape KVK, represented by /tat kak pap bak/. Categorical difference did in fact occur; however, the contrast was not simply a binary contrast between ÇVÇ and KVK syllables. Additional replicable differentiated allophonic variants existed within both sets of syllables, for some speakers. Within the ÇVÇ set, syllables which were potentially vocalic sequences (/jVj/) attained a differentiated allophonic variant from syllables which are CVC sequences (/čač/). Likewise, within the KVK set, syllables with alveolar consonants (/tat/) attained a differentiated allophonic variant from syllables with labial consonants (/pap bak/).

4.2.3.3 Allophonic Loci for the Phoneme /a/

The allophonic loci of /a/ were organized along two axes: a fronting axis from the prototypical locus of the kernel vowel /a/ to the locus of the pre-kernel glide /j/; and a centralizing axis from prototypical locus of the kernel vowel /a/ to the locus of schwa.

Within the syllables considered, a nucleus containing the phoneme /a/ behaved like a single-target monophthong /a/, like a two-target offglide diphthong /aj/ or a two-taret offglide diphthong /ja/, or like a triple-target triphthong /jaj/. In determining the allophonic loci of the kernel /a/ in these nuclei, measurements were collected at local extrema. The mid-syllable extrema represented the kernel of monophthongal /a/ and triphthongal /jaj/, the terminal extremum represented the kernel of diphthongal /ja/, and conversely, the initial extremum represented the kernel of diphthongal /aj/.

Thus, in the Figure 4.45, although entire vowel tracks of multiple tokens of the selected syllables are plotted, the allophonic loci for the kernel /a/ were isolated by averaging the appropriate localized extrema for the selected syllables, and these extrema (allophonic loci) of the kernel /a/ have been highlighted with oversized icons.

The terminal loci of the differing types of syllables clustered into seven categories, by sequence type:

1) ÇăÇ: the unstressed kernel of /(zdoro)vjakí/ terminated the highest and the furthest forward.

2) ÇăK: the unstressed kernel of /(zdoro)vjaká/ terminated high and forward.

Of the kernels that have extrema in low vowel-space,

3) ÇáÇ: the tonic kernel of /bjáki/ terminated the furthest forward.

4) ÇáK: the tonic kernel of the onglide diphthong /bjáka/ terminated at a slightly fronted position from the prototypical locus.

5) KáK/KáÇ: the prototypical locus was equally representative of tonic kernel with an offglide in /bájka/, which represent KáÇ sequences, and a tonic monophthong kernel in /(so)báka/, which represent KáK sequences.

6) KăÇ: the mid-syllable extremum of pre-tonic monophthongal kernel in /(ta)bakí/ was located in somewhat neutral space.

7) KăK: the mid-syllable extremum of pre-tonic monophthongal kernel in /(ta)baká/ was located in somewhat neutral space, but further back than KăÇ extrema.

Of the eight possible sequence types, after binary contrast in the pre-kernel elements (K/Ç), in the kernel elements (á/ă), and in the post-kernel elements (K/Ç), only two sequences (KáK and KáÇ) have equivalent extrema associated with the prototypical locus of the kernel /a/.

Furthermore, it is not coincidental that these are the only two sequences which obtain the prototypical locus of /a/. Only tonic KáC syllables have two consecutive mora (i.e., for the pre-kernel and the kernel) devoted to the same vocalic target. Tonic ÇáC syllables are contrastive pre-kernel /j/ and kernel /a/ sequences. Non-tonic ÇăC syllables have only the pre-kernel /j/ remaining in the nucleus. Non-tonic KăC syllables have an underspecified kernel.

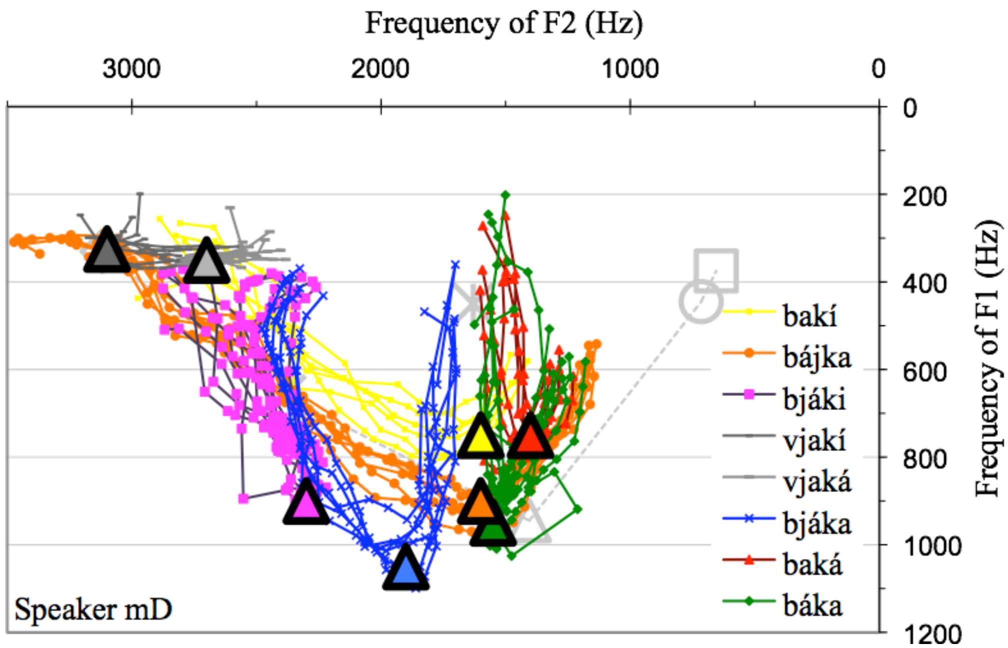


Figure 4.45 Comparison in Vowel-space of Tokens for the Kernel /a/. The figure contains six tokens of each of syllable type. Only the root syllables are depicted.

4.2.4 Allophones of the Phoneme /e/

The phoneme /e/ was observed in syllables without obstruents, in syllables with obstruents, and in syllables in which the primary contrast is stress placement. The behavior observed in the data indicated that a modification to DCT's allophonic mapping of /e/ was warranted. The modification entails removing the ÇéÇ category from DCT's CéÇ set, and establishing a separate allophone [e̟] for ÇéÇ, while applying the previous [e] allophone only to KéÇ sequences.

A comparison of the allophones of /e/ indicated by three studies is presented in Table 4.17. The new, distinct locus for ÇéÇ sequences has been highlighted in blue.

Table 4.17 Comparison of Observed Allophones for the Kernel /e/. The locus for ÇéÇ sequences was distinctly different (higher and further forward) from the locus [e] encountered in KéÇ sequences.

	Segment Contrast			Allophonic Loci		
	Pre-Kernel	Post-Kernel	Kernel Stress	Hamilton 1980	Jones & Ward 1969	Current Study
CeC	KeC	KeK	KéK	ɛ	ɛ	ɛ
			KĕK			
		KeÇ	KéÇ	e	e	e
			KĕÇ			
	ÇeC	ÇeK	ÇéK	ɛ	ɛ˔	ɛ̟
			ÇĕK	i	ɩ	ɪ
		ÇeÇ	ÇéÇ	e	e	e̟
			ÇĕÇ	i	ɩ	ɪ

4.2.4.1 The Phoneme /e/ as the Nucleus of Syllables Without Obstruents

As shown in Figure 4.46, syllables containing /e/ in the kernel position exhibit systematic behavior. In general, syllables that possessed equivalent pre-kernel sequences exhibited equivalent initial behavior, and syllables that possessed equivalent post-kernel sequences exhibited equivalent terminal behavior. If the pre-kernel or post-kernel sequences contained glides, mid-syllable behavior of was seldom equivalent.

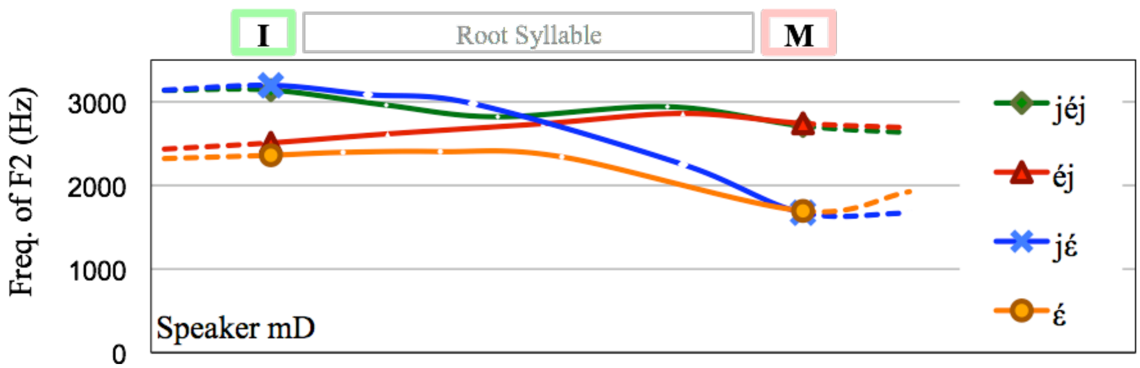


Figure 4.46 Comparison of F2 Tracks of Syllables of the Shape (j)e(j). Each track represents a composite of three tokens. Syllables comprised of /jɛ/ often terminated further forward than the prototypical locus for /ɛ/.

With the behavior exhibited by the bare vowel syllable [ɛ] posited as the prototypical behavior for the phoneme, the systematic behavior of the syllables with /e/ as the kernel was as follows:

1) The bare vowel syllable [ɛ] was a steady-state monophthong, and as such, F2 was asymptotic for the majority of duration of a normal monophthongal syllable.

2) Depending on speaker, the syllable /ej/, which is onsetless, did and did not conform initially to the behavior of onsetless [ɛ]. Some speakers did not differentiate the initial loci of these two syllables. Those speakers, who did differentiate the initial loci, did so in accordance with DCT. Thus, the syllables /e ej/ were performed with undifferentiated mid/near-front initial loci as [ɛ] and [ɛj] by some speakers; with undifferentiated close-mid/near-front initial loci as [e] and [ej] by some speakers; or with differentiated mid/near-front initial locus [ɛ] and close-mid/near-front initial locus [ej] by others. The terminal behavior of a particular individual's [ej] or [ɛj] conformed to the terminal behavior of /jej/, both of which terminated in the phonemic sequence /ej/.

3) The terminal behavior of the syllable /je/ ([jɛ̞]) failed to conform to the terminal behavior of the bare vowel syllable /e/ ([ɛ]), even though both syllables terminated in the same target. The syllable [jɛ̞] tended to terminate at approximately an open-mid/near-front locus, regardless of whether the prototypical locus for the particular speaker is mid or close-mid. As expected, the initial behavior of /je/ was categorically different from the initial behavior of onsetless /e/, and the initial behavior of /je/ conformed to the initial behavior of /jej/, both of which initiated with the sequence /je/.

4) The mid-syllable behavior of /jej/ is fronted from that of the bare vowel /e/, as indicated by a higher value for F2. The initial behavior of /jej/ conformed to the initial behavior of /je/, and the terminal behavior of /jej/ conformed to the terminal behavior of /ej/. All speakers performed the syllable /jej/ as [je̝̟j], with a kernel [e̝̟], which was higher and further forward than the kernel of the onsetless syllable /ej/, regardless of the initial locus [e] or [ɛ] for onsetless /ej/ exhibited by a particular speaker.

4.2.4.2 The Phoneme /e/ as the Nucleus of Syllables With Obstruents

As shown in Figure 4.47, syllables containing /e/ in the kernel position exhibited systematic behavior. In general, syllables with equivalent pre-kernel sequences exhibited equivalent initial behavior, and syllables with equivalent post-kernel sequences exhibited equivalent terminal behavior. If the pre-kernel or post-kernel sequences contained glides or soft consonants, the mid-syllable behavior of different syllable types was seldom equivalent.

With the behavior exhibited by the bare vowel syllable /e/ posited as the prototypical behavior for the phoneme, the systematic behavior of the kernel /e/ was:

1) The bare vowel syllable [ɛ] was a steady-state monophthong, and as such, F2 is asymptotic for the majority of the syllable. Since [ɛ] is unrounded, labial damping was usually registered at the initium or at the terminus of [pɛp].

2) The initial behavior of /pejp/ did or did not conform to the initial behavior of the syllable /pɛp/, depending on speaker. For some speakers, both syllables began at the same locus, i.e. [pɛp] and [pɛ̜jp], or [pep] and [pejp]. Those speakers, who differentiated the initial locus of /e/ based upon the trailing palatal environment, did so in accordance with DCT, i.e., [pɛp] vs [pejp]. The terminal behavior of /pejp/ usually conformed to the terminal behavior of [pjejp], both of which terminated in the sequence /ejp/.

3) The terminal behavior of the syllables [pjɛ̹p], [jɛ̹p] and [pɛp] was equivalent. Unlike the jVp syllables with back vowel kernels, which terminated forward of their respective prototypical loci, syllables terminating in [jɛ̹p] tended to overshoot the prototypical locus of [ɛ], which was posited as the initial steady-state position of the bare

vowel syllable [ɛ]. The initial behavior of [pjɛ̹p] was categorically different from that of [jɛ̹p], in that [pjɛ̹p] initiated at a lower value of F2. Also, the initial behavior of [pjɛ̹p], which possesses a soft onset, was categorically different from the initial behavior of [pɛp], which possesses a hard onset; however, the initial behavior of [pjɛ̹p] conformed to the initial behavior of [pjȩ̹jp], both of which initiated with similar sequences /pje/.

4) The mid-syllable behavior of [pjȩ̹jp] is fronted from that of [pɛp], as indicated by a higher value for F2. The initial behavior of [pjȩ̹jp] conformed to the initial behavior of [pjɛp], and the terminal behavior of [pjȩ̹jp] conformed to that of [pejp] (or [pɛjp]).

As shown in Figure 4.48, varying the consonant(s) of the onset and coda can generate allophonic variants of kernel vowel /e/. According to DCT, the allophonic variants of /e/ for syllables of the shape ÇVÇ, represented by the syllable /jej/, can be categorically different from the allophonic variant of /e/ for syllables of the shape KVK, represented by [pɛp] and [ɛk]. Categorical difference did in fact occur. The current data set did not contain syllables such as /čeč/ or /tɛt/ to test whether further differentiation within the ÇVÇ and KVK syllable sets occurs, as with the kernel /a/ or /u/.

Since the kernel vowel /e/ is unrounded, a labial obstruent in the coda imparted labial damping to the terminus of /e/, and thus the syllables [ɛ] and [pɛp] are not expected to terminate at equivalent values of F2. However, for some speakers, the open syllable [ɛ] tended to gravitate towards neutral vowel-space. In such cases, the terminal value of F2 for [pɛp], in which terminal labial damping was registered, was equivalent in F2 to the terminal value of [ɛ].

The closed syllables [pɛp] and [ɛk] did not terminate at equivalent loci in vowel-space, and hence, did not have equivalent values for F2. In the case of [pɛp], the terminal labial damping associated with /p/ was registered, because the kernel vowel /ɛ/ is unrounded. In the case of [ɛk], a terminal marginal effect was not registered, because /k/ tended not to impart terminal marginal effects.

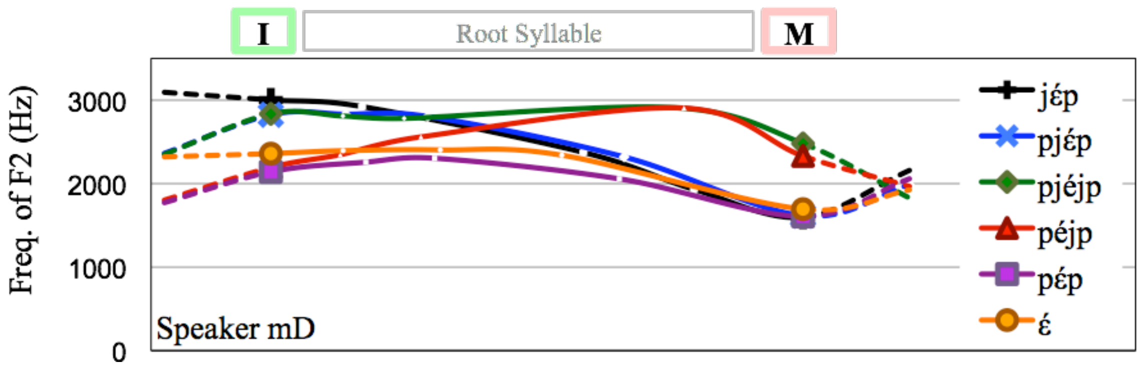


Figure 4.47 Comparison of F2 Tracks of Syllables of the Shape (p)(j)e(j)(p). The track for /e/ represents a composite of three tokens.

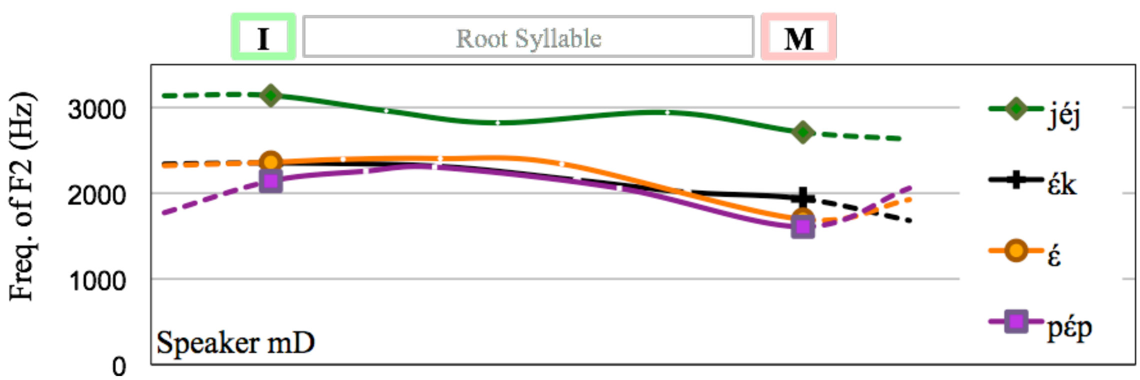


Figure 4.48 Comparison of F2 Tracks of Syllables of the Shape CeC. Each track represents a composite of multiple tokens (6 tokens for /pɛp ɛk/, and 3 tokens for [ɛ] and [je̯j]). The labial /p/ imparted discernible marginal effects on the unrounded kernel /e/. However, the velar obstruent /k/ did not impart marginal effects.

4.2.4.3 Allophonic Loci for the Phoneme /e/

The allophonic loci of /e/ were organized along a single axis: a fronting axis from the prototypical locus of the kernel vowel /e/ to the locus of the pre-kernel glide /j/. A centralizing axis from prototypical locus of the kernel vowel /e/ to the locus of schwa was not observed with the control frame of elicited responses. Unstressed /e/ suffixes did potentially create a centralizing axis from [e] to schwa. Unstressed /e/ suffixes ending as schwa were noted by Jones and Ward (1969: 53), and Hamilton (1980: 44).

Within the syllables considered, a nucleus containing the phoneme /e/ behaved like a single-target monophthong [e]/[ɛ], like a two-target offglide diphthong [ej]/[ɛj]; a two-target offglide diphthong [jɛ], or like a triple-target triphthong [je̝j]. In determining the allophonic loci of the kernel /e/ in these nuclei, measurements were collected at local extrema. The mid-syllable extrema represented the kernel of monophthongal /e/ and triphthongal /jej/, the terminal extremum represented the kernel of diphthongal /je/, and conversely, the initial extremum represented the kernel of diphthongal /ej/.

Thus, in the Figure 4.49, although entire vowel tracks of multiple tokens of the selected syllables are plotted, the allophonic loci for the kernel /e/ were isolated by averaging the appropriate localized extrema for the selected syllables, and these extrema (allophonic loci) of the kernel /e/ have been highlighted with oversized icons.

The terminal loci of the differing types of syllables clustered into five categories, by sequence type:

1) ÇĕC: the kernel of the [vjɛkáx] terminated at the highest locus.

2) ÇéÇ: the kernel of [vjéki] terminated the furthest forward.

3) KéÇ: the kernel of [éj] initiated either at [e] or [ɛ], depending on speaker.

4) KéK: the kernel of [ɛ́k] initiated either at [e] or [ɛ], depending on speaker.

5) ÇéK: the kernel of [vjékax] terminated the least forward.

Although the loci for KéÇ and KéK merged for some speakers, the locus of the kernel of KéK was never higher than that of KéÇ, and conversely, the locus for the kernel of KéÇ was never lower than that of KéK. If the two loci were not merged, then this relationship was more obvious, with the close-mid locus of KéÇ at [e] clearly higher than the open-mid locus KéK at [ɛ], which are the conventional loci posited by DCT.

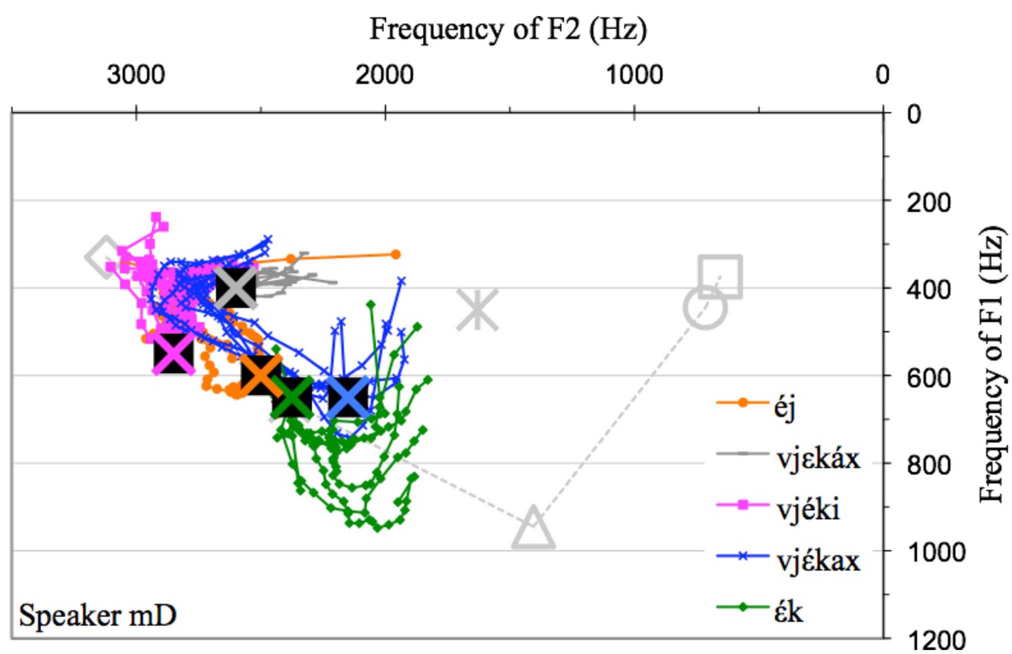


Figure 4.49 Comparison of Allophonic Loci for the Kernel /e/. The figure contains multiple tokens of each of the selected suffixed syllables containing the kernel /e/ (3 tokens for /ej/, and 6 for the remainder). Only the root syllables are depicted. For this speaker, some tokens of [ɛk] initiated at [e], and attained a position in the vicinity of [ɛ] circa mid-syllable, while other tokens attained a position closer to [æ] circa mid-syllable.

4.2.5 Allophones of the Phoneme /i/

The phoneme /i/ was observed in syllables without obstruents, in syllables with obstruents, and in syllables in which the primary contrast is stress placement. The behavior observed in the data indicated that separate loci for ÇíÇ and ÇíK sequences are warranted. This separation was previously presented by Jones and Ward (1969).

A comparison of the allophones of /i/ indicated by three studies is presented in Table 4.18. This section will only address nuclei with the kernel /i/, which do not contain the pre-kernel segment /ɨ/ (to be addressed in section 4.2.6).

Table 4.18 Comparison of Observed Allophones for the Kernel /i/ (and /y/). The locus for ÇíÇ sequences was distinctly different (higher and further forward) from the locus encountered in ÇéK sequences.

	Segment Contrast			Allophonic Loci		
	Pre-Kernel	Post-Kernel	Kernel Stress	Hamilton 1980	Jones & Ward 1969	Current Study
CiC	ÇiC	ÇiÇ	ÇíÇ	i	i˔	i˖
			ÇĭÇ	ɩ	ɩ	i(j)
		ÇiK	ÇíK	i	i	i
			ÇĭK	ɩ	ɩ	ɪ
	KyC	KyK	Ky̆K	ɨ	ᵻ	ɨ
			KýK	ɨ	ɨ ɨ˖ ɨ˔	ɨi
		KyÇ	KýÇ	ɨ	ɨ	ɨi(j)
			Ky̆Ç	ɨ	ᵻ	ɨ(j)

4.2.5.1 The Phoneme /i/ as the Nucleus of Syllables Without Obstruents

As shown in Figure 4.50, syllables containing /i/ in the kernel position exhibited systematic behavior. Syllables /i ij/, which possessed equivalent pre-kernel sequences, exhibited equivalent initial behavior. Syllables /i ij/, which did not possess equivalent post-kernel sequences, did not always exhibit equivalent terminal behavior.

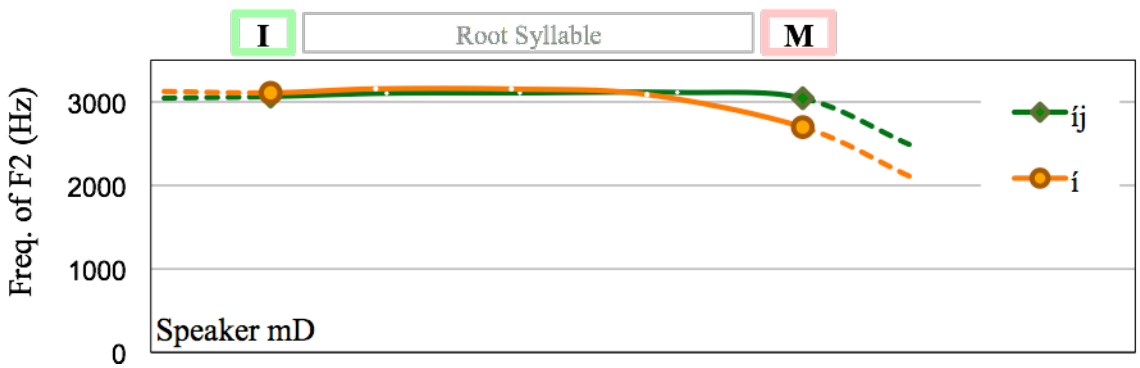


Figure 4.50 Comparison of F2 Tracks of Syllables of the Shape i(j). Each track represents a composite of three tokens. Monophthongal /i/ occasionally gravitated to a more centralized position before the terminus. The sonorous portion of the diphthong /ij/ was maintained as a steady-state.

For all speakers, the initial behavior and the terminal behavior of /ij/ was equivalent, in that the syllable was consistently on-target to the locus of [i], since the offglide /j/ in the coda usually protected the kernel from exhibiting a transition to the following segment, and reinforced the kernel's time-on-target, until after the terminus.

The codaless syllable /i/, however, was not protected from transition to the following segment, and an offset was often registered. On occasion, if the sonorous phonation of /i/ was terminated before a transitional offset occurred, then the terminal behavior of /i/ was equivalent to the terminal behavior of /ij/.

With the behavior exhibited by the bare vowel syllable /i/ posited as the prototypical behavior for the phoneme, the systematic behavior of the syllables with /i/ as the kernel as follows:

1) The bare vowel syllable /i/ was a steady-state monophthong, and as such F2 is asymptotic for the majority of duration of a normal monophthongal syllable.

2) The onsetless syllable /ij/ conformed initially to the behavior of onsetless /i/.

3) The terminal behavior of the syllable /ij/ usually failed to conform to the terminal behavior of the syllable /i/. This occurred primarily because the point of articulation of the offglide is equivalent to the point of articulation of the kernel. As such, the formant track(s) of a syllable containing /ij/ appeared to be constant, from mid-syllable until the terminus regardless of other coda effects. In contrast, the syllable /i/ without offglide often registered marginal effects in closed syllables or gravitated to neutral vowel-space in an open syllable.

4) Since the point of articulation of the kernel /i/ and the post-kernel glide are equivalent, the mid-syllable behavior for syllables containing /i/ was usually equivalent, regardless of the presence or absence of an offglide.

4.2.5.2 The Phoneme /i/ as the Nucleus of Syllables With Obstruents

As shown in Figure 4.51, syllables containing /i/ in the kernel position exhibited systematic behavior. Syllables with equivalent pre-kernel sequences exhibited equivalent initial behavior, and syllables with equivalent post-kernel sequences exhibited equivalent terminal behavior.

With the behavior exhibited by the bare vowel syllable /i/ posited as the prototypical behavior for the phoneme, the systematic behavior of syllables with /i/ as the kernel was as follows:

1) The bare vowel syllable /i/ is a steady-state monophthong, and as such, F2 is asymptotic for the majority of the syllable. Since /i/ is unrounded, labial damping was registered at the initium or at the terminus of /pip/. Labial damping was not registered at the initium, if the syllable onset was performed with a discernible amount of aspiration. In such cases, the labial damping had effectively dissipated prior to the initium.

2) The initial behavior of the syllable /pijp/ conformed to the initial behavior of the syllable /pip/, since both initiated with the sequence /pi/.

3) The terminal behavior of the syllables /pip ip/ was equivalent, since both terminated with the sequence /ip/. Based upon values of F2 alone, the terminal behavior of /pijp/ appeared to be equivalent to /i/. However, terminal labial damping is registered on /pijp/. The open syllable /i/ tended to gravitate towards neutral vowel-space, however, depending on speaker. These differences were disambiguated by consulting F1.

4) The mid-syllable behavior of /pijp pip/ are equivalent, because the offglide does not represent a change in the point of articulation in the syllable /pijp/.

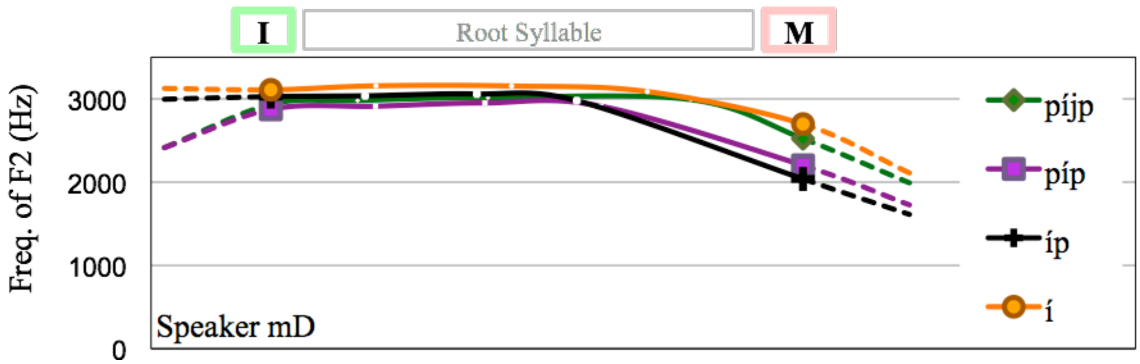


Figure 4.51 Comparison of F2 Tracks of Syllables of the Shape (p)i(j)(p). The track for /i/ represents a composite of three tokens. All other tracks represents a composite of six tokens. Terminal labial damping are registered on syllables terminating in /ip/. There is no apparent initial labial effect on syllables initiating with /pi/ by this speaker. Due to a prominent zone of aspiration, labial damping has ceased before the initium.

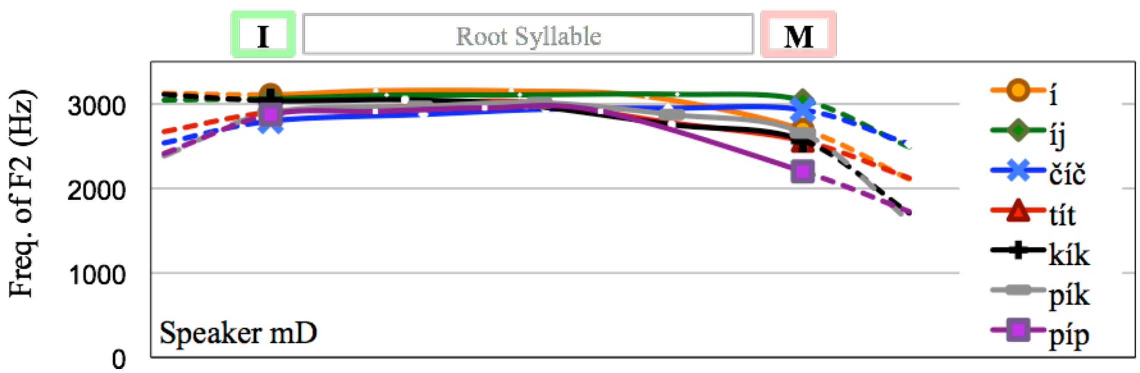


Figure 4.52 Comparison of F2 Tracks of Syllables of the Shape CiC. Each track represents a composite of multiple tokens (6 tokens for /pip pik/, and 3 tokens for the remainder).

As shown in Figure 4.52, varying the consonant(s) of the onset and coda did not generate allophonic mid-syllable variants of kernel vowel /i/. According to DCT, all syllables containing the nucleus /i/ are ÇV syllables, and the allophonic variant of /i/ in

KV syllables is represented by the locus of /y/. The current data set did not offer evidence to refute this premise of DCT on the grounds of syllables containing /i/ alone. Syllables containing /y/ were more illustrative in demonstrating that the binary contrast between /i y/ based upon classification of the consonants which DCT assigns to them is insufficient to account for the allophonic variants observed.

Regarding the syllables containing /i/ at hand, the labial obstruent /p/ imparted initial labial damping to the kernel /i/. In addition, the coronal onsets /t č/ impart an initial marginal effect in F2, directed at a frequency which is lower than the frequency of /i/ at the initium. An improvement in sensitivity in the acoustic software or liberal use of fricatives in the onset should help to isolate the particular frequency to which these onsets gravitate.

Regarding the terminus, a variety of effects were registered on the kernel /i/. Labial damping was registered by the labial obstruent /p/. The velar obstruent did not appear to impart any terminal marginal effects, and hence the terminal values of F2 for /i kik pik/ are equivalent. All three syllable appeared to be gravitating towards a more centralized position in vowel-space. The terminal locus of /i/ only tended to remain at a front position in vowel-space before the codas that contained palatal segments.

4.2.5.3 Allophonic Loci for the Phoneme /i/

The allophonic loci of /i/ were organized along a single axis: a centralizing axis from the prototypical locus of the kernel vowel /i/ into neutral vowel-space. Unstressed kernels for /i/ were only observed in unstressed suffixes. Only the initium of these suffixes existed within the control frame of elicited responses. These suffixes were open syllables, and tended to gravitate to neutral vowel-space. These unstressed suffixes did travel through the unstressed locus [ɪ], indicated in Table 4.18; however, they often continued further into neutral vowel-space, approaching the locus of schwa.

Measurements from unstressed kernels /i/ will need to be collected to determine if either of these potential loci ([ɪ] or [ə]) are attributable to external factors, or whether they accurately represent behavior attributable to unstressed /i/.

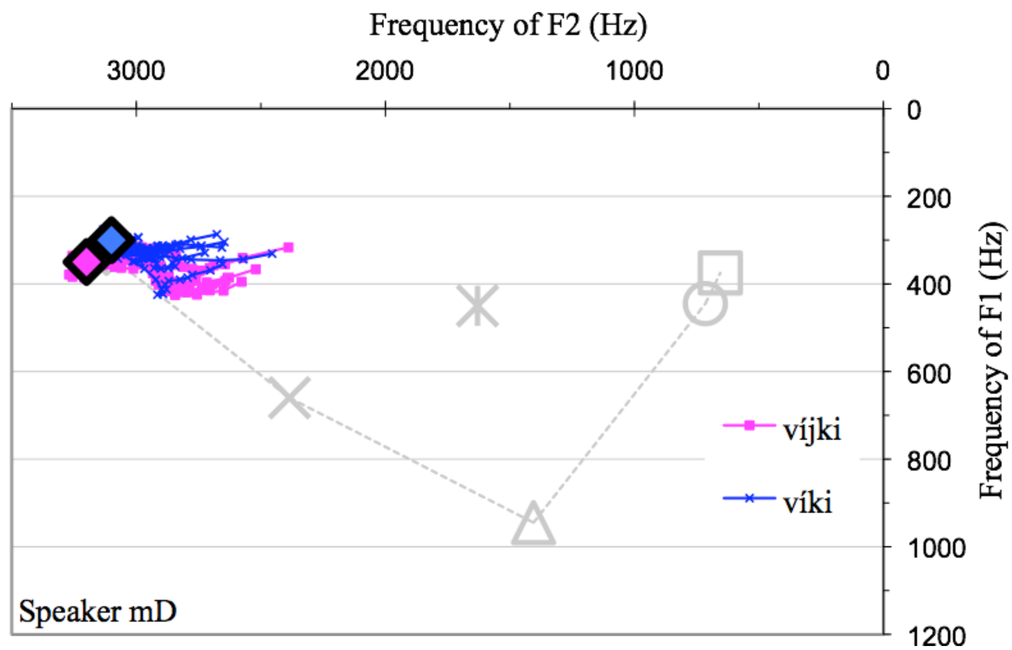


Figure 4.53 Comparison of Allophonic Loci for the Kernel /i/. The figure contains six tokens of syllable type. Only the root syllables are depicted. Oversized icons represent terminal extrema. Initial start point of syllables is less front, due to labial damping of F2.

Within the syllables considered, a nucleus containing the phoneme /i/ behaved like a single-target monophthong /i/, like a two-target offglide diphthong /ij/, based upon a change in sonority at the terminus; or a two-target offglide diphthong [jɪ], in the case of unstressed suffixes. In determining the allophonic loci of the kernel /i/ in these nuclei, measurements were collected at local extrema. Since the final root syllable of all of selected lexical items were labial-initial, labial damping was always registered at the initium of lexical items containing /i/ kernels. As such, the extrema of a kernel /i/ occurred either mid-syllable or at the terminus, depending on the next lingual target after the root kernel. The initial extremum was representative of the kernel for stressed and unstressed suffixes.

Thus, in the Figure 4.53, although entire vowel tracks of multiple tokens of the selected syllables are plotted, the allophonic loci for the kernel /i/ were isolated by averaging the appropriate localized extrema for the selected syllables, and these extrema (allophonic loci) of the kernel /i/ have been highlighted with oversized icons.

The terminal loci of the differing types of syllables clustered into three categories, by sequence type:

1) Çíj: the kernel of the [(lat)víjki] terminated forward of [i].

2) ÇíC. ÇíÇ: the kernel of [(ježe)viki] occurred at the locus of [i], and ÇíÇ sequences also terminated at [i]. ÇíK: the kernel of [(ježe)vika] occurred at the locus of [i]; however, ÇíK sequences terminated at locations between [i] and suffix vowel.

3) Çĭ: the kernel of unstressed suffixes initiated between [i] and [ɪ], and the suffixes then tended to gravitate towards neutral vowel-space.

4.2.6 Allophones of the Nucleus /y/

The nucleus /y/ will be observed in syllables without obstruents, in syllables with obstruents, and in syllables in which the primary contrast is stress placement. Unlike the monophthongal nuclei /u o a e i/, the nucleus /y/ exhibits a great degree of variability from context to context, and from speaker to speaker.

A comparison of the allophones of /y/ indicated by three studies is presented in Table 4.19. Only the locus exhibited in unstressed KўK sequences is solely represenatitve of [ɨ]. In KýK, KýÇ, and KўÇ sequences, the on-target behavior of [ɨ] is contained within the onset, and any location in vowel-space measured during the interior of the syllable is likely to be an intermediate position between the pre-kernel target [ɨ] and the kernel (or post-kernel) /i/.

Table 4.19 Comparison of Observed Allophones for the Nucleus /y/. In vowel-space, the sequences [ɨj], [ɨi], and [ɨij] will appear to travel equivalent trajectories. Viewing the fromant tracks in a timed domain will reveal differences in scheduling, pertaining to the arrival at the locus of [i]/[j]. Measurements of formant frequencies at the initial (or terminal) extrema will likely yield equivalent results, regardless of the sequence type.

	Segment Contrast			Allophonic Loci		
	Pre-Kernel	Post-Kernel	Kernel Stress	Hamilton 1980	Jones & Ward 1969	Current Study
CiC	ÇiC	ÇiÇ	ÇíÇ	i	i˔	i˖
			ÇĭÇ	ɩ	ɩ	i(j)
		ÇiK	ÇíK	i	i	i
			ÇĭK	ɩ	ɩ	ɪ
	KyC	KyK	KўK	ɨ	ᵻ	ɨ
			KýK	ɨ	ɨ ɨ˖ ɨ̘	ɨi
		KyÇ	KýÇ	ɨ	ɨ	ɨij
			KўÇ	ɨ	ᵻ	ɨj

4.2.6.1 The Nucleus /y/ in Syllables Without Obstruents

As shown in Figure 4.54, syllables containing /y/ in the kernel position exhibit less systematic behavior than single target-nuclei. The assertion that those syllables that possess equivalent pre-kernel sequences exhibit equivalent initial behavior was more tenuous with syllables containing /y/. However, the claim that those syllables possessing equivalent post-kernel sequences exhibit equivalent terminal behavior proved to be more defendable.

With the behavior exhibited by the onsetless syllable /y/ posited as the prototypical behavior for the nucleus, the systematic behavior of the syllables with /y/ as the nucleus was as follows:

1) The onsetless syllable /y/ was a diphthong [ɨi], and as such, F2 usually increased across the duration of the syllable, as the diphthong travels forward.

2) The onsetless syllable /yj/ did not necessarily conform initially to the behavior of onsetless /y/. The initial locus of the pre-kernel target of the diphthong was hypothetically [ɨ]; however, the nucleus was usually already in transition at the initium, traveling forwards toward the kernel target of /i/. Since the diphthong was usually in transition at the initium, the exact position of the diphthong at the initium is highly variable from token to token.

3) The terminal behavior of the syllable /yj/ (triphthong [ɨij]) often failed to conform to the terminal behavior of the syllable /y/ (diphthong [ɨi]). This was primarily because the point of articulation of the offglide /j/ is equivalent to the point of articulation of the kernel [i]. As such, the formant track(s) of a syllable containing /yj/ consistently

terminated at [i], regardless of other coda effects. In contrast, the syllable /y/ without offglide often registered marginal effects in closed syllables or a gravitated to neutral vowel-space in open syllables.

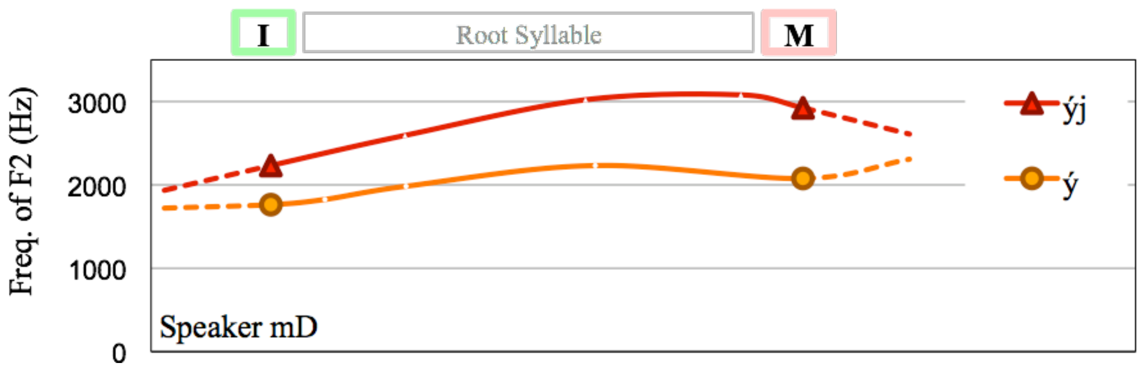


Figure 4.54 Comparison of F2 Tracks of Syllables of the Shape y(j). Each track represents a composite of three tokens.

4.2.6.2 The Element /y/ as the Nucleus of Syllables With Obstruents

As shown in Figure 4.55, syllables containing /y/ as a nucleus exhibited partially systematic behavior. With the behavior exhibited by the onsetless syllable /y/ posited as the prototypical behavior for the nucleus, the systematic behavior of syllables with /y/ as the nucleus was as follows:

1) The onsetless syllable /y/ was a diphthong, which traveled forward across the high perimeter of vowel-space, and as such, F2 increased for the majority of the syllable. Since /y/ is unrounded, labial damping was registered at the initium. However, since the track of F2 for the nucleus /y/ was already increasing, and the initial behavior of onsetless

/y/ syllables was often inconsistent, the additional marginal effects of initial labial damping were not particularly striking.

2) The instantaneous behavior of the syllable /pyjp/ at its initium conformed briefly to the initial behavior of the syllable /pyp/; however, since both syllable types are in transition at the initium, and, owing to the target /j/ in the coda, /pyjp/ had a greater imperative to obtain the high front target associated with the kernel [i] (and the offglide).

3) The terminal behavior of the syllables /pyp yp/ appeared to be equivalent, since both terminate with the similar sequences. In many cases, the variability exhibited at the initium by syllables containing /y/ had stabilized by mid-syllable, and as such syllables which terminated in similar sequences managed to exhibit similar terminal behavior.

As shown in Figure 4.56, varying the consonant(s) of the onset and coda tended to further increase the variability exhibited by syllables containing /y/. Although the syllables /pyp byk/ both began with similar onsets, there was non-conformity of their initial behavior. Likewise, although the syllables /y yj/ were both onsetless, there was non-conformity of their initial behavior.

According to DCT, all syllables containing the nucleus /i/ are ÇV syllables, and the allophonic variant of /i/ in KV syllables is represented by the nucleus /y/. The current data set offers evidence that an additional feature differentiates syllables containing /y/ from syllables containing /i/, regardless of the nature of the consonantal onset, or the initial locus of /y i/, namely, that /y/ is a dynamic diphthong, while /i/ is static.

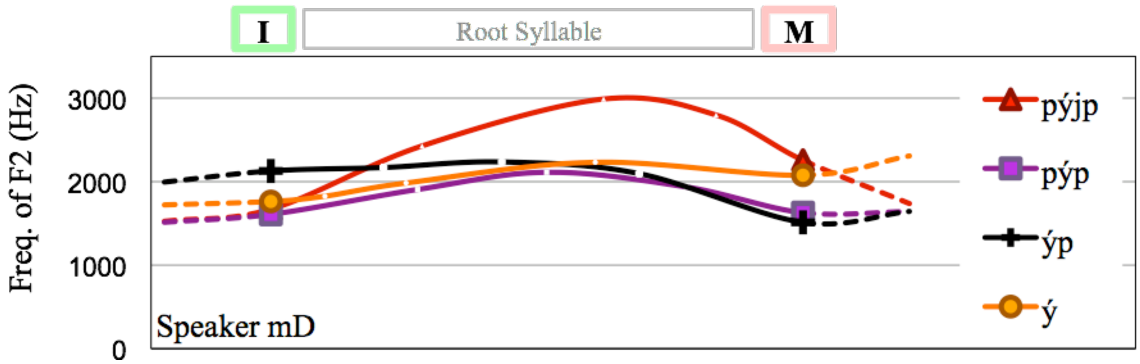


Figure 4.55 Comparison of F2 Tracks of Syllables of the Shape (p)y(j)(p). Each track represents a composite of multiple tokens (3 for /y/, and 6 for the remainder). Terminal labial damping are registered on syllables terminating in /yp yjp/, as evidenced by local maxima prior to the terminus.

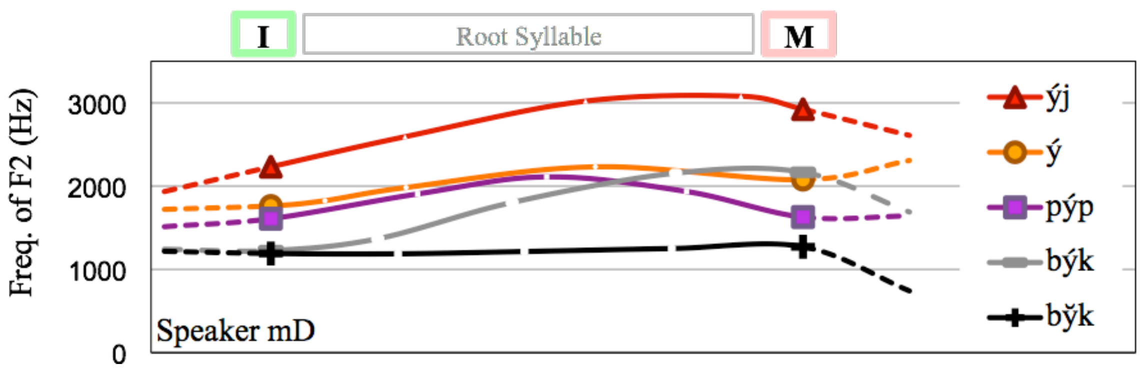


Figure 4.56 Comparison of F2 Tracks of Syllables of the Shape CyC. The unstressed nucleus /y/ did not exhibit diphthongal behavior. The labial /p/ imparted discernible terminal damping on the unrounded kernel of /y/. However, the velar obstruent /k/ did not impart marginal effects. Each track represents a composite of multiple tokens (6 tokens for /pyp byk/, and 3 tokens for the remainder).

For cases in which the nucleus /i/ might be construed to be a diphthong [ji], with a pre-kernel onglide /j/ and a kernel /i/, it should be noted that the structural diphthong [ji] is still static in vowel-space. However, the nucleus /y/ is not static in vowel-space, unless the kernel is deleted, and the diphthong is reduced to a single segment.

4.2.6.3 Allophonic Loci for the Element /y/

In one respect, the allophonic loci of /y/ were organized along a single axis: a fronting axis from the prototypical locus of the pre-kernel vowel /ɨ/ to the locus of /i/. However, it should be noted that this axis represents the trajectory of travel of the diphthong, and not necessarily the alignment of occurrences of the pre-kernel target itself. Identifying the variants of the locus of the pre-kernel was not possible within the constraints imposed by the basic design of the research: namely, that formant measurements would only be taken during the sonorant postion of the syllable. This created a dilemma. As will be presented in section 4.3, the pre-kernel is on-target only during the onset, prior to the initium. As such, the diphthong is already in transition at the initium, and any measurement taken at the initium will only be an intermediate position, somewhere on the transition, between the pre-kernel [ɨ] and the kernel [i]. And therefore, the circumstantial orientation of the locations of the nucleus /y/, taken at the initium, form a fronting axis from [ɨ] to [i].

Since the nucleus /y/ is a diphthong, which typically did not exhibit asymptotic behavior associated with its pre-kernel target during the sonorous portion of the syllable, it is necessary to record more information on the allophonic map of /y/, than was done for the monophthongs /u o a e i/. For this reason, in Figure 4.56, which depicts the behavior of /y/, the position of the vowel in vowel-space is labeled at both the initium and the terminus, for six syllable types containing /y/.

Thus, in the Figure 4.57, although entire vowel tracks of multiple tokens of the selected syllables are plotted, the allophonic positions for the nucleus /y/ were isolated by averaging the initial and terminal extrema for the selected syllables, and these extrema of the nucleus /y/ have been highlighted with oversized icons.

The initial position of the differing types of syllables clustered into three categories, by sequence type:

1) Onsetless ýj: the initium of ýj occurred the furthest forward.

2) Onsetless ý: the initium of ý occurred the position marked as the prototypical locus of /y/.

3) Labial onsets (/vy/ and /by/): the root syllables of the two lexical items exhibited initial labial damping, and initiate further back than onsetless nonsense syllables /y yj/.

The terminal position of the differing types of syllables were distributed into four categories, by sequence type:

1) ýj: with tautosyllabic offglide terminated the furthest forward.

2) KyÇ: sequences with an /i/ suffix terminated in near-front vowel-space, with stressed sequences terminating slightly forward of unstressed sequneces.

3) KýK: sequences with a stressed syllable, but the absence of a following front vowel suffix, terminated slightly less forward.

4) Ky̌K: only unstressed syllables, with the absence of a following front vowel suffix, failed to exhibit any appreciable forward movement and failed to escape central vowel-space.

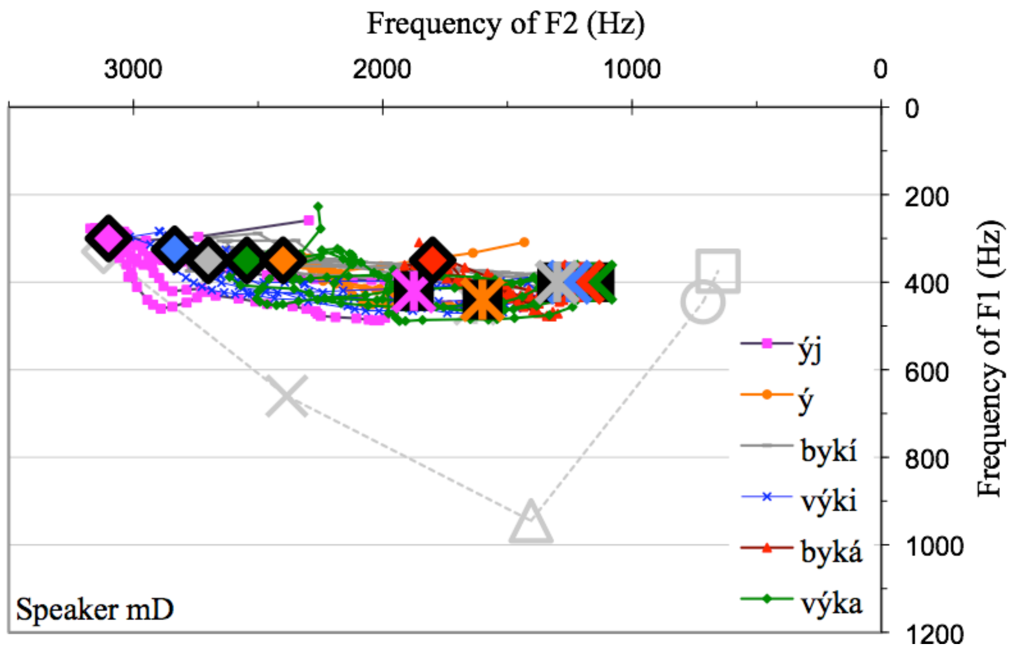


Figure 4.57 Comparison of Initial and Terminal Positions of the Nucleus /y/. The oversized star icons represent the position of the nucleus /y/ at the initium. The four stacked star icons on the far right have a lower value of F2 at the initium due to labial damping. The centralized orange and magenta star icons represent the initium of onsetless nonsense syllables, and thus do not exhibit labial damping. The oversized diamond icons represent the corresponding position of the nucleus /y/ at the terminus. The degree of frontness attained by the /y/ nucleus is affected by the temporal proximity of the initial target of the nucleus to a following high front vowel target and the amount of time that the nucleus has to develop its trajectory to this high front target. Thus the tautosyllabic triphthong /yj/ ([ɨij]) attains the greatest degree of frontness prior to the terminus, because the pre-kernel /ɨ/ is immediately adjacent to the kernel /i/, which in turn carries into the offglide /j/ as a steady-state [i]. Note: Icons buried beneath the uppermost icons have been tiled to one side to verify that all tokens are represented. Thus, only three initial positions are depicted, at the magenta, orange and gray star icons.

4.2.7 Summary of Allophonic Systems for Modern Standard Russian

A number of recurring behaviors were observed with the position in vowel-space attained by allophones of the phonemic vowels of the perimeter of vowel-space.

If the nucleus did not contain an onglide, then the prototypical locus of the phoneme was typically only fully obtained for tonic syllables. In general, if the nucleus was non-tonic, then the allophonic locus of the kernel occurred at a slightly centralized locus in the vicinity of the prototype, or at schwa. If the nucleus occurred in a tautosyllabic or heterosyllabic diphthong with offglide, then the diphthong traveled a trajectory from the allophonic locus of the nucleus, forwards towards the locus of /i/.

If the tonic syllable contained an onglide, but not an offglide, the prototypical locus of the phoneme was not fully obtained, and the diphthong terminated at allophonic locus approximately 200-300 Hz forward of the prototype. If the tonic syllable contained an onglide and a high front vowel occurred as the tautosyllabic offglide of the syllable (and/or as the first lingual target of the following syllable), then the prototypical locus of the phoneme was not fully obtained, and the tautosyllabic/heterosyllabic triphthong ceased backwards movement well in advance of the prototypical target. If the nucleus contained an onglide and the syllable was non-tonic, the nucleus seldom escaped high front vowel-space. All allophonic loci (and transitional trajectories) of nuclei containing an onglide occurred along an axis from /i/ to the prototypical locus of the kernel vowel.

4.2.7.1 Summary of Phonemic Targets

As shown in pane (a) of Figure 4. 52, the phonemic system of Modern Standard Russian contains seven vowel phonemes. Six of the vowel phonemes are distributed around the perimeter of vowel-space, and the seventh phoneme is centralized, at the approximate position of schwa. This schwa position is tentatively posited as the underlying locus for the back jer-u /ъ/, which was not knowingly observed in this data set. The phoneme /ъ/ is posited as the maximally-underspecified vowel of the system.

As shown in pane (b) of Figure 4.58, five of the six perimeter vowels (/i_k e_k a_k o_k u_k/) can occur lexically as the kernel of a syllable nucleus (denoted by the subscript "k"). If this syllable is tonic, an allophone of the lexical kernel vowel will be realized in the surface form of the syllable. If the syllable is non-tonic and reduced, the lexical kernel will be deleted, and the surface form of the syllable will be realized as an allophone of the remaining vocalic information in the pre-kernel of the nucleus.

As shown in pane (c) for Figure 4.58, there are three phonemes permitted to occur lexically in the pre-kernel position of the nucleus, are:

1) The phoneme /i/ can occur in the pre-kernel position of the nucleus (denoted by the subscript "j"), in lexically-defined tautosyllabic onglide diphthongs /$i_j i_k$ $i_j e_k$ $i_j a_k$ $i_j o_k$ $i_j u_k$/. The phoneme /i/ may also occur lexically in the pre-kernel position of a nucleus without a lexically-assigned kernel (e.g., /$i_j Ø_k$/).

2) The phoneme /ɨ/ can occur in the pre-kernel position of the nucleus, only in the lexically defined tautosyllabic diphthong /$ɨ_j i_k$/.

3) The phoneme /ъ/ may occur lexically in the pre-kernel position of a nucleus

without a lexically-assigned kernel (e.g., /$ъ_j Ø_k$/).

As shown in pane (d) of Figure 4.58, only one vocalic phoneme is permitted in the sonorant position of the coda, which is immediately post-kernel. This solitary vocalic phoneme is /i_c/. As such, the phoneme /i/ can potentially be the offglide й (/j/), the tonic kernel vowel и (/í/), or the pre-kernel onglide /j/, which can be realized as ь (/j/), if it occurs word-finally in the pre-kernel position of a partial syllable.

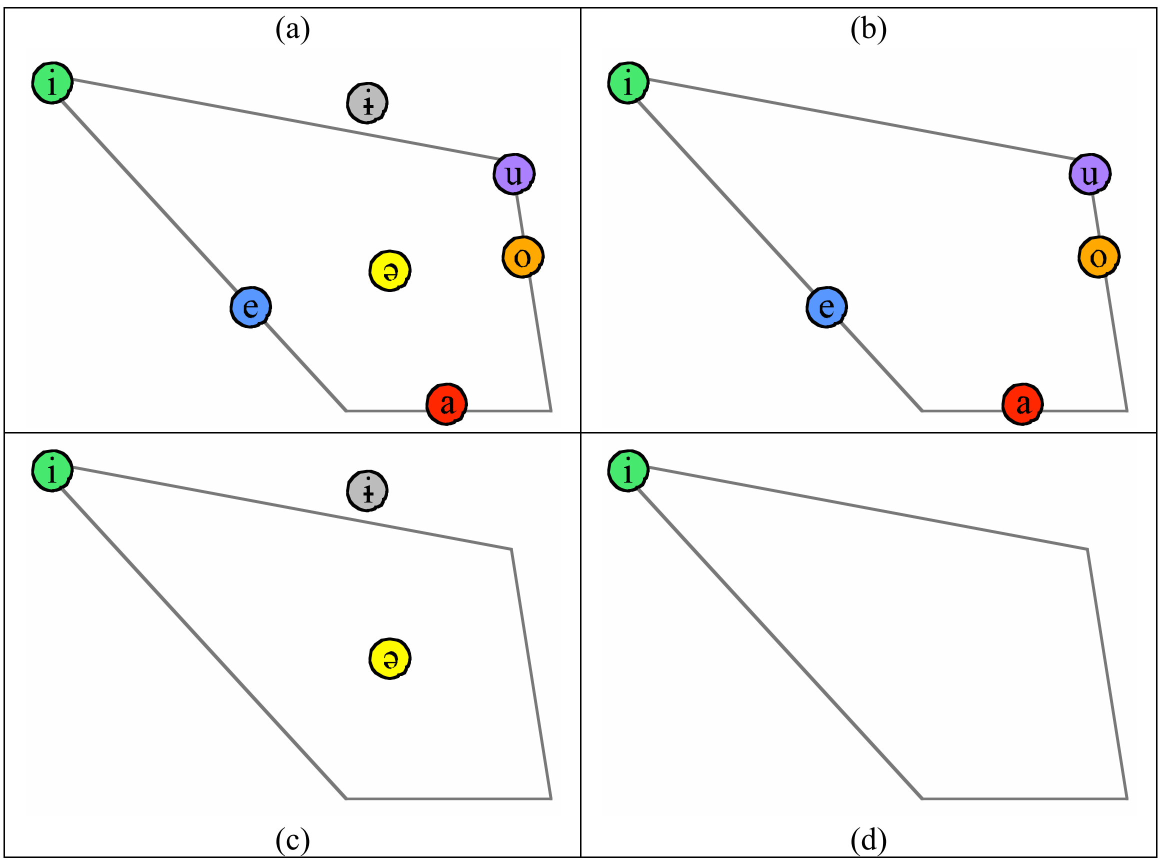


Figure 4.58 A Stylized Configuration of the Phonemic Targets and Their Roles. (a) Prototypical Phonemic Targets; (b) Lexical Kernel Targets; (c) Nucleic Pre-Kernel Targets; (d) Offglide Targets in the Coda. Schwa is tentatively posited as the location of the back jer-u. Schwa also represents the maximally underspecified position of reduced kernels. Note: Targets in the diagram have been dispersed for maximum visibility.

4.2.7.2 Summary of Allophonic Assignments

As in pane (a) of Figure 4.59, a system of axes has been posited to account for the location of allophonic loci of the vowel of the phonemic system. The axes are divided into two categories: fronting axes and centralizing axes[7].

The fronting axes, which are isolated in pane (b) of Figure 4.59, represent the alignment of allophonic loci of a phoneme, when it occurs in conjunction with /i/, in tautosyllabic and heterosyllabic diphthongs and triphthongs. The fronting axes also represent the acoustic trajectories of these diphthongs and triphthongs, which will be presented more fully in section 4.2.7.3.

The centralizing axes, which are isolated in pane (c) of Figure 4.59, represent alignment of potential reassignment of allophonic loci, associated with lexically-defined kernels, as well as the potential trajectories of heterosyllabic coarticulations which do not involve a glide /j/ (since these trajectories were already considering in the configuration of fronting axes).

In pane (d) of Figure 4.59, the link between /ɨ/ and schwa has been removed, because /ɨ/ does not exist as a nucleic kernel, and as such, it is not subject to rules which might reassign it to a maximally underspecified vowel as a kernel. However, as depicted in pane (c), /ɨ/ might still be involved in trajectories of heterosyllabic diphthongs.

[7] Note: the axes represent relationships between the phonemes, and do not necessarily depict acoustic trajectories through vowel-space. The phoneme targets have been artificially dispersed to enhance visibility, and to prevent overlap of the conceptual axes between targets.

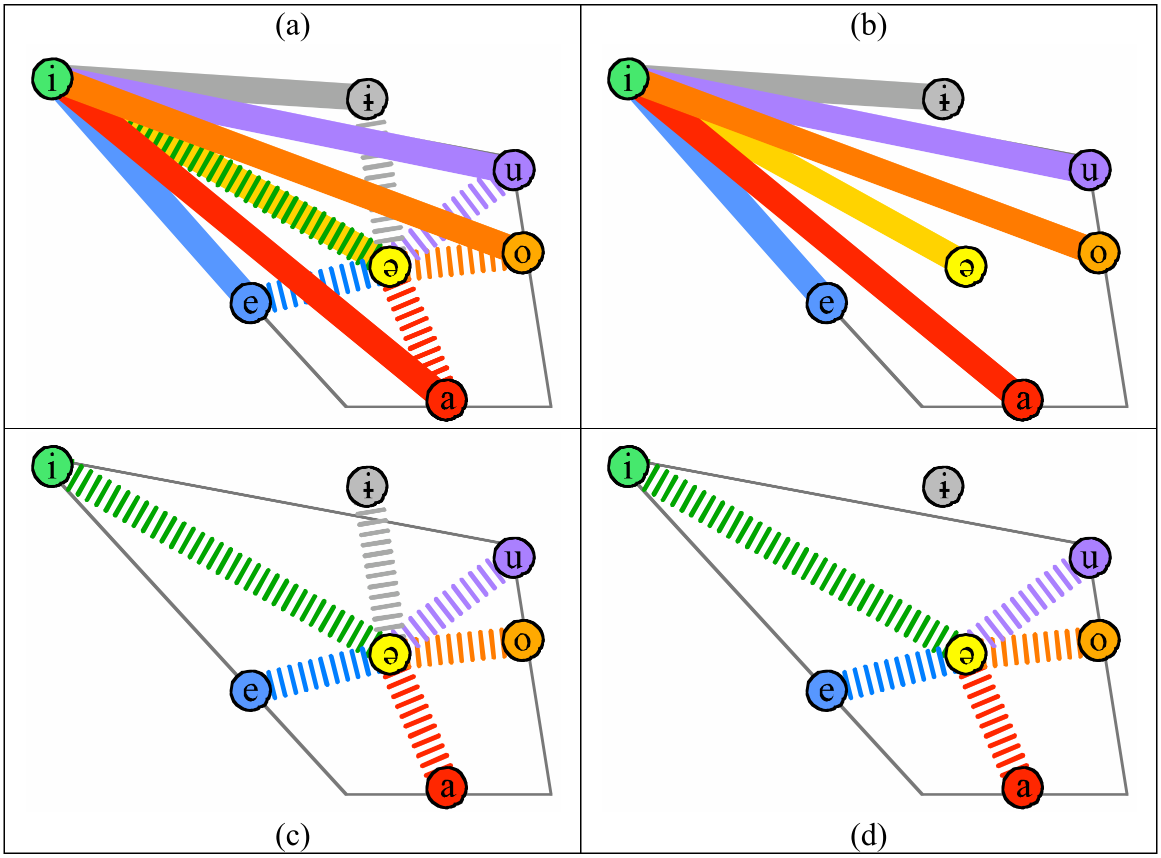


Figure 4.59 A Stylized Configuration of Fronting and Centralizing Axes Involving the Phonemic Targets. (a) All Potential Axes; (b) Potential Fronting Axes; (c) Potential Centralizing Axes; (d) Allophonic Centralizing Axes. Fronting axes represent tautosyllabic and heterosyllabic trajectories through vowel-space, and also represent axes of relocated loci of reduced kernels in diphthongs/triphthongs. Centralizing axes primarily represent the alignment of relocated loci for reduced kernels, but potentially may also represent heterosyllabic trajectories between kernels, across interludes, in the absence of glides. In pane (d), /ɨ/ does not exist as a kernel (reduced or otherwise), and hence, cannot have a centralizing axis denoting potential relocation of kernel loci.

In pane (d) of Figure 4.59, centralizing axes have been connected between schwa and the five potential lexical kernel targets. These five axes represent the maximum number of relationships that can occur in a dialect in Modern Russian; however, depending on dialect, not all of the potential axes will be realized.

For instance, in the standard dialect, phonological processes will preserve the kernel information of high vowels, and reduced high vowels will not be reassigned to a maximally underspecified schwa-like vowel. As such, in the standard dialect, the unstressed allophonic loci for the kernels /i u/ do not become completely centralized to schwa, but only slightly centralized to the approximate position of [ɪ] and [ʊ], respectively. These allophonic reassignments do not necessarily involve a change in ATR, which is associated with [ɪ] and [ʊ] in some systems of notation.

In the southern dialect, phonological processes preserve the contrastive information of all lexically-defined kernel vowels, and hence, kernels effectively do not reduce to schwa, and this in turn effectively eliminates all of the centralizing axes in pane (d) of Figure 4.59, as depiction of allophonic reassignment. In such cases, the centralizing axes will represent the trajectories of heterosyllabic coarticulations.

The system of potential centralizing axes provides a mechanism to describe those dialects which exhibit reduction for all kernels, only specific kernels (as is the case of non-high kernels in the standard dialect), or no kernels (as in the case of the southern dialect). The system provides for complete centralization (to schwa) or partial centralization to an intermediate locus between schwa and the kernel's prototypical perimeter locus, and (vacuously) zero movement along an axis, which will result in the allophonic reassignment to the original prototypical perimeter locus of a kernel.

4.2.7.3 Summary of Tautosyllabic Trajectories

As submitted previously, the fronting axes not only represent the alignment of allophonic loci associated with the targets of the perimeter and their interaction with the target /i/, but they also represent the contiguous trajectories through vowel-space of tautosyllabic (and heterosyllabic) diphthong and triphthongs. These trajectories may traverse uni-directionally forwards in vowel-space along the axis, as in the case of offglide diphthongs or the diphthong /ɨi/ or /ɨj/; may traverse uni-directionally backwards in vowel-space along the axis, as in the case of onglide diphthongs, and may traverse bi-directionally along the axis, from /i/ to the kernel, and then returning forwards to /i/.

The fronting axes involving the high front target /i/ may be uni-directional (in either direction) or bi-directional. If travel along the axis is uni-directional, and forwards in vowel-space (i.e., an offglide diphthong), and the kernel is tonic, then the trajectory will originate at the prototypical locus of the kernel vowel, and the kernel will be fully obtained, at the initium. If the kernel is non-tonic, then the diphthong will originate at allophonic locus of the reduced nucleus. Depending on dialect, this allophonic locus will be at various locations along the centralizing axis associated with the phonemic kernel.

If travel along the axis is uni-directional and backwards in vowel-space (i.e., an offglide diphthong), and if the kernel is tonic, then the trajectory will originate at the prototypical locus of /i/, and the kernel will be not fully obtained; as a result, the diphthong will usually terminate at an allophonic locus forward of the prototype. If the kernel is non-tonic, then the diphthong will terminate at an allophonic locus of the reduced nucleus. In the standard dialect, if this reduced nucleus is a suffix, then the diphthong may terminate of the fronting axis associated with schwa.

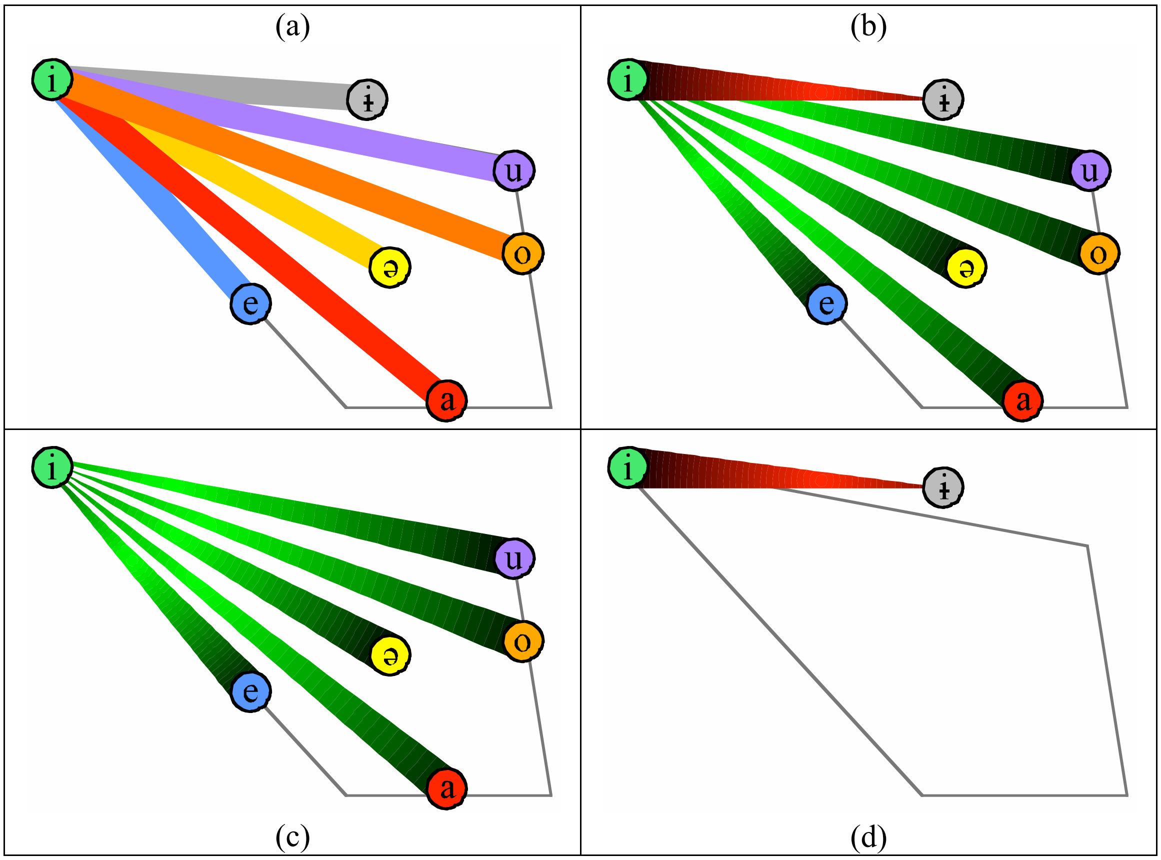


Figure 4.60 A Stylized Configuration of the Directionality of Fronting Axes. (a) Potential Fronting Axes; (b) Actual Fronting Axes; (c) Fronting Axes with Pre/Post-kernel /i/; (d) Fronting Axes with Pre-kernel /ɨ/. In pane (c), if the axes with the pre/post-kernel /i/ represent trajectories, they may traverse in either direction for onglide or offglide diphthongs, or bi-directionally for triphthongs. In pane (d), the axis with the pre-kernel /ɨ/ may only traverse forwards for diphthongal /ɨi/ or triphthongal /ɨij/.

If travel along the axis is bi-directional (i.e., a triphthong) and the kernel is tonic, then the trajectory will attain a localized extremum associated with the kernel. The location of this extremum in vowel-space will occur on the fronting axis, and the degree to which this extremum attains the prototypical locus of the kernel can vary greatly from speaker to speaker. If the kernel is non-tonic, the allophonic locus attained by the nucleus will be [i] for front vowels (which is on the fronting axis for /e/, and on the stationary fronting axis for /i/), or at [ɪ] which is at the convergence of all fronting axes for back vowel kernels.

The fronting axis for /ɨ/ (depicted in pane (d) of Figure 4.60) is usually constrained to be uni-directional, traveling forwards from the pre-kernel /ɨ/ to following /i/-target, whether it be a tautosyllabic kernel /i/, a tautosyllabic offglide/j/, a heterosyllabic pre-kernel /j/, or a heterosyllabic kernel /i/. The axes of these four combinations are equivalent. The only instances in which the fronting axis for /ɨ/ will travel backwards through vowel-space will involve heterosyllabic sequences in which /ɨ/ follows a syllable with a final lingual target of /i/ or /j/.

4.2.7.4 Phonological Processes Resolving Underlying Nucleus Constituency

The following discussion of processes, which can be resolved by a small number of primitives to create an array of various surface forms, capitalizes on the concept of a bifurcated nucleus, the phonemic vowel targets, and their fulfillment of roles within the bifurcated nucleus.

Utilizing the phoneme inventory presented in Section 4.2.7.1, Table 4.20 can be generated, exhausting the potential valid combinations of pre-kernel and kernel constituents in the nucleus. Thus, the pre-kernel can have four states: it can be unoccupied or it can be occupied by one of the three phonemes: /i ɨ ъ/ (with /ъ/ being the back jer-u). The kernel can have six states: it can be unoccupied, or it can be occupied by one of the five vowels of the perimeter: /i e a o u/.

The perimeter phonemes have been organized into two subsets: alpha and omega. The members of set alpha are prone to vowel reduction in unstressed environments. The members of set omega are resistant to vowel reduction. The membership of the two subsets is defined by dialect. For the standard dialect, the omega set contains high vowels /u i/, and the alpha set contains non-high vowels /a o e/.

The following set of steps is posited to produce phonemic sequences to be used as input to phonological rules. The starting conditions of this set of steps make use of only four primitives: stress placement, a bifurcated nucleus (with selective membership control on the constituency of each node), seven phonemic vowels, and (variable) dialectal definition of selective membership of sets alpha/omega for kernel vowels. This process is accomplished without invoking any systematic division of consonants: soft/hard, sharped/unsharped, palatalized/unpalatalized, etc.

Step 1) (Re)syllabification: Assign the segments of the underlying phonemic sequence to nodes in the syllables structure.

Step 2) Glide Epenthesis: Insert an onglide /j/ into the pre-kernel node, if any node of the onset is occupied.

Concentrating only on the segments which have been assigned to the nucleus,

Step 3) Stress Check: Assign stress to the appropriate nucleus nodes. Accept the position of stress placement assigned by the lexicon, or else resolve any issues arising from affixation, which can override the position of lexical stress.

Step 4) Stress Morafication: Assign one mora to each nucleus node which is marked for stress. Ignore nuclei not marked for stress.

Step 5) Kernel Verification: Verify that the kernel of a nucleus marked for stress is occupied. If it is unoccupied, insert an underspecified vowel into the kernel. This will ensure that all stressed nuclei contain a segment which can bear sonorous phonation. Ignore nuclei that already contain a kernel. This step will effectively only address underlying jer vowels.

Step 6) Constituency Morafication: Assign one mora to each nucleus containing an occupied kernel. Additional mora can potentially be assigned during this step for syllables containing a sonorant in the post-kernel node of the coda, or word-final open syllables, or word-initial onsetless syllables. Ignore syllables which do not contain an occupied kernel. This step will effectively only address underlying jer vowels.

Step 7) Alpha/Omega: Copy the kernel onto an unoccupied pre-kernel node for kernels with members in subset omega, or for kernels of stressed nuclei. This effectively creates double-target (long) vowels. This step may potentially entail copying some features of an omega kernel onto an occupied pre-kernel, e.g., copying the feature of roundness from the kernel onto the pre-kernel to preserve a salient feature of back vowels, even if the kernel is deleted.

Step 8) Unstressed Kernel Deletion: Delete the kernel of an unstressed nucleus.

Step 9) Set Targets: Project the specified phonemic articulatory features from the remaining occupants of the nucleus (and post-kernel glide) onto the vowel tier. If a segment is underspecified and lacks features, project only sonority to the timing chain.

Step 10) Set Anchor-points: Set timing anchor-points for the first element of the nucleus onto the timing chain. The articulators are to be reliably on-target for the specified features of the target at the time of the anchor-point. At this point in the derivation, the pre-kernel has either retained contrastive features from its origin in the lexicon, or has adopted redundant features from the kernel. As such, it should be possible to access only the pre-kernel node for articulatory to accurately obtain the features of the first segment of the nucleus. Only two possible combinations will yield unspecified segments in the pre-kernel: Lines 1 and 5 of Table 4.20, and in each of these cases the pre-kernel is equally as underspecified as the kernel.

Step 11) Vocalic Coarticulations: Plan transitions from the vocalic targets, which are fixed at the anchor-points, to surrounding targets. The glide transitions from the pre-kernel segments to the phonemic targets of the perimeter are relatively gradual, and typically require more than one mora to be successfully completed.

As will be shown in Section 4.3, the pre-kernel target has precedence over both the kernel and the post-kernel targets, in terms of preserving specified articulatory information. In turn, the post-kernel target has precedence over the kernel. As such, the features of the kernel are most likely to be sacrificed, and the kernel will most fully obtain its prototypical target when the pre-kernel is not contrastive. Furthermore, this full obtainment will likely occur only at the initium, since post-kernel segment, which can only be /i/ (and then the pre-kernel of the following syllable), will gain control of the articulators, in an attempt to arrive on-target circa their appointed anchor-points. The partial sacrifice of the kernel does not necessarily result in loss of contrast, since the fronting axes associated with the various phonemic targets are distinct from one another.

Table 4.20 Derivation of Phonetic Surface Forms from Underlying Phonemic Segments. μ = a mora assigned to the nucleus; Ø = an unoccupied node; V = an underspecified vowel; α = a specified vowel which is prone to reduction; and ω = a specified vowel which is protected from reduction. The membership of α and ω varies by dialect. The membership listed with the table is for the standard (Moscow) dialect.

Reference	Cyrillic	Pre-kernel & Kernel Constituents	Output of Step 4	Output of Step 5	Output of Step 6	Output of Step 7	Output of Step 8	Phonemic Result	Phonetic Result	Moraic Count
1	ъ	ъ Ø	ъ Ø	ъ Ø	ъ Ø	ъ Ø	ъ Ø	ъ	ə	0
2	ь	j Ø	j Ø	j Ø	j Ø	j Ø	j Ø	j	i	0
3	ъ + '	'ъ Ø	μ'ъ Ø	μ'ъ V	μ'ъ Vμ	μ'ъ Vμ	μ'ъ Vμ	ъV	ə	2
4	ь + '	'j Ø	μ'j Ø	μ'j V	μ'j Vμ	μ'j Vμ	μ'j Vμ	jV	i/jə	2
5	а, о	Ø α	Ø α	Ø α	Ø αμ	Ø αμ	Ø Øμ	V	ə	1
6	а́ о́ э́	'Ø α	μ'Ø α	μ'Ø α	μ'Ø αμ	μ'α αμ	μ'α αμ	α	α	2
7	и у	Ø ω	Ø ω	Ø ω	Ø ωμ	ω ωμ	ω Øμ	ω	ω	1
8	и́ у́	'Ø ω	μ'Ø ω	μ'Ø ω	μ'Ø ωμ	μ'ω ωμ	μ'ω ωμ	ω	ω	2
9	я ё е	j α	j α	j α	j αμ	j αμ	j Øμ	j	i	1
10	я́ ё́ е́	'j α	μ'j α	μ'j α	μ'j αμ	μ'j αμ	μ'j αμ	jα	jα	2
11	ю	j ω	j ω	j ω	j ωμ	j ωμ	j Øμ	j	i	1
12	ю́	'j ω	μ'j ω	μ'j ω	μ'j ωμ	μ'j ωμ	μ'j ωμ	jω	jω	2
13	ы	ɨ i	ɨ i	ɨ i	ɨ iμ	ɨ iμ	ɨ Øμ	ɨ	ɨ	1
14	ы́	'ɨ i	μ'ɨ i	μ'ɨ i	μ'ɨ iμ	μ'ɨ iμ	μ'ɨ iμ	ɨi	ɨi	2

Step 12) Consonantal Transitions: Plan transitions from the consonants onto the existing contour of the vocalic tier. Only coronal consonantal transitions will compete

for articulators which were planned in step 11) vocalic coarticulations. Because coronal consonants compete for articulators with the lingual articulation of vowels, they represent confounding factors to the study of vowel-to-vowel coarticulations, and as such interludes with coronal consonants were eliminated from the current data set. Further study would need to be conducted beyond the current data set, to include coronal consonants, to determine to what extent Steps 11 and 12 can be combined or restructured.

As shown in Table 4.20, the surface forms of underlying nuclei are as follows:

1. An unstressed back jer-u represents a partial (kernelless) nucleus. The surface form of a back jer-u has no feature specifications, and without a mora count, an unstressed back jer-u will not exhibit sonorous phonation.

2. An unstressed front jer-i represents a kernelless nucleus. The surface form of a front jer-i has feature specifications, but without a mora count, an unstressed front jer-i will not exhibit sonorous phonation, but can manifest as a voiceless fricative.

3. A stressed back jer-u will exhibit sonorous phonation, but having no feature specifications, it is likely to exhibit preservative or anticipatory effects of surrounding specified (anchored) vowel targets or coronal consonants.

4. A stressed front jer-i will be expressed as [i], or potentially as [jə] in a word-final position.

5. An unstressed alpha vowel will be lose its feature specifications and be expressed as schwa, or exhibit preservative or anticipatory effects of surrounding specified (anchored) vowel targets or coronal consonants.

6. A stressed alpha vowel will retain its feature specifications, and be expressed as a perimeter vowel. It will receive two or more mora, and as such the initium (which is anchored) will be protected from competition from the next vowel target, and the initium will be reliably on-target to its prototypical target.

7. An unstressed omega vowel will retain its feature specifications, and will be expressed as a perimeter vowel. The anchor-point for the omega nucleus will ensure that the vowel is on-target. However, the nucleus will receive only one mora of sonorous phonation. As will be shown in section 4.3, approximately one half of the pre-kernel mora is contained within the consonant onset. As such, only approximately one half mora bears the sonorous phonation of an unstressed syllable. The pre-kernel of the following syllable gains control of the articulators, planning a transition backwards in time (into the prior unstressed syllable) in order to guarantee is arrival on-target for its own anchor-point. As such, the terminus (and perhaps earlier) of the unstressed syllable in line 7 is vulnerable to gravitating off-target, towards the following pre-kernel. Therefore, although the unstressed omega vowel has retained its feature specifications, the likelihood that this nucleus will remain on-target decreases as the number of feature contrasts with the following pre-kernel increases. As such, an unstressed omega vowel is only guaranteed to be expressed as a steady-state vowel if the following vowel shares feature specifications (or has no feature specifications).

8. A stressed omega vowel, on the other hand, is guaranteed two mora, the first of which is anchored at its prototypical target. A stressed omega vowel will be on-target.

9. An unstressed alpha vowel with a high front pre-kernel will be expressed as [i]. The nucleus will be reliably on-target to [i] prior to the initium. Since the unstressed vowel is only provided one mora, and the pre-kernel of the following syllable will gain control of the articulators well in advance of its own anchor-point, the high front pre-kernel of the current unstressed alpha vowel will form a diphthong with the next available vowel target. This unstressed alpha nucleus will be expressed as [i], if there is an offglide /j/, if the next pre-kernel is /j/, or if the next pre-kernel is underspecified. If the next pre-kernel is /a o u/ or /ɨ/, then the current pre-kernel will begin traveling along the fronting axis to the following perimeter vowel, will be in transition at the initium and the portion of the trajectory which will surface during sonorous phonation will be from [ɪ] to a centralized locus.

10. A stressed alpha vowel with onglide will be expressed as a diphthong, traveling backwards along the fronting axis towards its prototypical locus. If the following vocalic target is a high front vowel, then the alpha vowel will be expressed as a triphthong, and it will only attain an allophonic locus along its fronting axes. The degree to which this locus approximates the prototypical locus depends on the speaker.

11. An unstressed omega vowel with onglide will be expressed as a high front vowel. A means of detecting rounding was not identified in the Praat software, and it was not clear if the tokens of this nucleus type in the current data set retained any rounding from the kernel vowel or not. However, the kernel vowel did conclusively lose its point of articulation and the nucleus reduced/relocated to a high front vowel.

12. A stressed omega vowel with onglide resolves the same as line 10.

13. An unstressed /y/ nucleus will be expressed as a steady-state vowel in the vicinity of [ɨ], if and only if the next vocalic target is not /i/. Otherwise, the unstressed nucleus /y/ will be expressed as a diphthong [ɨi], indistinguishable from its stressed counterpart, except for scheduling of anchor-points and transitions.

14. A stressed /y/ nucleus will always be expressed as the diphthong [ɨi]. The kernel target /i/ will be fully obtained, if the next vocalic target is also /i/. The terminus of the /i/ kernel may exhibit transition to the next vocalic target prior to the terminus, if the next target is not /i/.

Lastly, considering the nuclei of lines 5-10 of Table 4.20, in conjunction with palatal consonant onsets /č š ž/, these onsets will produce a marginal consonantal transition similar to that of an onglide /j/. However, whereas the onset transition of /č š ž/ will tend to be less lengthy and conclude prior to mid-syllable, the onset transition of the glide /j/ in the pre-kernel position of the nucleus typically persists until the terminus.

The lingual transitions of these consonants (/č š ž/) may produce allophonic loci for the kernel vowels, along the fronting axes associated with the kernel vowels, if the lingual segment on the opposite side of the kernel is also palatal or a high front vowel. As such, these consonants produce similar allophonic and trajectory effects along the fronting axes of perimeter vowels, as does the glide /j/.

However, unstressed nuclei with a palatal onset /č š ž/ will resolve to the appropriate vowel indicated by lines 5 and 7 of Table 4.20 (i.e., unstressed /ča čo/ will resolve to [čə], and /ču/ will resolve to [ču], and /či/ will resolve to [či]), because these syllables no longer contain a pre-kernel. The pre-kernel glide was historically absorbed into the onset, creating a new class of contrastive consonants, while eliminating the original contrasts in nuclei (i.e., a historical contrast in the pre-kernel /kj gj xj/ vs. /k g x/ evolved into a contrast in point of articulation /č š ž/ vs. /k g x/). However, the unstressed sequence /če/ will resolve to [či], because the effect of Halle's SPR Rule P1a is to insert an epenthetic /j/ between a consonant and a kernel /e/. This insertion of an epenthetic /j/ removes the sequences of /č š ž/ plus /e/[8] from lines 5/7 of Table 4.20, and relocates them to lines 9/11.

Therefore, any nuclei following palatal consonants /č š ž/ will correctly resolve to their surface forms, the same as they would with any other consonant class, without the creation of ad hoc features or special consonant sets. That is to say, in the standard dialect, unstressed /ča/ and /čo/ are assigned to line 5 of Table 4.20 and both will resolve to a surface form of [čə]; unstressed /ču/ and /či/ are assigned to line 7 and will resolve to surface forms of [ču] and [či], respectively; and /če/ (which was hypothetically assigned to line 5) is relocated to line 9 after an epenthteic /j/ has been inserted, yielding /čje/, which will then resolve to a surface form of [či].

[8] The unstressed kernel /e/ will belong to either set alpha on line 5 of Table 4.20, or set omega on line 7, depending on dialectal assignment. Insertion of an epenthetic onglide /j/ will shift the syllable to either line 9 or line 11.

4.3 Coarticulation Across a Consonant Interlude

In this section, the effects of coarticulation across a consonant interlude will be presented. These effects will be observed at the site of suffixation. In 4.3.1, tonic and pre-tonic roots will be observed prior to post-tonic suffixes. In 4.3.2, the targeting and scheduling behavior at the initium of the suffixes will be observed. In subsequent sub-sections, individual topics that bear upon coarticulation will be discussed.

This section will focus on the final syllable of a lexical root and the following attached suffix. The analysis will revolve around the differentiation of the root vowel's trajectory through vowel-space, prior to contrastive suffixes. The nominal roots were inflected for following suffixes (where applicable): /i je u a ax o om ov oj/, and "zero" suffix. The suffixes /i je u/ were available for all lexical items. The suffixes /o om oj ov/ were available to selected lexical items, depending on gender of the nominal root. The suffixes /a ax/ were selected for the root, based upon stress paradigm.

The elicited tokens were organized into type classifications, based upon root plus suffix combinations. The types were then organized into peer groups, based upon common roots or common suffixes. In general, comparisons were only conducted upon contrastive types within a peer group. In 4.3.1, types within lexical root peer groups will be observed. In 4.3.2, types within suffix peer groups will be observed.

Analysis of a peer group involved holding the root fixed and varying the suffix, or vice versa. Univariate ANOVAs, with Tukey Post Hoc test, were conducted to determine if the suffix produced any anticipatory effect on the root, or if the root produced any preservative effect on the suffix.

4.3.1 Anticipatory Coarticulation Across a Consonant Interlude

A number of recurring behaviors occurred with observed coarticulation between the final vocalic target of a tonic root, and the initial vocalic target of the suffix. Contrary to DCT conventions, which only allow a binary contrast between soft and hard consonant interludes, the terminus of a tonic root routinely was differentiated as a trinary contrast, between suffixes initiating in front, centralized and back vowel targets. On rare occasion, a particular speaker might differentiate the terminus of a root as a quaternary contrast.

The routine trinary differentiation for front, centralized and back vowel targets of suffixes occurred regularly after roots terminating in a front or low vowel target. The trinary front/centralized/back differentiation became less regular, if the root terminated in a back vowel /o/ or /u/, prior to the suffix. However, a different type of trinary differentiation arose for root terminating in back vowels, in which the terminus before the suffixes /i je/ were differentiated.

If the root terminated in the offglide /j/, it was common for only a binary differentiation to occur. However, this binary differentiation did not conform to DCT provisions that /i je/ (which supposedly follow soft consonants) would be distinct from /a o u/ (which supposedly follow hard consonants). Instead, the binary differentiation groups front vowels suffixes with centralized suffixes, and hence contrasts back vs. non-back suffixes.

Violations to DCT conventions will be noted if the front vowel suffixes /i je/ occurred in separate homogeneous subsets of the ANOVA test, or non-front vowel suffixes /a o u/ occurred in separate homogeneous subsets.

4.3.1.1 Anticipatory Coarticulation with the Tonic Root /buk/

The tonic kernel /u/ was observed in the inflected forms of the lexical item бук /buk/ ‘beech,’ which has immobile stress on the root, in all grammatical cases. Thus, all suffixes were post-tonic.

Tonic monophthongal /u/ was consistently on-target at the initium, regardless of the features of the following suffix, as shown in pane I of Figure 4.61. The vowel remained on-target, until mid-syllable, at which point, the vowel began to differentiate due to anticipatory effects from the suffix.

Prior to front vowel suffixes, tonic kernels of /u/ began to diphthongize with the first target of following front vowel sequence /i/ or /je/. The diphthongization of tonic kernel /u/ occurred prior to a contrastive unreduced target, namely /i/ (/j/).

Prior to non-front vowel suffixes, the tonic kernel /u/ remained consistently on-target, until after the terminus. With regard to the kernel /u/, the suffixes represented either a (non-contrastive) repetition of the kernel’s target (i.e., /u/ suffix), or a contrastive (but underspecified) target (i.e., schwa of post-tonic /a o/, or neutral tongue position of zero suffix/pause/etc.).

In general, all five primary speakers exhibited similar behavior when performing inflected forms of the tonic root /buk/, and generated a binary distinction in the tonic kernel, contrasting front vs. non-front vowel suffixes. This binary distinction did not violate the binary distinction, established by DCT. Speaker mD (featured in Figure 4.61) exhibited the greatest degree of differentiation of the kernel at the terminus, which further differentiates /i/ suffix from the /je/ suffix.

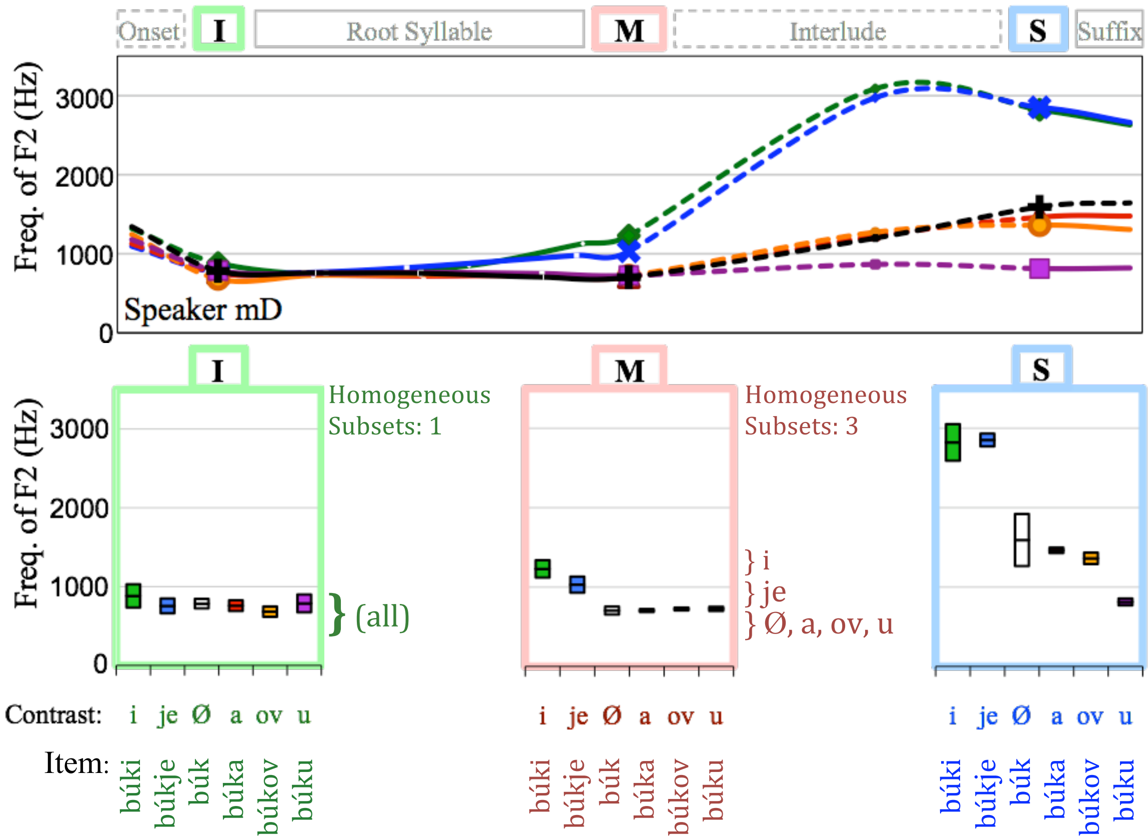


Figure 4.61 Differentiation at Terminus of Tonic Root of бук /buk/ 'beech.' The terminus is divided into three sub-sets, according to suffixes: non-front vs. front (/i je/ are beginning to split). Each track represents a normalized composite of six tokens.

Table 4.21 Results of Univariate ANOVA for F2 at the Terminus of Tonic Root /buk/. Speaker pF's binary distinction did not adhere to DCT conventions. Speaker mD also differentiated /i/ from /je/, but did not group /je/ with back vowels.

Subset / Speaker	Number of Subsets	DCT Violations	Homogeneous Subsets		
pF	2	1	i		je, a, ov, u
pG	2	0	i je		a, ov, u
mC	2	0	i, je		a, ov, u
mB	2	0	je		a, ov, u
mD	3	1	i	je	a, ov, u

4.3.1.2 Anticipatory Coarticulation with the Tonic Root /bok/

The tonic kernel /o/ was observed in the inflected forms of the lexical item бок /bok/ 'side.' This lexical item is a member of a split-paradigm stress pattern. In the singular grammatical cases and in the nominative plural, stress is placed on the root syllable. These grammatical cases will now be addressed. Those grammatical cases with stress on the suffix will be addressed in Section 4.3.1.17. In additional, the idiomatic phrase /bòk ó bok/ 'side by side' exhibited two successive syllables of stressed /o/.

Tonic monophthongal /o/ was consistently on-target at the initium, regardless of the features of the following suffix, as shown in pane I of Figure 4.62. (The ANOVA test nominated two homogeneous subsets for the initium; however, the range between the highest and lowest initium was less than 100 Hz.) The vowel remained on-target, until mid-syllable, at which point, the vowel began to differentiate due to anticipatory effects from the suffix.

Prior to front vowel suffixes, tonic kernels of /o/ began to diphthongize with the first target of following front vowel sequence /i/ or /je/. The diphthongization of tonic kernel /o/ occurred prior to a contrastive unreduced target. The acoustic quality of this diphthongization is noted by Jones and Ward:

> "Before a soft consonant, as in 'koɲ конь (horse), the off-glide is in the nature of an i-sound, as the tongue begins to move into the position of the soft consonant. Again, the off-glide must not be exaggerated so that the o-sound with i-glide is replaced by a diphthong of the type oj, which also occurs in Russian." (Jones & Ward 1969: 57)

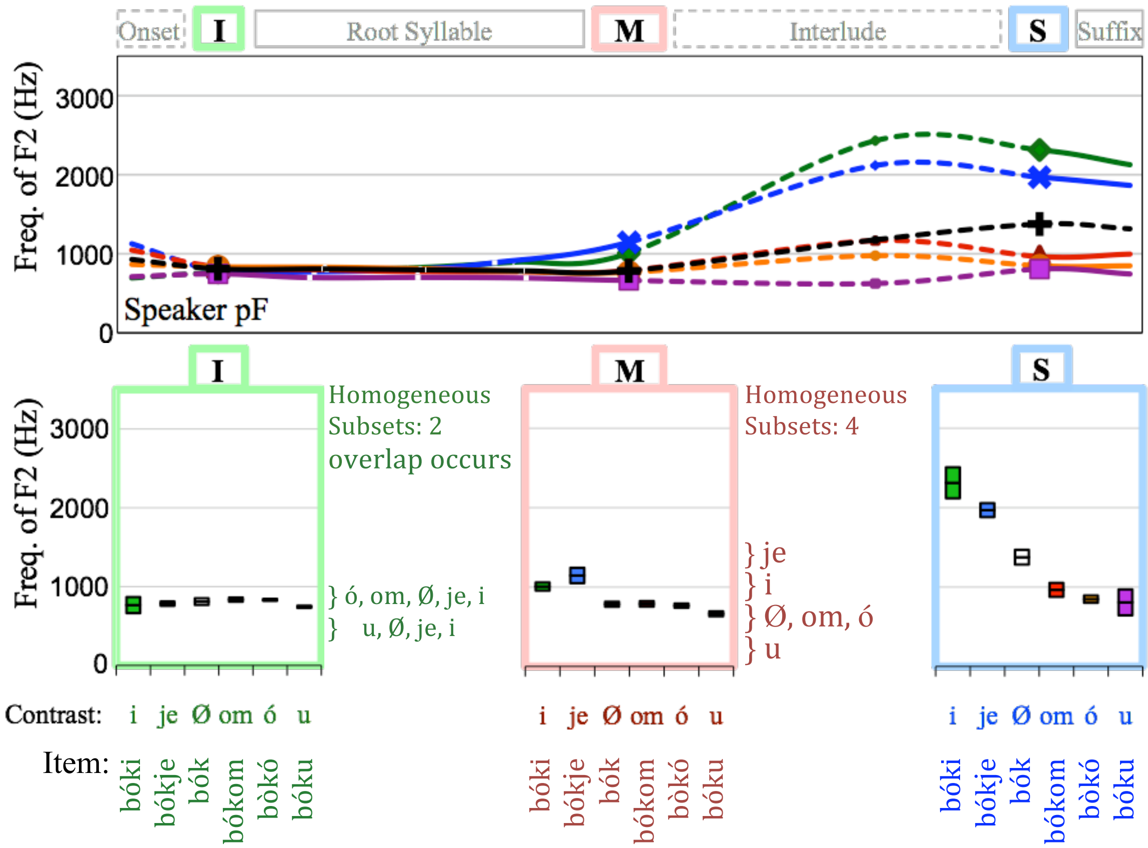


Figure 4.62 Differentiation at Terminus of Tonic Root of бок /bok/ 'side.' The terminus is divided into four sub-sets, according to suffixes: {je}, {i}, {Ø, om ó}, and {u}. The phrase бок о́ бок /bòk ó bok/ 'side by side' is a different stress pattern than the other inflected forms. In бок о́ бок, the first root syllable is receiving secondary stress.

Table 4.22 Results of Univariate ANOVA for F2 at the Terminus of Tonic Root /bok/. Speakers pF and pG exhibit additional distinction prior to suffixes, beyond the binary contrast accommodated by DCT conventions.

Subset / Speaker	Number of Subsets	DCT Violations	Homogeneous Subsets			
pF	4	2	je	i	Ø, om, ó	u
pG	4	2	i	je	Ø, om, ó	u
mC	2	0	i, je		Ø, a, om, ó, u	
mB	2	0	i, je		Ø, a, om, ó, u	
mD	2	0	i, je		Ø, a, om, ó, u	

The current analysis concludes that /o/ before a soft consonant (oÇ) is actually /oCj/, and thus, as a result of coarticulation, the /o/ and /j/ form a diphthong /oj/. It is argued that the difference between the tautosyllabic diphthong /oj/ and the heterosyllabic diphthong /oCj/ is a scheduling issue, not a gestural issue. The offglide of tautosyllabic /oj/ was obtained circa the terminus, and hence the entire transition from /o/ to /j/ was contained within the syllable with kernel /o/. In contrast, the offglide of the heterosyllabic /oj/ was obtained during the interlude (more than one-half mora after the terminus), and hence only the first half of the transition from /o/ to /j/ was contained within the sonorous portion of the syllable with the kernel /o/.

Returning attention to Figure 4.62, prior to non-front vowel suffixes, the remaining syllables with tonic kernel /o/ occasionally began to differentiate before non-front vowels as well. With regard to the kernel /o/, the suffixes which represent a contrastive unreduced target (i.e., /u/ suffix) often caused an anticipatory effect and differentiation from suffixes which represented a contrastive (but underspecified) target (i.e., schwa of post-tonic /a o/, or neutral tongue position of zero suffix/pause/etc.).

In general, all five primary speakers exhibited similar behavior when performing inflected forms of the tonic root /bok/, and generated a binary distinction in the tonic kernel, contrasting front and non-front vowel suffixes. In general, this binary distinction did not violate the binary distinction established by DCT. If individual speakers did further differentiate within the front and non-front subsets, then this did constitute a violation of DCT conventions.

4.3.1.3 Anticipatory Coarticulation with the Tonic Root /ljepjóxa/

The tonic kernel /o/ was also observed in the inflected forms of the lexical item лепёха /ljepjóxa/ 'flatbread,' which has immobile stress on the root, in all grammatical cases. Thus, all suffixes are post-tonic.

Tonic diphthongal /jo/ was not consistently on-target at the initium, as shown in pane I of Figure 4.63. Differentiation of the kernel becomes increasingly greater in time, up to the terminus.

Prior to front vowel suffixes, the anticipatory differentiation at the terminus often extended backwards in time and caused anticipatory differentiation at the initium, as well. In addition, the tonic nucleus /jo/ tended to remain in the front of vowel-space, for the entire duration of the root syllable, with the track of the vowel and the allophonic locus attained by the vowel remaining of the fronting axis for /o/. This fronting of tonic kernel /o/ occurred prior to the contrastive, unreduced target /i/ (/j/).

Prior to non-front vowel suffixes, the remaining syllables with tonic diphthong /jo/ tended not to sub-differentiate the non-front vowels. However, the terminus before the /u/ suffix was routinely lower than the termini prior to reduced suffixes.

In general, all five primary speakers exhibited similar behavior when performing inflected forms of the tonic root /ljepjóx/, and generated a binary distinction in the tonic kernel, contrasting front and non-front vowel suffixes. This binary distinction did not violate the binary distinction established by DCT. However, two specific individuals did further differentiate the root before front vowel suffixes, as shown in Table 4.23.

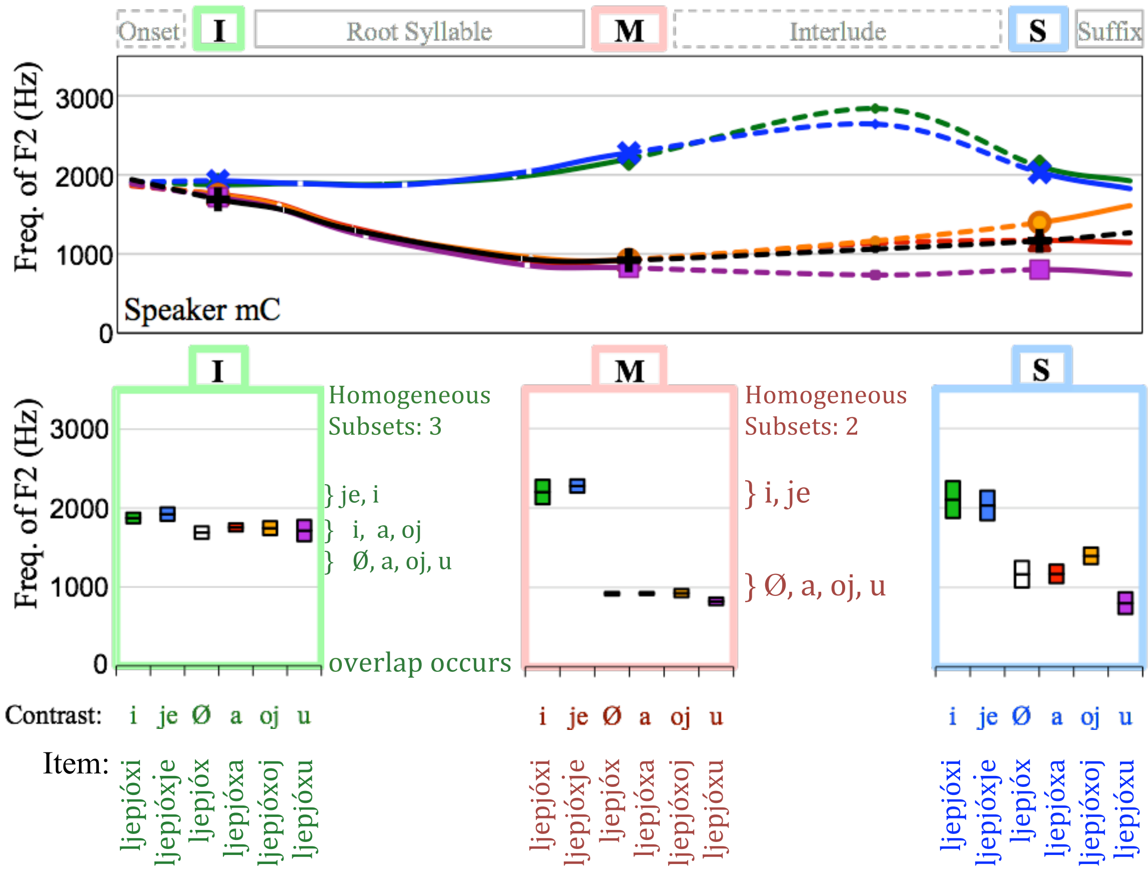


Figure 4.63 Differentiation at Terminus of Tonic Root of лепёха /ljepjoxa/ 'flatbread.' The terminus is divided into two sub-sets, according to suffixes: front vs. non-front. The contrast at the terminus extended backwards in time, and was registered at the initium.

Table 4.23 Results of Univariate ANOVA for F2 at the Terminus of Tonic Root /ljepjoxa/. Speakers mB and pG exhibited additional distinction prior to suffixes, beyond the binary contrast accommodated by DCT conventions.

Subset / Speaker	Number of Subsets	DCT Violations	Homogeneous Subsets		
pF	2	0	i, je		Ø, a, oj, u
pG	3	1	je	i	Ø, a, oj, u
mC	2	0	i, je		Ø, a, oj, u
mB	2	0	i	je	Ø, a, oj, u
mD	3	1	i, je		Ø, a, oj, u

4.3.1.4 Anticipatory Coarticulation with the Tonic Root /sobáka/

The tonic kernel /a/ was observed in the inflected forms of the lexical item собака /sobaka/ ‘dog,’ which has immobile stress on the root, in all grammatical cases. Thus, all suffixes will be post-tonic.

Tonic monophthongal /a/ was consistently on-target at the initium, regardless of the features of the following suffix, as shown in pane I of Figure 4.64. The vowel remained on-target, until mid-syllable, at which point, the vowel began to differentiate due to anticipatory effects from the suffix.

Prior to front vowel suffixes, tonic kernels of /a/ began to diphthongize with the first target of following front vowel sequence /i/ or /je/. The diphthongization of tonic kernel /a/ occurred prior to a contrastive unreduced target, namely /i/ (/j/).

Prior to non-front vowel suffixes, the tonic kernel /a/ began to diphthongize prior to contrastive unreduced /u/ suffix, as well. The kernel /a/ tended not to diphthongize only if the first vocalic target of the suffix the suffixes represented an underspecified target (i.e., schwa of post-tonic /a o/, or neutral tongue position of zero suffix/pause/etc.).

In general, all five primary speakers exhibited similar behavior when performing inflected forms of the tonic root /sobak/, and generated a trinary distinction in the tonic kernel, contrasting front, centralized and back vowel suffixes. This trinary distinction violated the binary distinction established by DCT. DCT does not have a mechanism which permits systematic replicable, contrastive subsets before hard consonants.

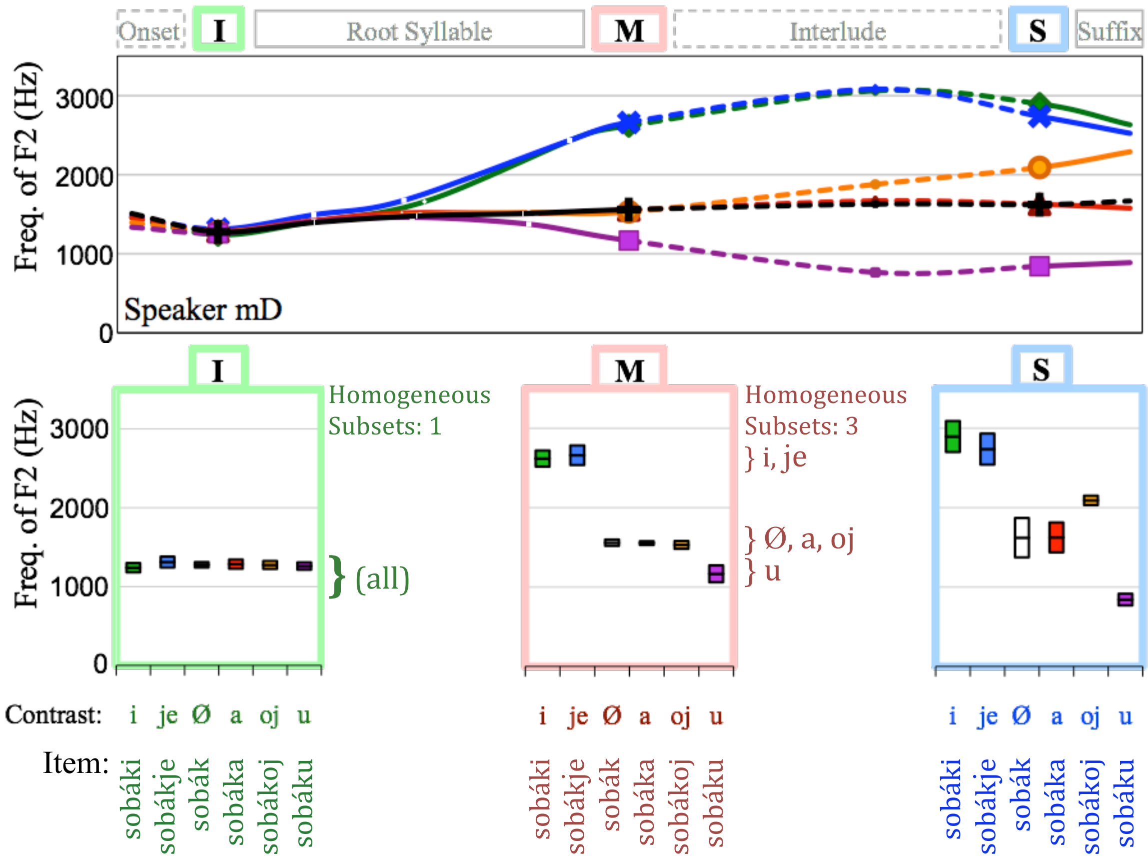


Figure 4.64 Differentiation at Terminus of Tonic Root of собака /sobaka/ 'dog.' The terminus is divided into three sub-sets, according to suffixes: front, centralized and back.

Table 4.24 Results of Univariate ANOVA for F2 at the Terminus of Tonic Root /sobaka/. All speakers differentiate the terminus of the root, based upon the vowel of suffix: front, centralized or back.

Subset / Speaker	Number of Subsets	DCT Violations	Homogeneous Subsets		
pF	3	1	i, je	Ø, a, oj	u
pG	2	0	je, i	Ø, a, oj, u	
mC	2	0	i, je	Ø, a, oj, u	
mB	3	1	i, je	Ø, oj, a	a, u
mD	3	1	i, je	Ø, a, oj	u

4.3.1.5 Anticipatory Coarticulation with the Tonic Root /bjaka/

The tonic kernel /a/ was also observed in inflected forms of the lexical item бяка /bjaka/ ‘nasty thing,’ which has immobile stress on the root, in all grammatical cases.

Tonic diphthongal /ja/ was consistently on-target at the initium, as shown in pane I of Figure 4.65. However, by mid-syllable, prior to front vowel suffixes, the tonic nucleus /ja/ began to triphthongize; however, before non-front suffixes, the tonic nucleus /ja/ began to exhibit anticipatory differentiation between back and centralized suffixes.

Prior to front vowel suffixes, the anticipatory differentiation at the terminus often extended backwards in time and cause anticipatory differentiation at mid-syllable as well. In addition, the tonic nucleus /ja/ tended to remain in the front of vowel-space, for the entire duration of the root syllable, with the track of the vowel and the allophonic locus attained by the vowel remaining of the fronting axis for /a/. This fronting of tonic kernel /a/ occurred prior to the contrastive, unreduced target /i/ (/j/).

Prior to non-front vowel suffixes, the tonic nucleus /ja/ began to gravitate higher and further back, prior to contrastive unreduced /u/ suffix. The tonic nucleus /ja/ tended to attain the prototypical locus of /a/ more fully, prior to an underspecified target (i.e., schwa of post-tonic /a o/, or neutral tongue position of zero suffix/pause/etc.).

In general, most speakers exhibited similar behavior when performing inflected forms of the tonic root /bjak/, and generated a trinary distinction in the tonic kernel, contrasting front, centralized and back vowel suffixes. This trinary distinction violated the binary convention established by DCT.

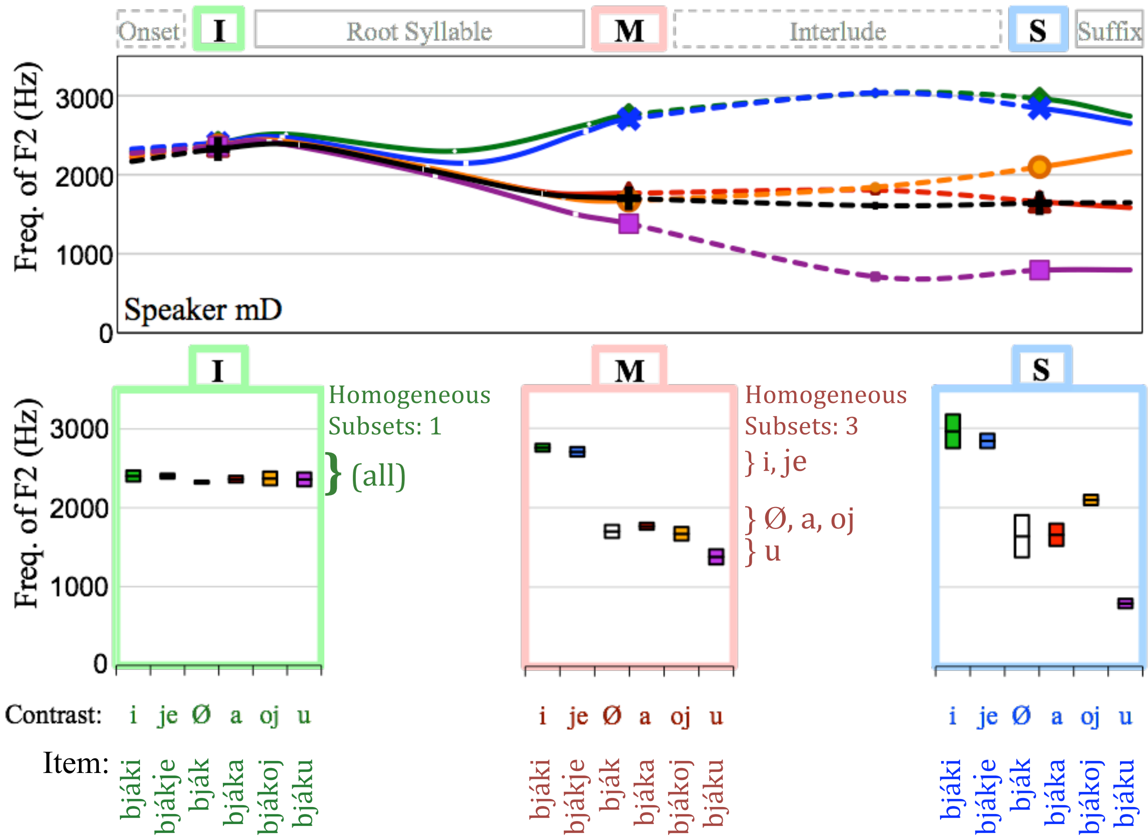


Figure 4.65 Differentiation at Terminus of Tonic Root of бяка /bjaka/ 'nasty thing.' The terminus is divided into three sub-sets, according to suffixes: front, centralized and back.

Table 4.25 Results of Univariate ANOVA for F2 at the Terminus of Tonic Root /bjaka/. All speakers differentiate the terminus of the root, based upon the vowel of suffix: front, centralized or back. Speaker pG further differentiates prior to reduced suffix targets.

Subset / Speaker	Number of Subsets	DCT Violations	Homogeneous Subsets			
pF	2	0	i, je	Ø, a, oj, u		
pG	4	2	i, je	a, oj	oj, Ø	u
mC	3	1	i, je	Ø, oj, a		a, u
mB	3	1	i, je	Ø, a, oj		u
mD	3	1	i, je	Ø, a, oj		u

4.3.1.6 Anticipatory Coarticulation with the Tonic Root /kavýka/

Tonic /y/ was observed in inflected forms of the lexical item кавыка /kavyka/ ‘inverted comma,’ which has immobile stress on the root, in all grammatical cases.

Tonic /y/ was not differentiated at the initium, as shown in pane I of Figure 4.65. However, the nucleus was in transition at the initium, and in anticipation of the suffix, differentiation began shortly after the initium. The differentiation of the vowel increased across the duration of the syllable. Closer to the terminus, additional differentiation occurred between specified back suffixes and underspecified centralized suffixes. For the speaker featured in Figure 4.66, the scheduling of transition for the prior to the “zero” suffix did not conform to the scheduling of transition for nonzero suffixes.

Prior to front vowel suffixes, the tonic nucleus /y/ terminated in front vowel-space, in the vicinity of its kernel target [i]. However, prior to non-front vowel suffixes, the tonic nucleus /y/ began to cease forward movement circa mid-syllable. Furthermore, prior to contrastive unreduced suffix /u/, the nucleus /y/ began to reverse course in vowel-space and travel to the back of vowel-space. The nucleus /y/ tended to remain in central vowel-space prior to an underspecified target (i.e., schwa of post-tonic /a o/, or neutral tongue position of zero suffix/pause/etc.).

In general, all five primary speakers exhibited similar behavior when performing inflected forms of the tonic root /kavyk/, and generated a trinary distinction at the terminus of the tonic kernel, contrasting front, centralized and back vowel suffixes. This trinary distinction violated the DCT binary convention, that separates soft consonants, which occur before front vowels, from hard consonants, which occur before back vowels.

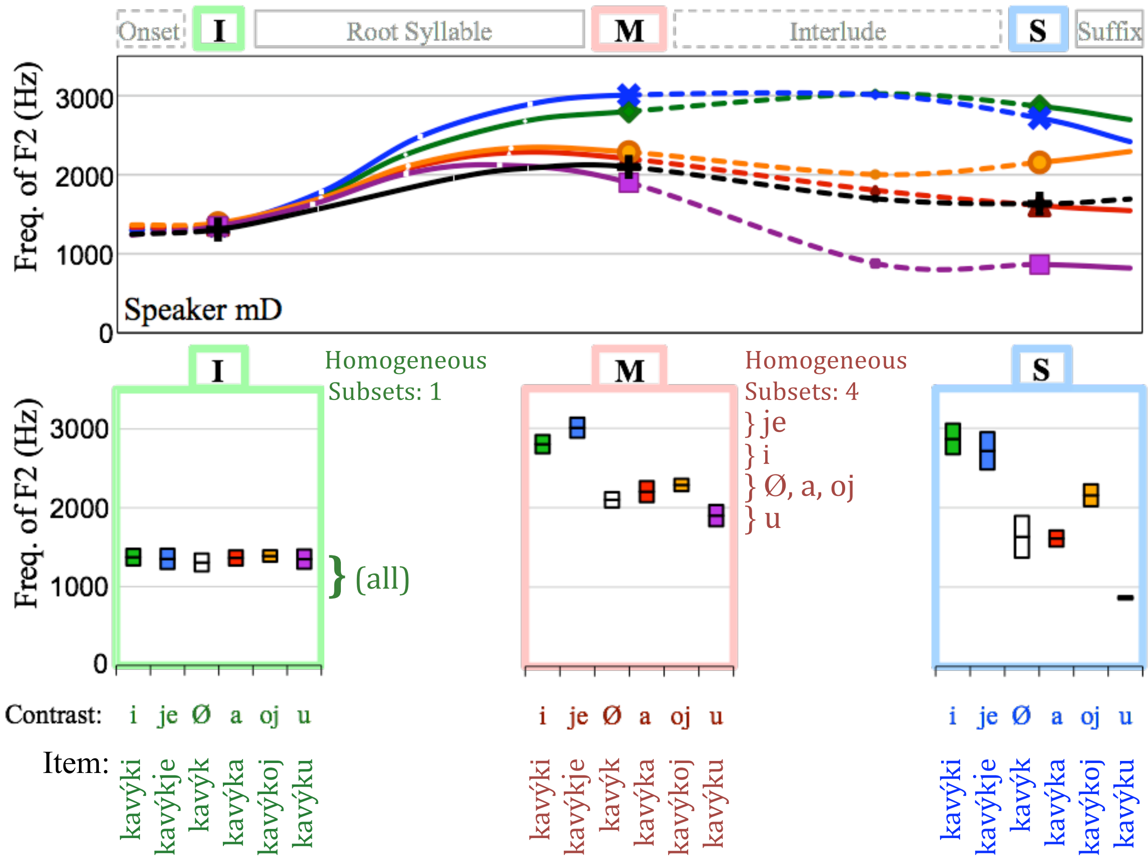


Figure 4.66 Differentiation at Terminus of Tonic Root of кавыка /kavyka/ 'inverted comma.' The terminus is divided into four sub-sets, according to suffixes: {je}, {i}, centralized and back.

Table 4.26 Results of Univariate ANOVA for F2 at the Terminus of Tonic Root /kavyka/. Most speakers differentiated the terminus of the root, based upon the vowel of suffix: front, centralized or back. Speaker mD further differentiates prior to front suffix targets.

Subset / Speaker	Number of Subsets	DCT Violations	Homogeneous Subsets			
pF	3	1	je, i		Ø, a, oj	oj, u
pG	3	1	i, je		Ø, oj, a	a, u
mC	2	0	i, je		Ø, a, oj, u	
mB	2	0	i, je		Ø, a, oj, u	
mD	4	2	je	i	Ø, oj, a	u

4.3.1.7 Anticipatory Coarticulation with the Tonic Root /ek/

The tonic kernel /e/ was observed in inflected forms of the lexical item экий /ekij/ hyperbole 'what a,' which has immobile stress on the root, in all grammatical cases. Thus, all suffixes were post-tonic. One additional variable arises with this lexical item: since it declines as an adjective, many of its suffixes[9] are disyllabic.

Tonic monophthongal /e/ was differentiated at the initium, as shown in pane I of Figure 4.67. The differentiation of the vowel increased across the duration of the syllable. Closer to the terminus, additional differentiation occurred between specified back suffixes and underspecified centralized suffixes.

Prior to the front vowel suffix /ij/, tonic kernel of /e/ often originated at a higher locus that the prototypical [ɛ], and began to diphthongize with the front vowel of suffix /ij/. The diphthongization of tonic /e/ occurred prior to a contrastive unreduced target.

Prior to non-front vowel suffixes, the tonic kernel /e/ began to diphthongize prior to contrastive unreduced /u/ of suffix /uju/, as well. The kernel /e/ tended not to diphthongize only if the first vocalic target of the suffix represented an underspecified target (i.e., schwa of /aja/ and "ogo", or neutral tongue position of zero suffix/pause/etc.).

In general, all five primary speakers exhibited similar behavior when performing inflected forms of /ek/, and generated a trinary distinction at the terminus that violated the binary convention established by DCT.

[9] The consonant "g" of the masculine/neuter genitive singular case is pronounced [v], and since this [v] is intervocalic, the post-tonic suffix is performed [ɐvə], [əvə], [əwə], etc. For the sake of uniformity, the suffix will be listed according to its orthography "ogo."

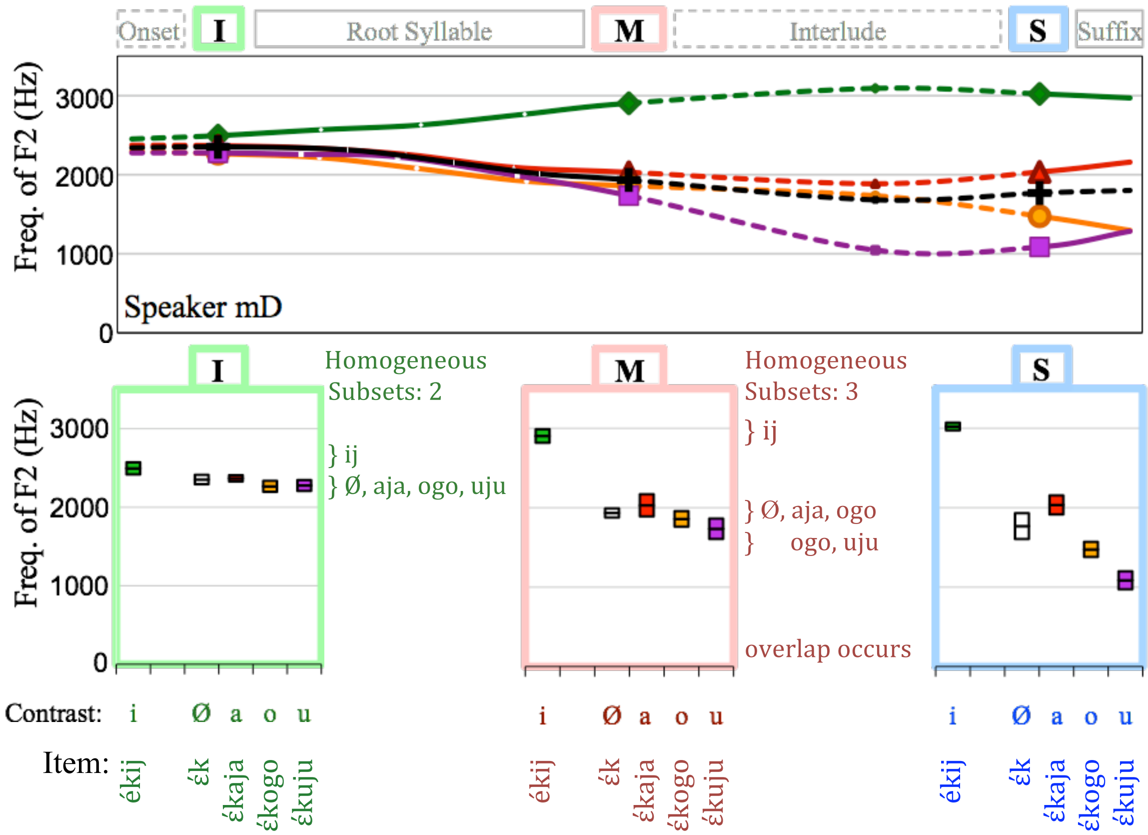


Figure 4.67 Differentiation at Terminus of Tonic Root of экий /ekij/ 'what a.' The terminus is divided into three sub-sets, according to suffixes: front, centralized and back. The suffix "ogo" overlaps the centralized and back subsets

Table 4.27 Results of Univariate ANOVA for F2 at the Terminus of Tonic Root /ek/. All speakers differentiate the terminus of the root, based upon the vowel of suffix: front, centralized or back. Speaker mB further differentiates prior to centralized suffix targets.

Subset / Speaker	Number of Subsets	DCT Violations	Homogeneous Subsets			
pF	3	1	ij	Ø, aja		ogo, uju
pG	3	1	ij	Ø, aja, ogo		ogo, uju
mC	2	0	ij	Ø, aja, ogo, uju		
mB	4	2	ij	Ø, aja	ogo	uju
mD	3	1	ij	Ø, aja, ogo		ogo, uju

4.3.1.8 Anticipatory Coarticulation with the Tonic Sequence /vjek/

The tonic kernel /e/ was also observed in the inflected forms of the lexical items веко /vjéko/ 'eyelid,' which has immobile stress on the root in all grammatical cases, and век /vjek/ 'age,' which has stress on the root in specific grammatical cases. Only inflected forms of век /vjek/ 'age' with stress on the root will be addressed in this section.

Tonic diphthongal /je/ was generally on-target at the initium, as shown in pane I of Figure 4.68. However, by mid-syllable, the tonic nucleus /je/ prior to front vowel suffixes began to triphthongize, whereas the tonic nucleus /je/ before non-front suffixes began to exhibit anticipatory differentiation between back and non-back suffixes.

Prior to front vowel suffixes, the anticipatory differentiation at the terminus often extended backwards in time and cause anticipatory differentiation at mid-syllable as well. In addition, the tonic nucleus /je/ tended to remain in the extreme front of vowel-space for the entire duration of the root syllable, with the track of the vowel and the allophonic locus attained by the vowel remaining of the fronting axis for /e/. This fronting of tonic kernel /e/ occurred prior to the contrastive, unreduced target /i/ (/j/).

Prior to non-front vowel suffixes, the tonic nucleus /je/ began to gravitate further back, prior to contrastive unreduced /u/ suffix. The tonic nucleus /je/ tended to attain the prototypical locus of /e/ more fully, prior to an underspecified target (i.e., schwa of post-tonic /a o/, or neutral tongue position of zero suffix/pause/etc.).

In general, all five primary speakers exhibited similar behavior when performing inflected forms /vjek/, and generated a trinary distinction at the terminus that violated the binary convention established by DCT.

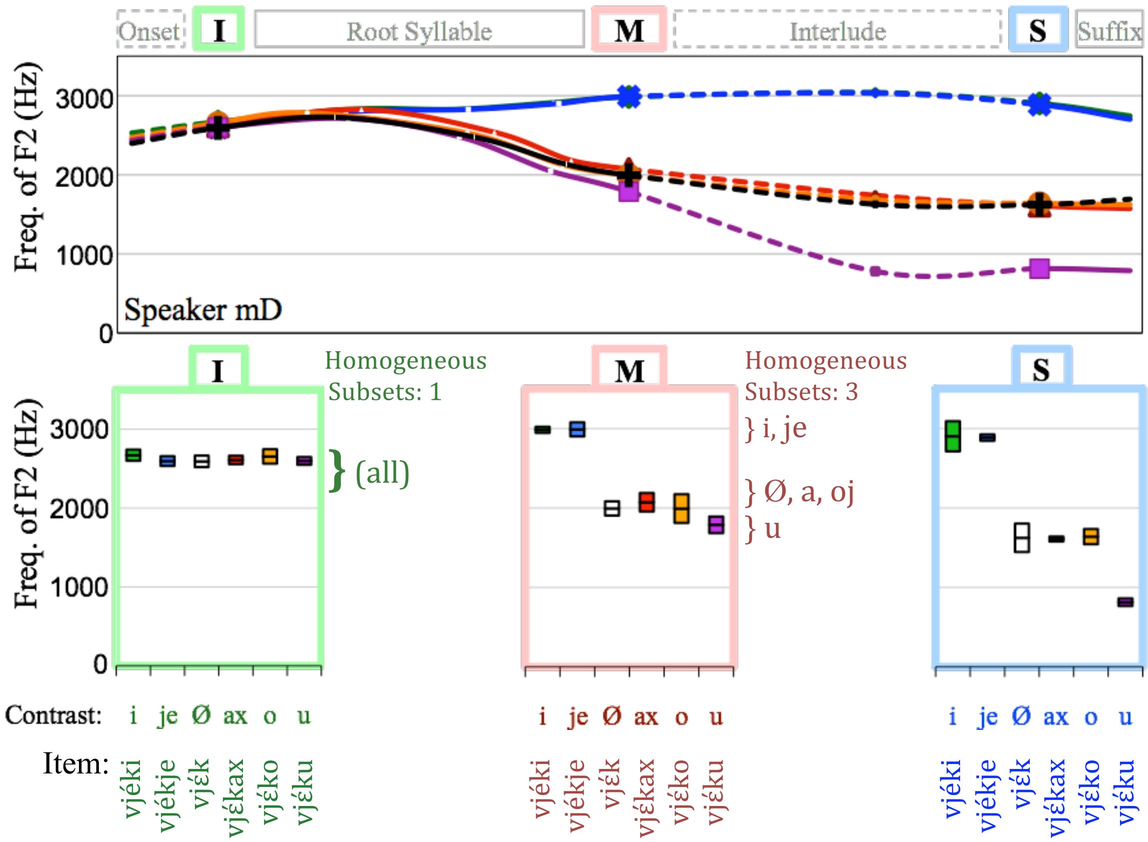


Figure 4.68 Differentiation at Terminus of Tonic Root of веко /vjéko/ 'eyelid' and век /vjek/ 'age.' The terminus is divided into three sub-sets, according to suffixes: front, centralized and back. The item for /i/ suffix is form /vjéki/ 'age' nom.pl. All other items are inflected forms of /vjéko/ 'eyelid.'

Table 4.28 Results of Univariate ANOVA for F2 at the Terminus of Tonic Root /vjek/. All speakers differentiate the terminus of the root, based upon the vowel of suffix: front, centralized or back. Speaker mB further differentiates prior to centralized suffix targets.

Speaker \ Subset	Number of Subsets	DCT Violations	Homogeneous Subsets			
pF	3	1	i, je	Ø, ax, o		u
pG	3	1	i, je	Ø, ax, o		u
mC	3	1	i, je	Ø, ax		o, u
mB	4	2	i, je	Ø, ax	o	u
mD	3	1	je, i	Ø, ax, o		u

4.3.1.9 Anticipatory Coarticulation with the Tonic Root /ježevíka/

The tonic kernel /i/ was observed in inflected forms of the lexical item ежевика /ježevika/ ‘blackberry,’ which has immobile stress on the root, in all grammatical cases.

Tonic monophthongal /i/ is consistent at the initium, regardless of the features of the following suffix, as shown in pane I of Figure 4.69. Acoustically, the vowel is not on-target due to labial damping. The vowel remains consistent, until mid-syllable, at which point, the vowel begins to differentiate due to anticipatory effects from the suffix.

Prior to front vowel suffixes, tonic kernels of /i/ fully obtained the prototypical locus of [i]. Thus, the kernel /i/ is fully obtained prior to a non-contrastive target.

Prior to non-front vowel suffixes, the tonic kernel /i/ began to travel backwards in vowel-space. The kernel /i/ tended to travel backwards the least, if the first vocalic target of the suffix the suffixes represented an underspecified target (i.e., schwa of post-tonic /a o/, or neutral tongue position of zero suffix/pause/etc.).

In general, all five primary speakers exhibited similar behavior when performing inflected forms of the tonic root /ježevik/, and generated a distinction at the terminus of the tonic kernel, contrasting back vs. non-back vowel suffixes. Some speakers further differentiated non-back suffixes into front vs. centralized suffixes. Both the binary and trinary distinctions violated the DCT binary convention. DCT does not have a mechanism which permits systematic replicable, contrastive subsets before hard consonants.

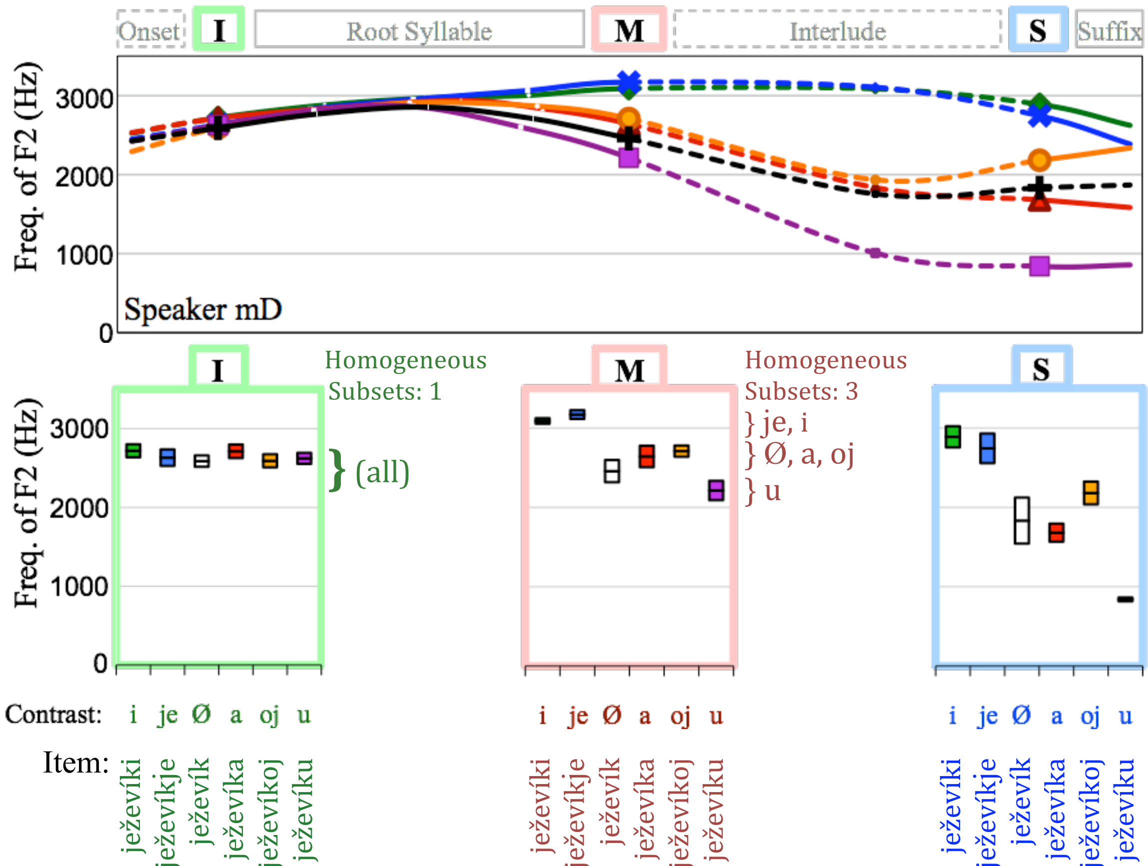


Figure 4.69 Differentiation at Terminus of Tonic Root of ежевика /ježevíka/ 'blackberry.' The terminus is divided into three sub-sets, by suffix: front, centralized and back.

Table 4.29 Results of Univariate ANOVA for F2 at the Terminus of Tonic Root /ježevíka/. All speakers differentiate the terminus of the root, based upon the vowel of suffix: back vs. centralized/front. Some speakers further differentiate the terminus of the root prior to centralized and front suffix targets.

Subset / Speaker	Number of Subsets	DCT Violations	Homogeneous Subsets		
pF	2	0	je, a, i, oj	a, i, oj, u	
pG	3	2	je, a, i	oj, Ø	Ø, u
mC	3	1	i, je	Ø, a, oj	u
mB	3	1	i, je	Ø, a, oj	u
mD	3	1	je, i	Ø, oj, a	u

4.3.1.10 Anticipatory Coarticulation with the Tonic Root /latvíjka/

The tonic kernel /i/ was observed in inflected forms of латвийка /latvijka/ ‘Latvian woman,’ which has immobile stress on the root, in all grammatical cases.

Tonic diphthongal /ij/ was consistent at the initium, regardless of the following suffix, as shown in pane I of Figure 4.70. Acoustically, the vowel was not on-target due to labial damping. The vowel remained consistent, until after mid-syllable, at which point, the vowel began to differentiate due to anticipatory effects from the suffix.

Prior to non-back vowel suffixes, tonic diphthong /ij/ fully obtained the prototypical locus of [i] at the terminus. Thus, the offglide /j/ was fully obtained prior to a non-contrastive or an underspecified target. The tonic diphthong /ij/ and the following front suffix represented three successive equivalent high front targets. The offglide /j/ was surrounded by equivalent targets.

Prior to the back vowel suffixes /u/, the tonic diphthong /ij/ began to travel backwards in vowel-space, prior to the terminus. The diphthong /ij/ failed to obtain the prototypical locus of [i], prior to a contrastive unreduced target (i.e., /u/).

In general, all five primary speakers exhibited similar behavior when performing inflected forms of the tonic root /latvijka/, and generated a distinction at the terminus of the tonic kernel, contrasting back vs. non-back vowel suffixes. Some speakers further differentiated non-back suffixes into front vs. centralized suffixes. Both the binary and trinary distinctions violated the DCT binary convention. DCT does not have a mechanism which permits systematic replicable, contrastive subsets before hard consonants.

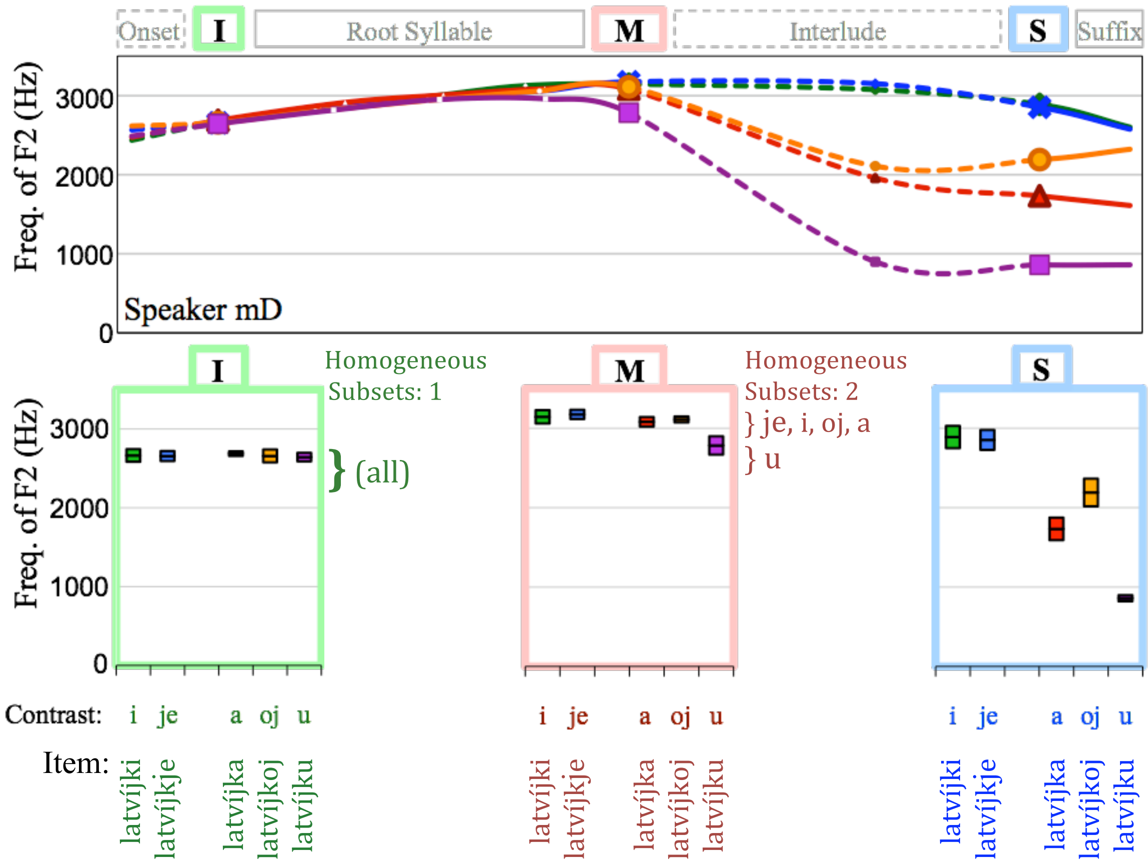


Figure 4.70 Differentiation at Terminus of Tonic Root of латвийка /latvijka/ 'Latvian woman.' The terminus is divided into two sub-sets, by suffix: front and non-front.

Table 4.30 Results of Univariate ANOVA for F2 at the Terminus of Tonic Root /latvijka/. All speakers differentiate the terminus of the root, based upon the vowel of suffix: back vs. centralized/front. Some speakers further differentiate prior to centralized and front suffix targets.

Subset / Speaker	Number of Subsets	DCT Violations	Homogeneous Subsets		
pF	2	1	i, a, oj, je		u
pG	2	1	i, je, a, oj		u
mC	3	1	i, je, oj, a		u
mB	3	1	i, je	oj, a	a, u
mD	3	1	je, i, oj, a		u

4.3.1.11 Anticipatory Coarticulation with the Tonic Root /bájka/

The tonic kernel /a/ was observed in the inflected forms of the lexical item байка /bajka/ ‘fable,’ which has immobile stress on the root, in all grammatical cases.

Tonic diphthongal /aj/ was consistent at the initium, regardless of the features of the following suffix, as shown in pane I of Figure 4.71. The vowel remained consistent, until mid-syllable, at which point, the vowel began to differentiate due to anticipatory effects from the suffix.

Prior to front vowel suffixes, tonic diphthong /aj/ fully obtained the offglide at the prototypical locus of [i] at the terminus. Thus, the offglide /j/ is fully obtained prior to a non-contrastive target.

Prior to the non-front vowel suffixes, the tonic diphthong /aj/ began to travel backwards in vowel-space, prior to the terminus. The diphthong /aj/ failed to obtain the offglide at the prototypical locus of [i], prior to a contrastive target.

In general, most primary speakers exhibited similar behavior when performing inflected forms of the tonic root /bajka/, and generated a distinction at the terminus of the tonic kernel, contrasting front, centralized and back vowel suffixes. The trinary distinction violated the DCT binary convention. Speaker pF maintained the offglide through the terminus, and did not differentiate for the suffixes until during the interlude. As such, there is only one homogeneous group, including all suffixes. This unary “distinction” does not violate DCT binary convention, because, in DCT, there is a provision for binary differentiation, but not a mandate that the provision be invoked.

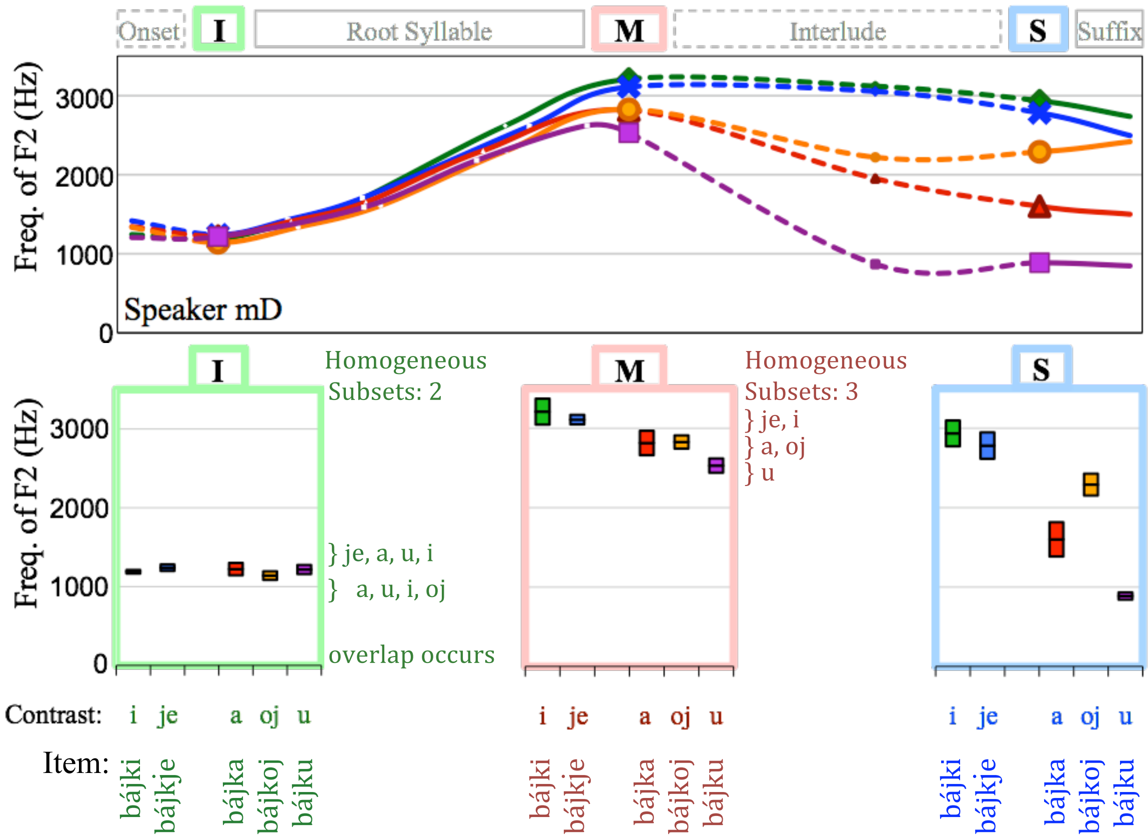


Figure 4.71 Differentiation at Terminus of Tonic Root of байка /bajka/ 'fable.' The terminus is divided into three sub-sets, according to suffixes: front, centralized and back.

Table 4.31 Results of Univariate ANOVA for F2 at the Terminus of Tonic Root /bajka/. Most speakers differentiate the terminus of the root, based upon the vowel of suffix: front, centralized, and back.

Subset / Speaker	Number of Subsets	DCT Violations	Homogeneous Subsets		
pF	1	0	i, je, a, oj, u		
pG	2	1	i, je	je, oj, a	u
mC	3	1	i, je	oj, a	a, u
mB	3	1	i, je	oj, a	u
mD	3	1	i, je	oj, a	u

4.3.1.12 Anticipatory Coarticulation with the Tonic Root /popójka/

The tonic kernel /o/ was observed in inflected forms of the lexical item попойка /popojka/ ‘drinking party,’ which has immobile stress on the root, in all grammatical cases. Thus, all suffixes will be post-tonic.

Tonic diphthongal /oj/ was consistent at the initium, regardless of the features of the following suffix, as shown in pane I of Figure 4.72. The vowel began to differentiate prior to mid-syllable due to anticipatory effects from the suffix.

Prior to front vowel suffixes, tonic diphthong /oj/ fully obtained the offglide at the prototypical locus of [i] at the terminus. Thus, the offglide /j/ was fully obtained prior to a non-contrastive target.

Prior to the non-front vowel suffixes, the tonic diphthong /oj/ began to travel backwards in vowel-space, prior to the terminus. The diphthong /oj/ failed to obtain the offglide at the prototypical locus of [i], prior to a contrastive target.

In general, most primary speakers exhibited similar behavior when performing inflected forms of the tonic root /popojka/, and generated a distinction at the terminus of the tonic kernel, contrasting back vs. non-back vowel suffixes. Some speakers further differentiated non-back suffixes into front vs. centralized suffixes. Both the binary and trinary distinctions violated the DCT binary convention, that separates soft consonants Ç, which occur before front vowels, from hard consonants K, which occur before back vowels. DCT does not have a mechanism which permits systematic replicable, contrastive subsets before hard consonants.

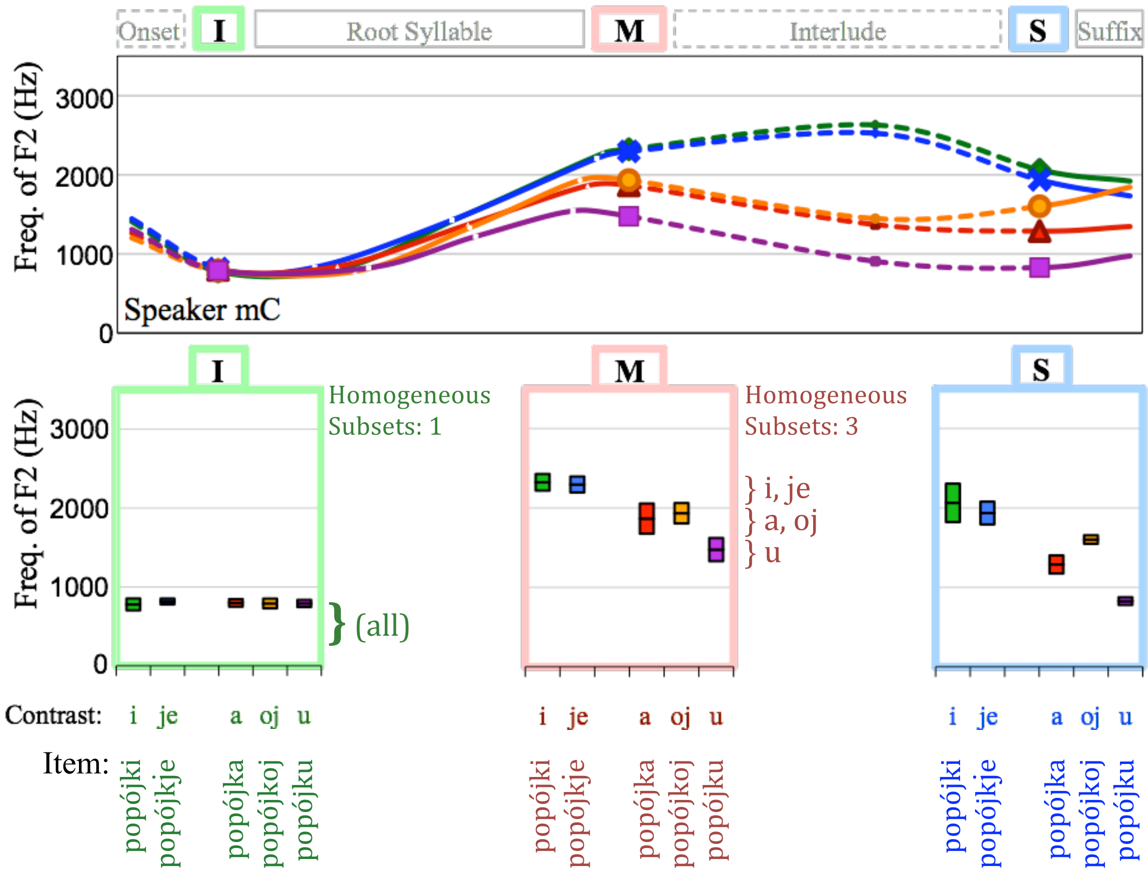


Figure 4.72 Differentiation at Terminus of Tonic Root of попойка /popójka/ 'drinking party.' The terminus is divided into three sub-sets, by suffix: front, reduced, and back.

Table 4.32 Results of Univariate ANOVA for F2 at the Terminus of Tonic Root /popojka/. In all cases, the position of the vowel at the terminus prior to the suffix /u/ did not pattern with the other non-front vowels.

Subset / Speaker	Number of Subsets	DCT Violations	Homogeneous Subsets		
pF	2	0	je, a, i, oj		u
pG	2	1	je, i, a, oj		u
mC	3	1	i, je	a, oj	u
mB	3	1	i, je	a, oj	u
mD	2	1	i, je, a, oj		u

4.3.1.13 Anticipatory Coarticulation with the Pre-Tonic Root /zdorovjak/

The pre-tonic diphthong /ja/ was observed in the inflected forms of the lexical item здоровяк /zdorovjak/ 'healthy person,' which has stress on the suffix, except for "zero" suffix, in which case, stress is on the final syllable of the root.

Pre-tonic /ja/ reduces to the pre-kernel /j/, and was relatively inconsistent at the initium, as shown in pane I of Figure 4.73. Since the reduced nucleus has no kernel, differentiation began circa or prior to the initium, due to anticipatory effects from the suffix.

Prior to front vowel suffixes, pre-tonic /ja/ (which has reduced to pre-kernel /j/) fully obtained the prototypical locus of [i] at the terminus. Thus, the pre-kernel /j/ is fully obtained prior to a non-contrastive target.

Prior to non-front vowel suffixes, pre-tonic /ja/ began to travel backwards in vowel-space. The degree to which pre-tonic /ja/ traveled backwards is directly related to the contrastive degree of backness of the tonic suffix.

In general, all five primary speakers exhibited similar behavior when performing inflected forms of the pre-tonic root /zdorovjak/, and generated a distinction at the terminus of the pre-tonic root, contrasting front vs. low vs. non-low/back vowel suffixes. Some speakers further differentiated non-low/back suffixes into high /ú/ vs. non-high /ó/ suffixes. Both the binary and trinary distinctions within the non-front subset violated the DCT binary convention. DCT does not have a mechanism which permits systematic replicable, contrastive subsets before hard consonants.

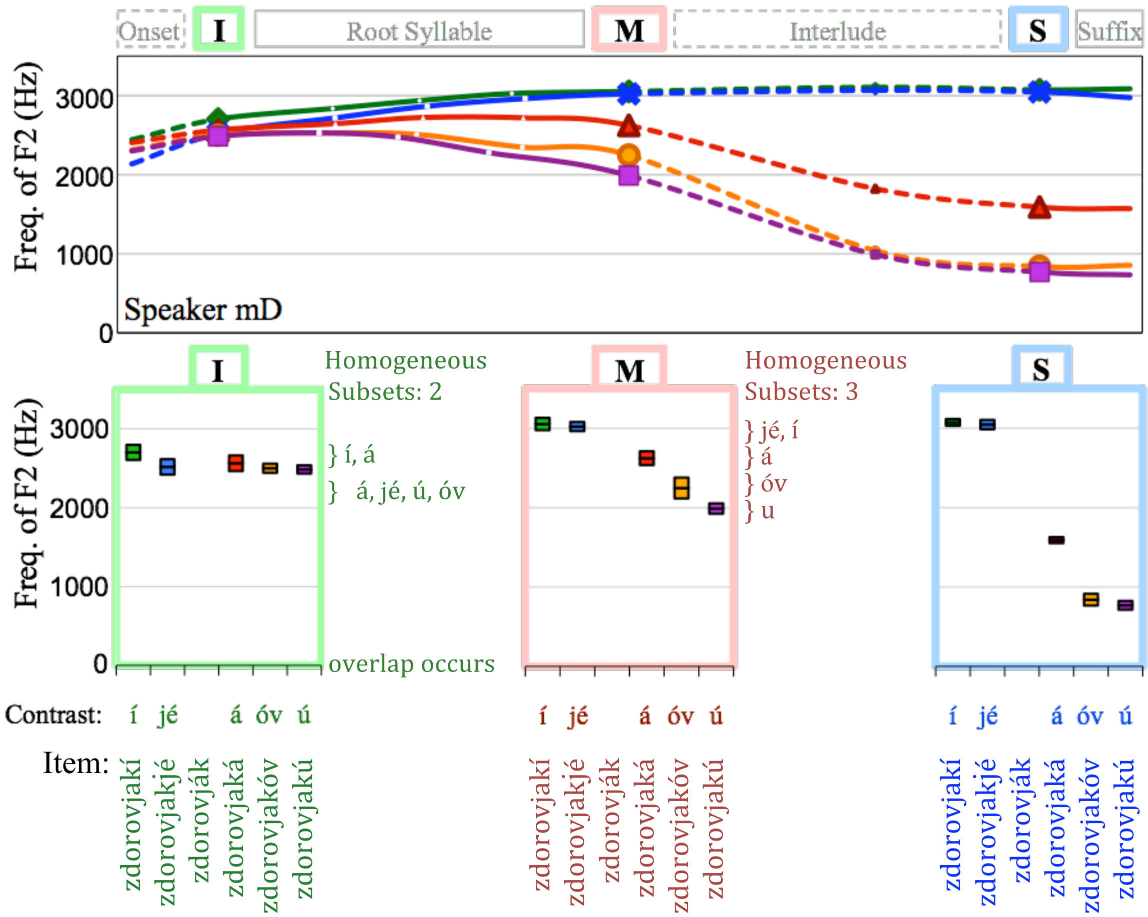


Figure 4.73 Differentiation at Terminus of Pre-tonic Root of здоровяк /zdorovjak/ 'healthy person.' The terminus is divided into four sub-sets, according to suffixes: {í/jé}, {á}, {óv}, and [ú}.

Table 4.33 Results of Univariate ANOVA for F2 at the Terminus of Pre-tonic Root /zdorovjak/. All speakers differentiate the terminus of the root, based upon the vowel of suffix: front, low, and back.

Subset / Speaker	Number of Subsets	DCT Violations	Homogeneous Subsets			
pF	3	1	í, jé	á	ú, óv	
pG	3	1	í, jé, á	á, óv	óv, ú	
mC	3	1	í, jé	á	óv, ú	
mB	3	1	í, jé	á	óv, ú	
mD	4	2	í, jé	á	óv	ú

4.3.1.14 Anticipatory Coarticulation with the Pre-Tonic Root /vjek/

The pre-tonic diphthong /je/ was observed in the inflected forms of the lexical item век /vjek/ ‘age/century,’ which has mobile stress. The inflected forms to be considered for this section of the presentation all have tonic suffixes.

Pre-tonic /je/ reduces to the pre-kernel /j/, and was relatively inconsistent at the initium, as shown in pane I of Figure 4.74. Since the reduced nucleus has no kernel, differentiation began circa or prior to the initium, due to anticipatory effects from the suffix.

Tonic front vowel suffixes were not observed with this lexical item.

Prior to non-front vowel suffixes, pre-tonic /je/ began to travel backwards in vowel-space. The degree to which pre-tonic /je/ traveled backwards is directly related to the contrastive degree of backness of the tonic suffix.

In general, all five primary speakers exhibited similar behavior when performing inflected forms of the pre-tonic root /vjek/, and generated a distinction at the terminus of the pre-tonic root, contrasting low vs. non-low/back vowel suffixes. Some speakers further differentiated non-low/back suffixes into high /ú/ vs. non-high /ó/ suffixes. Both the binary and trinary distinctions within non-front suffixes violated the DCT binary convention, that separates soft consonants Ç, which occur before front vowels, from hard consonants K, which occur before back vowels. DCT does not have a mechanism which permits systematic replicable, contrastive subsets before hard consonants.

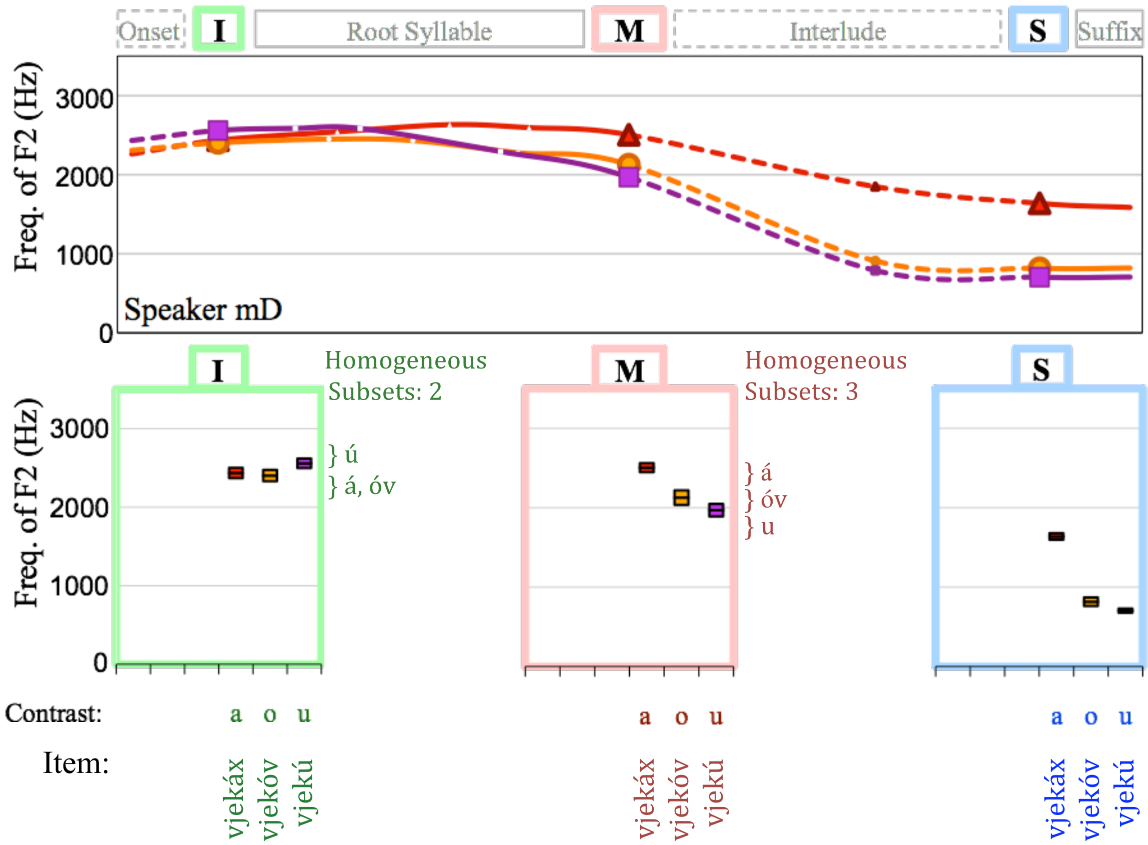


Figure 4.74 Differentiation at Terminus of Pre-tonic Root of век /vjek/ 'age/century.' The terminus is divided into three sub-sets, according to suffixes: front, centralized and back.

Table 4.34 Results of Univariate ANOVA for F2 at the Terminus of Pre-tonic Root /vjek/. All speakers differentiate the terminus of the root, based upon the vowel of suffix: front, low, and back. Some speakers further differentiate, based upon the height of back suffixes. Tonic front suffixes were not available in the data set.

Subset / Speaker	Number of Subsets	DCT Violations	Homogeneous Subsets			
pF	3	2	not observed	á	óv	ú
pG	2	1	not observed	á, óv		ú
mC	2	1	not observed	á	óv, ú	
mB	3	2	not observed	á	óv, ú	
mD	3	2	not observed	á	óv	ú

4.3.1.15 Anticipatory Coarticulation with the Pre-Tonic Root /byk/

The pre-tonic nucleus /y/ was observed in the inflected forms of the lexical item бык /byk/ ‘bull,’ which has stress on the suffix, except for “zero” suffix, in which case, stress is on the final syllable of the root.

Pre-tonic /y/ reduces to the pre-kernel /ɨ/, and was relatively inconsistent at the initium, as shown in pane I of Figure 4.75. Since the reduced nucleus has no kernel, differentiation begins circa or prior to the initium, due to anticipatory effects from the suffix.

Prior to front vowel suffixes, pre-tonic /y/ (which has reduced to pre-kernel /ɨ/) began to diphthongize with the pre-kernel /j/ of the suffix syllable, thereby, effectively re-establishing the original sequence /ɨi/ of the underlying nucleus. Thus, the primary difference between tonic /y/ and pre-tonic /y/ before an /i/ target is one of scheduling. Tonic nucleus /y/ will more fully obtain the target /i/ as a tautosyllabic kernel, than the pre-tonic /y/, which will obtain the target /i/ only as a heterosyllabic pre-kernel.

Prior to non-front vowel suffixes, pre-tonic /y/ began to travel backwards in vowel-space. The degree to which pre-tonic /y/ traveled backwards is usually directly related to the contrastive degree of backness of the tonic suffix.

In general, all five primary speakers exhibited similar behavior when performing inflected forms of the pre-tonic root /byk/, and generated a distinction at the terminus of the pre-tonic root, contrasting front vs. non-front vowel suffixes. Some speakers further differentiated non-front suffixes into low vs. non-low suffixes. The binary distinctions within non-front suffixes violated DCT conventions.

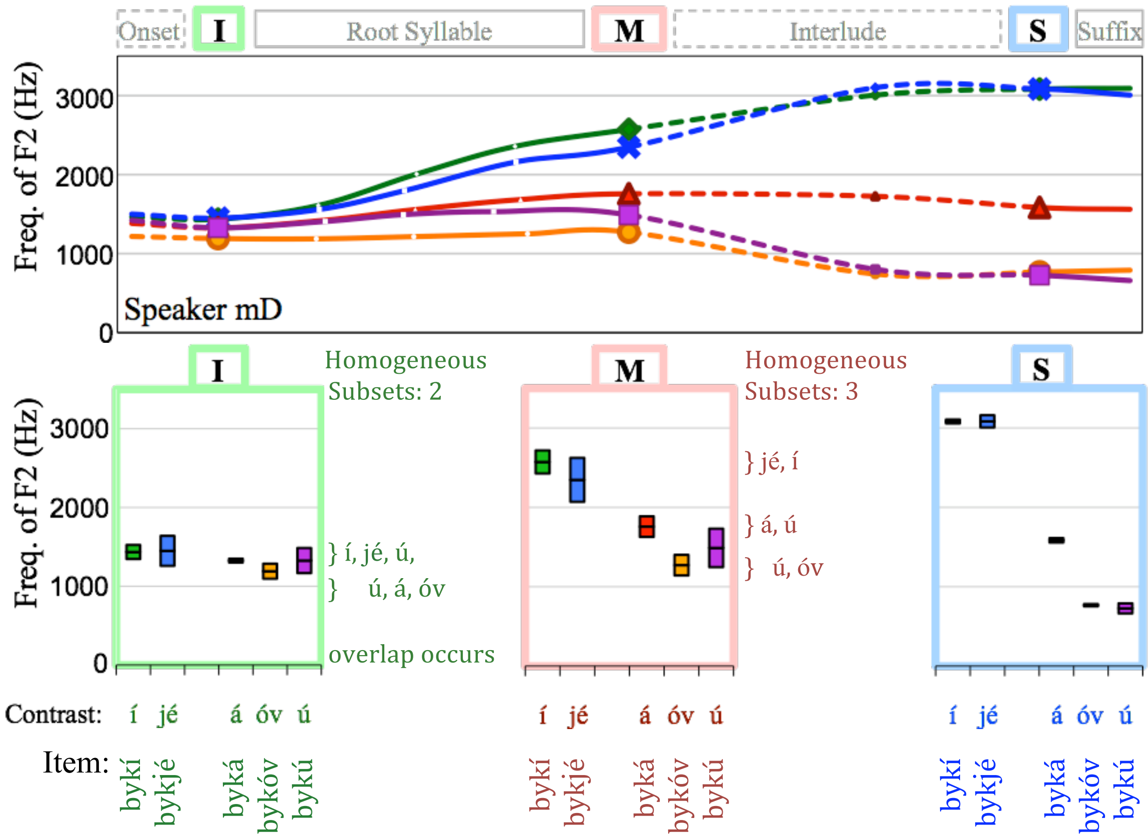


Figure 4.75 Differentiation at Terminus of Pre-tonic Root of бык /byk/ 'bull.' The terminus is divided into three sub-sets, according to suffixes: front, centralized and back.

Table 4.35 Results of Univariate ANOVA for F2 at the Terminus of Pre-tonic Root /byk/. All speakers differentiate the terminus of the root, based upon the vowel of suffix: front vs. non-front. Some speakers further differentiate, based upon suffix: centralized vs. back.

Subset / Speaker	Number of Subsets	DCT Violations	Homogeneous Subsets		
pF	3	1	í, jé	á	óv, ú
pG	2	0	í, jé	jé , á, óv, ú	
mC	2	0	í, jé	á, óv, ú	
mB	2	0	í, jé	á, óv, ú	
mD	3	1	í, jé	á, ú	ú, óv

4.3.1.16 Anticipatory Coarticulation with the Pre-Tonic Root /tabak/

The pre-tonic nucleus /a/ was observed in the inflected forms of the lexical item табак /tabak/ ‘tobacco,’ which has stress on the suffix, except for “zero” suffix, in which case, stress is on the final syllable of the root.

Pre-tonic /a/ exhibited anticipatory effects from the suffix even at the initium, as shown in pane I of Figure 4.76. Differentiation continued to increase across the duration of the root syllable.

Prior to front vowel suffixes, pre-tonic /a/ began to diphthongize with the contrastive pre-kernel target /i/ or /j/ of the suffix syllable, forming a heterosyllabic diphthong.

Prior to non-front vowel suffixes, pre-tonic /a/ often began diphthongize with the first contrastive vocalic target of the suffix syllable, forming a heterosyllabic diphthong [ɐu]. This occurred with both rounded suffix vowels /u o/. The pre-tonic /a/ behaved like a steady-state monophthong prior to the non-contrastive /a/ of the suffix syllable.

In general, all five primary speakers exhibited similar behavior when performing inflected forms of the pre-tonic root /tabak/, and generated a distinction at the terminus of the pre-tonic root, contrasting front vs. non-front vowel suffixes. Some speakers further differentiated non-front suffixes, into low vs. non-low suffixes. The binary distinctions within non-front suffixes violated DCT conventions. DCT does not have a mechanism which permits systematic replicable, contrastive subsets before hard consonants.

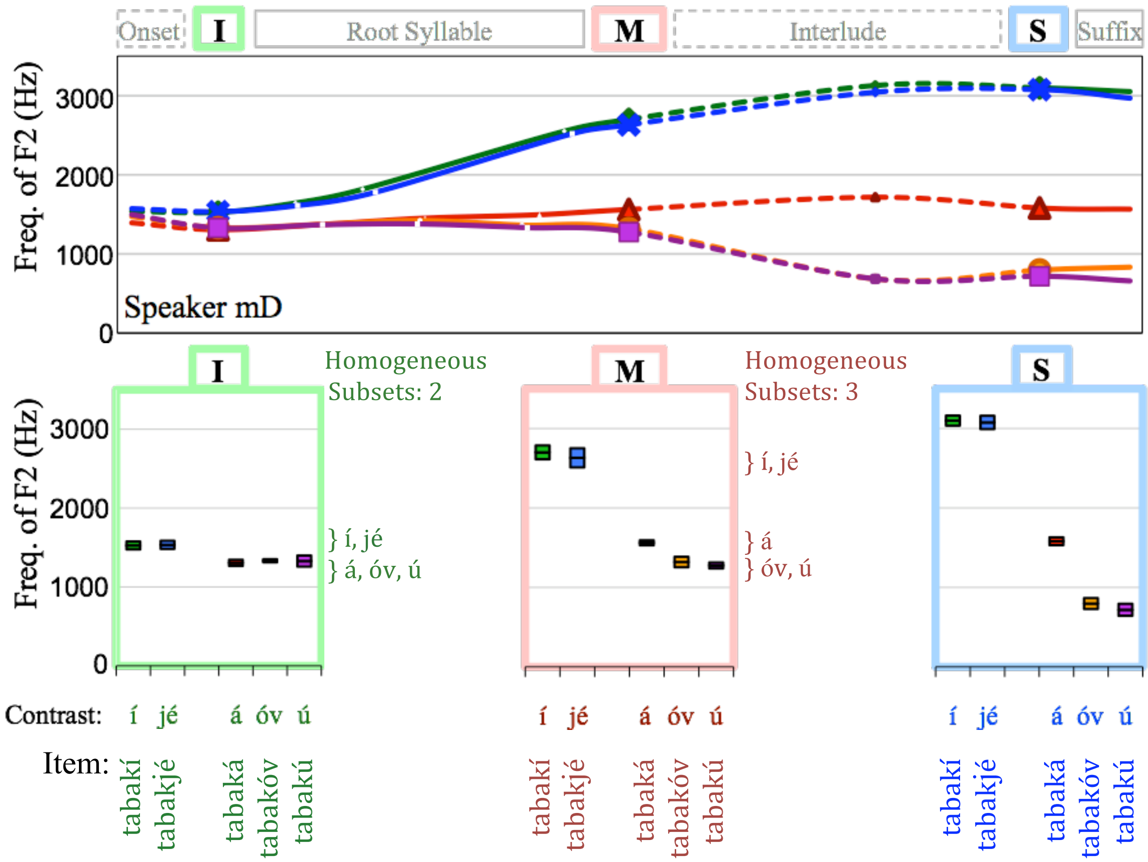


Figure 4.76 Differentiation at Terminus of Pre-tonic Root of табак /tabak/ ‘tobacco.’ The terminus is divided into three sub-sets, according to suffixes: front, centralized and back.

Table 4.36 Results of Univariate ANOVA for F2 at the Terminus of Pre-tonic Root /tabak/. All speakers differentiate the terminus of the root, based upon the vowel of suffix: front vs. non-front. Some speakers further differentiate, based upon suffix: low vs. back.

Subset / Speaker	Number of Subsets	DCT Violations	Homogeneous Subsets			
pF	2	0	í, jé		á, óv, ú	
pG	2	0	í, jé		á, óv, ú	
mC	4	2	jé	í	á, óv	óv, ú
mB	2	0	í, jé		á, óv, ú	
mD	3	1	í, jé		á	óv, ú

4.3.1.17 Anticipatory Coarticulation with the Pre-Tonic Root /bok/

The pre-tonic nucleus /o/ was observed in the inflected forms of the lexical item бок /bok/ 'side,' which has stress on the suffix, except for "zero" suffix, in which case, stress is on the final syllable of the root.

Pre-tonic /o/ exhibited anticipatory effects from the suffix as early as the initium, as shown in pane I of Figure 4.77. Differentiation continued to increase across the duration of the root syllable.

Prior to front vowel suffixes, pre-tonic /o/ began to diphthongize with the contrastive pre-kernel target /j/ of the suffix syllable, forming a heterosyllabic diphthong.

Prior to non-front vowel suffixes, pre-tonic /o/ often behaved like a steady-state monophthong. For some speakers, pre-tonic /o/ differentiated for low vs. non-low tonic back suffixes, just prior to the terminus of the pre-tonic root syllable.

In general, all five primary speakers exhibited similar behavior when performing inflected forms of the pre-tonic root /bok/, and generated a distinction at the terminus of the pre-tonic root, contrasting front vs. non-front vowel suffixes. Some speakers further differentiated non-front suffixes into low vs. non-low/ suffixes. The trinary or non-conventional binary distinctions within non-front suffixes violated DCT parameters. DCT does not have a mechanism which permits systematic replicable, contrastive subsets before hard consonants.

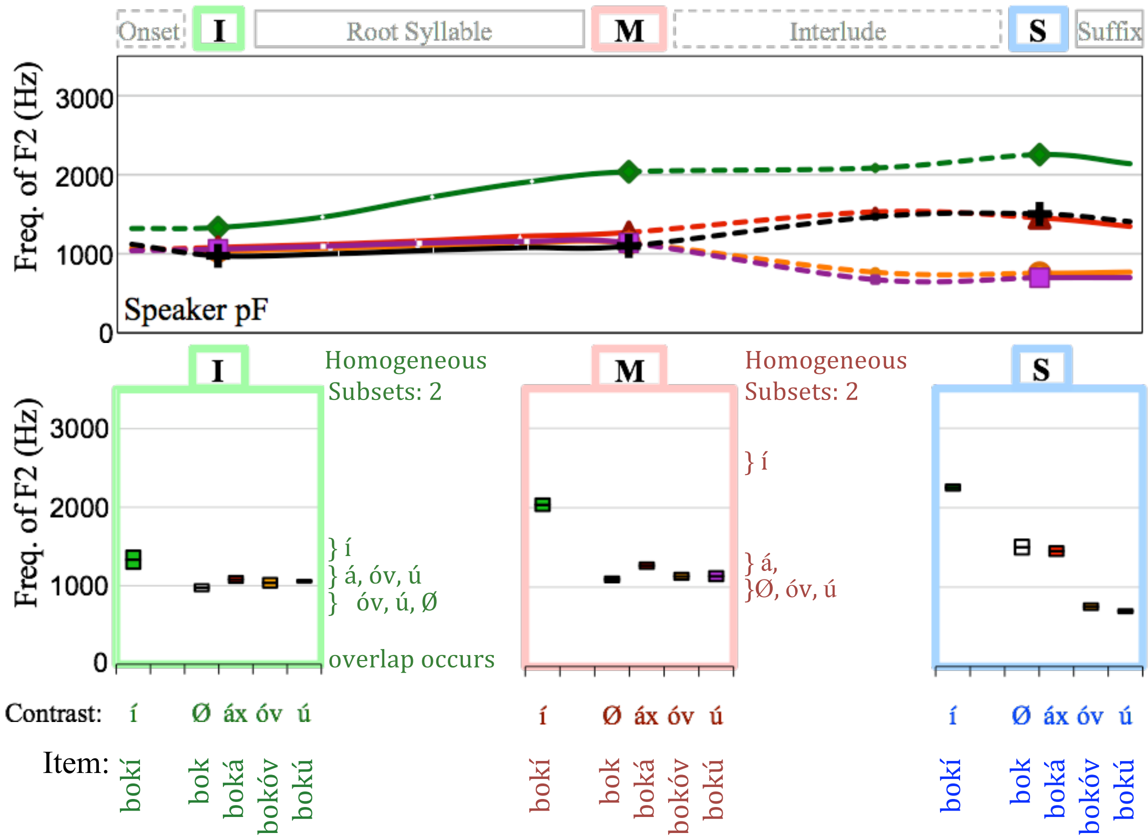


Figure 4.77 Differentiation at Terminus of Pre-tonic Root of бок /bok/ 'side.' Note: The root before zero suffix is post-tonic, being the final syllable of the phrase бо́к о́ бок. It is not possible to produce a pre-tonic root before zero suffix, since zero cannot bear stress. The terminus is divided into three sub-sets, according to suffixes: front, low and back.

Table 4.37 Results of Univariate ANOVA for F2 at the Terminus of Pre-tonic Root /bok/. All speakers differentiate the terminus of the root, based upon the vowel of suffix: front vs. non-front. Some speakers further differentiate, based upon suffix: low vs. back.

Subset / Speaker	Number of Subsets	DCT Violations	Homogeneous Subsets		
pF	3	1	í	á	óv, ú
pG	2	0	í	á, óv, ú	
mC	1	0		á, óv	
mB	2	0	í	á, óv	
mD	2	1		á	óv

4.3.1.18 Anticipatory Coarticulation with the Pre-Tonic Root /čubuk/

The pre-tonic nucleus /u/ was observed in the inflected forms of the lexical item чубук /čubuk/ 'pipe mouthpiece,' which has stress on the suffix, except for "zero" suffix, in which case, stress is on the final syllable of the root.

Pre-tonic /u/ exhibited a slight degree of anticipatory effects from the suffix even at the initium, as shown in pane I of Figure 4.78. The pre-tonic /u/ of this particular lexical item also exhibited preservative effects from the word-initial palatal consonant /č/. For all tokens within the /čubuk/-type peer group, the two successive unstressed syllables of the root with kernel /u/ effectively created the lingual sequence /ču:/. The lingual trajectory of the first two syllables of the token did not obtain the prototypical locus of [u] until the latter half of the pre-tonic syllable. As such, front vowel suffixes effectively completed a sequence /ču:j/, which behaved similar to a triphthong /juj/, and caused the allophonic locus of some tokens to occur on the fronting axis for /u/.

Prior to front vowel suffixes, pre-tonic /u/ began to (tri)/diphthongize with the contrastive pre-kernel target /j/ of the suffix, forming a heterosyllabic (tri)/diphthong.

Prior to non-front vowel suffixes, pre-tonic /u/ often behaved like a steady-state monophthong. For some speakers, pre-tonic /u/ differentiated for low vs. non-low tonic back suffixes, just prior to the terminus of the pre-tonic root syllable.

In general, all five primary speakers exhibited similar behavior with the pre-tonic root /čubuk/, and generated a distinction at the terminus, contrasting front vs. non-front vowel suffixes. Some speakers further differentiated non-front suffixes into low vs. non-low suffixes. The binary distinctions within non-front suffixes violated DCT conventions.

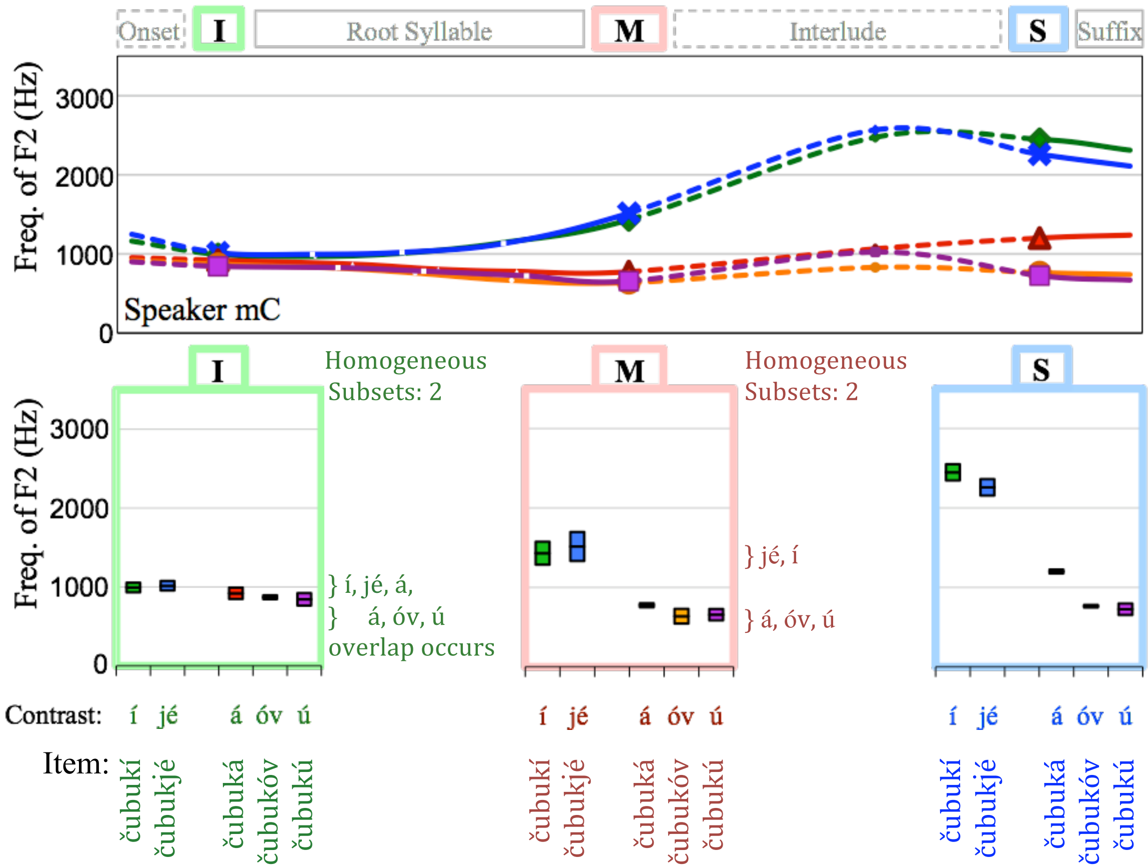


Figure 4.78 Differentiation at Terminus of Pre-tonic Root of чубук /čubuk/ 'pipe mouthpiece.' The terminus is divided into two sub-sets, according to suffixes: front vs. non-front.

Table 4.38 Results of Univariate ANOVA for F2 at the Terminus of Pre-tonic Root /čubuk/. All speakers differentiate the terminus of the root, based upon the vowel of suffix: front vs. non-front. Some speakers further differentiate, based upon suffix: centralized vs. back.

Subset / Speaker	Number of Subsets	DCT Violations	Homogeneous Subsets		
pF	3	1	í, jé	jé, á	á, óv, ú
pG	2	0	jé, í	á, óv, ú	
mC	2	0	í, jé	á, óv, ú	
mB	2	0	í, jé	á, óv, ú	
mD	3	1	í, jé	á, óv	óv, ú

4.3.1.19 Summary of Anticipatory Coarticulation Prior to Suffixes

The homogeneous subsets from univariate ANOVA tests for individual lexical roots have been combined into Table 4.39. As shown in Table 4.39, non-conformity to DCT conventions is more common than conformity to the DCT conventions that can only accommodate a binary differentiation of the root vowel before soft vs. hard consonants.

For tonic roots, if the final target of the root syllable is a high front target /i/ or /j/ (i.e., /píka/, /ježevíka/, /latvíjka/, /bájka/, or /popójka/), then the differentiation at the terminus failed to conform to DCT conventions. The actual distinctions are either trinary or non-conventional binary. The non-conventional binary distinction which does arise differentiates contrastive unreduced (/u/) suffixes vs. non-contrastive (/i je/) and reduced (centralized) (/a oj/) suffixes. The non-conventional trinary distinction further separates non-contrastive unreduced (/i/ or /je/) from centralized (/a/ or /oj/) suffixes.

For the remaining roots with front kernels, if the final target of the root syllable is /e/ or only the pre-kernel /j/ (i.e., /ék vjék/, or pre-tonic /zdorovjak vjek/), then the differentiation at the terminus failed to conform to DCT conventions. The distinctions are actually trinary or quaternary. The trinary distinction contrasts front vs. centralized vs. back suffixes. The quaternary distinction contrasts front vs. /a/ vs. /o/ vs. /u/ suffixes.

For roots with centralized nuclei containing /y/, tonic kernel /a/, or non-tonic kernels /a o/, the differentiation at the terminus variably conform to DCT conventions. If the nucleus of these roots is a tonic /y/, then the kernel target /i/ will be impacted by the tractive force of the following pre-kernel of the suffix. This kernel /i/ will be fully obtained if the suffix pre-kernel is /j/, and will not be fully obtained if the suffix pre-kernel is not /j/. If the nucleus is a non-tonic /y/, then the kernel will be deleted and the nucleus will only consist of the centralized pre-kernel /ɨ/. If the differentiation at the terminus conforms to DCT conventions, then the distinction will be binary and contrast front vs. centralized and back suffixes. If the differentiation at the terminus fails to conform to DCT conventions, then the distinction will be trinary and contrast front vs. centralized vs. back suffixes.

For roots with mid to high back kernels, the differentiation at the terminus may or may not conform to DCT conventions. If the differentiation conforms to DCT conventions, then the distinction will be binary and contrast front vs. centralized or back suffixes. If the differentiation at the terminus failed to conform to DCT conventions, then the distinction will be trinary and contrast /i/ vs. /je/ vs. centralized/back suffixes.

The peer groups of a fixed root plus contrastive suffix pairings in Table 4.39 can be compared directly by converting frequency values of F2 into rankings within the peer group. Thus, the effect of /u/ suffix (with its low value of F2) on a root with a kernel /i/ can be compared to the effect of /u/ suffix on a root with a kernel /a/, despite the contrastive values of F2 for the respective roots.

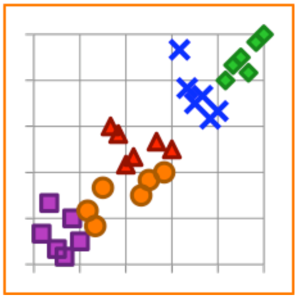
Consider the left pane of Figure 4.79, in which the values of F2 for the terminus and the leading edge of the suffix of the 30 tokens within the tonic /vjék/ peer group (i.e., 6 tokens each of /vjéki vjékje vjékax vjéko vjéku/) have been sorted in ascending order and ranked from 1-30. The rank of the terminus has been plotted against the rank of the suffix, for each token of the peer group. A lower rank of the value of F2 for the terminus reflects a lower rank of the value of F2 for the suffix.

Table 4.39 Univariate ANOVA Test Homogeneous Subsets, Denoting DCT Conformity to Potential Contrast at Terminus Before Soft/Hard Consonants Associated With Suffixed Vowels.
S=Speaker; L=Lexical Item; R=Last Root Target; 1-5=Terminus Before Suffix; H=Subsets; V=Violations

S	L	R	1	2	3	4	5	H	V
pF	ježevíka	í	je	a	i	oj	u	2	
pG	ježevíka	í	je	a	i	oj	u	3	2
mC	ježevíka	í	i	je	a	oj	u	3	1
mB	ježevíka	í	i	je	a	oj	u	3	1
mD	ježevíka	í	je	i	oj	a	u	3	1
pF	píka	í	a	je	i	oj	u	3	2
pG	píka	í	i	a	je	oj	u	2	1
mD	píka	í	i	je	oj	a	u	3	1
pF	ɛ́k	ɛ́	ij		aja	ogo	uju	3	1
pG	ɛ́k	ɛ́	ij		aja	ogo	uju	3	1
mC	ɛ́k	ɛ́	ij		aja	ogo	uju	2	
mB	ɛ́k	ɛ́	ij		aja	ogo	uju	4	2
mD	ɛ́k	ɛ́	ij		aja	ogo	uju	3	1
pF	vjɛ́k	ɛ́	i	je	a	o	u	3	1
pG	vjɛ́k	ɛ́	i	je	a	o	u	3	1
mC	vjɛ́k	ɛ́	i	je	a	o	u	3	1
mB	vjɛ́k	ɛ́	i	je	a	o	u	4	2
mD	vjɛ́k	ɛ́	je	i	a	o	u	3	1
pF	uzbjɛ́k	ɛ́	i	je	a	ov	u	3	1
pG	uzbjɛ́k	ɛ́	i	je	a	ov	u	4	2
mD	uzbjɛ́k	ɛ́	i	je	a	ov	u	3	1
pF	kavýka	í	je	i	a	oj	u	3	1
pG	kavýka	í	i	je	oj	a	u	3	1
mC	kavýka	í	i	je	a	oj	u	2	
mB	kavýka	í	i	je	a	oj	u	2	
mD	kavýka	í	je	i	oj	a	u	4	2
pF	bjáka	á	i	je	oj	a	u	2	
pG	bjáka	á	i	je	a	oj	u	3	1
mC	bjáka	á	i	je	oj	a	u	3	1
mB	bjáka	á	i	je	a	oj	u	3	1
mD	bjáka	á	i	je	a	oj	u	3	1
pF	sobáka	á	i	je	a	oj	u	3	1
pG	sobáka	á	je	i	a	oj	u	2	
mC	sobáka	á	i	je	oj	a	u	2	
mB	sobáka	á	i	je	oj	a	u	3	1
mD	sobáka	á	i	je	a	oj	u	3	1
pF	bók	ó	je	i		om	u	4	2
pG	bók	ó	i	je		om	u	4	2
mC	bók	ó	i	je	a	om	u	2	
mB	bók	ó	i	je	a	om	u	2	
mD	bók	ó	i	je	a	om	u	2	
pF	ljepjëxa	ó	i	je	a	oj	u	2	
pG	ljepjëxa	ó	je	i	a	oj	u	3	1
mC	ljepjëxa	ó	i	je	a	oj	u	2	
mB	ljepjëxa	ó	i	je	a	oj	u	3	1
mD	ljepjëxa	ó	i	je	oj	a	u	2	
pF	búk	ú	i	je	a	ov	u	2	1
pG	búk	ú	i	je	a	ov	u	2	
mC	búk	ú	i	je	a	ov	u	2	
mB	búk	ú		je	a	ov	u	2	
mD	búk	ú	i	je	u	ov	a	3	1

S	L	R	1	2	3	4	5	H	V
pF	latvíjka	j	i	a	oj	je	u	2	1
pG	latvíjka	j	i	je	oj	a	u	2	1
mC	latvíjka	j	i	oj	je	a	u	2	1
mB	latvíjka	j	i	je	oj	a	u	3	1
mD	latvíjka	j	je	i	oj	a	u	2	1
pF	bájka	j	i	je	a	oj	u	1	
pG	bájka	j	i	je	oj	a	u	3	1
mC	bájka	j	i	je	oj	a	u	3	1
mB	bájka	j	i	je	oj	a	u	3	1
mD	bájka	j	i	je	oj	a	u	3	1
pF	popójka	j	je	a	i	oj	u	2	1
pG	popójka	j	je	i	a	oj	u	2	1
mC	popójka	j	i	je	a	oj	u	3	1
mB	popójka	j	i	je	a	oj	u	3	1
mD	popójka	j	i	je	a	oj	u	2	1
pF	vjek	j			áx	óv	ú	3	2
pG	vjek	j			áx	óv	ú	2	1
mC	vjek	j			áx	óv	ú	2	1
mB	vjek	j			áx	óv	ú	2	1
mD	vjek	j			áx	óv	ú	3	2
pF	zdorovjak	j	í	jé	á	ú	óv	3	1
pG	zdorovjak	j	í	jé	á	óv	ú	3	1
mC	zdorovjak	j	í	jé	á	óv	ú	3	1
mB	zdorovjak	j	í	jé	á	óv	ú	3	1
mD	zdorovjak	j	í	jé	á	óv	ú	4	2
pF	byk	ɨ	í	jé	á	óv	ú	3	1
pG	byk	ɨ	í	jé	á	óv	ú	2	
mC	byk	ɨ	í	jé	á	óv	ú	2	
mB	byk	ɨ	í	jé	á	óv	ú	2	
mD	byk	ɨ	í	jé	á	ú	óv	3	1
pF	tabak	ɐ	í	jé	á	óv	ú	2	1
pG	tabak	ɐ	í	jé	á	óv	ú	2	1
mC	tabak	ɐ	jé	í	á	óv	ú	4	2
mB	tabak	ɐ	í	jé	á	óv	ú	2	
mD	tabak	ɐ	í	jé	á	óv	ú	3	1
pF	bók	ɐ	í		á	óv	ú	3	1
pG	bók	ɐ	í		á	óv	ú	2	
mC	bók	ɐ			á	óv		1	
mB	bók	ɐ	í		á	óv		2	
mD	bók	ɐ			á	óv		2	1
pF	čubuk	u	í	jé	á	óv	ú	3	1
pG	čubuk	u	jé	í	á	óv	ú	2	
mC	čubuk	u	í	jé	á	óv	ú	2	
mB	čubuk	u	í	jé	á	óv	ú	2	
mD	čubuk	u	í	jé	á	óv	ú	3	1

Subset overlaps subset to its right	Unstressed Root
Non-violations to DCT for contrast before suffix	Violations to DCT for contrast before suffix
Non-differentiated before front/non-front suffix	Differ within non-front; Differ within non-front
Differ before front vs. Differ before non-front	Differ within front set



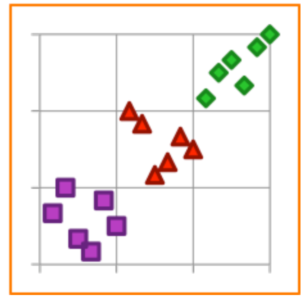


Figure 4.79 Ranked Relationship Between the Terminus and Leading Edge of the Suffix. The figure depicts the relationship between the ranked termini of tokens of the /vjék/ peer group and contrastive suffixes. The left pane consists of 6 tokens each of the root /vjék/ prior to suffixes /i je ax o u/ (icons ◆, ✖, ▲, ●, ■, resepctively). The right pane consists of the /i ax u/ suffixes only. The figure features speaker mB.

The left pane of Figure 4.79 depicts an alternative view of the 4 homogeneous subsets from the univariate ANOVA test of speaker mB's /vjék/ peer group form Table 4.39. As shown in left pane of Figure 4.79, the range of the six tokens of /vjéku/ is basically confined to the first tier of the five delimited vertical tiers, although there is overlap with some tokens of /vjéko/. The range of the six tokens of /vjéko/ is basically confined to the second tier, although there is some overlap with tokens of /vjéku/. The range of the six tokens of /vjékax/ is basically confined to the third tier, and there is no overlap (i.e., the tokens of /vjékax/ represent an uninterrupted series of the ranks 13-18 of the peer group). The range of the tokens of /vjékje/ extends from tier 4 to tier 5 and overlaps with tokens of /vjéki/.

Since the suffixes /je i/ begin with equivalent segments, it is common for the range of these two suffixes to overlap. Likewise, due to vowel reduction, the range of /o/ suffixes often overlap with /a/, as evidenced by overlap of /o a/ tokens on the horizontal axis of the left pane of Figure 4.79. In order to eliminate persistent overlap due to a lack of contrast, the /je o/ suffixes will be temporarily removed from consideration, and hence, the right pane of Figure 4.79 contains only the tokens involving /u a i/ suffixes.

As shown in the right pane of Figure 4.79, of the 18 tokens depicted, the tokens of the /u/ suffix represent the six tokens with the lowest (ranked) value of F2 for the suffix (on the horizontal scale). Due to anticipatory effects, the termini of the tokens prior to the /u/ suffix also have the lowest (ranked) value of F2. Similarly, the tokens of the /i/ suffix represent the six tokens with the highest (ranked) value of F2 for the suffix (on the horizontal scale). Due to anticipatory effects, the termini of the tokens prior to the /i/ suffix also have the highest (ranked) value of F2. The six tokens of the /ax/ suffix occupy the intermediate range on the horizontal axis, and hence, due to anticipatory effects, occupy the intermediate range on the vertical axis.

Since the values of F2 (in Hz) have been converted to relative ordinal rankings, the behavior of contrastive peer groups can be compared more readily. In Figure 4.80, the ordinal rankings of all peer groups have been superimposed, in an effort to determine any systematic relationship between the phoneme of the suffixes, their relative rankings for F2, and the relationships between the syllable edges of collected tokens.

In the left column of Figure 4.80, the behavior of the initium of the root is compared to the behavior of the terminus. The initium may occur over the full range of values (from 1-18) on the vertical axis, regardless of any behavior of the termini on the horizontal axis. Therefore, the behavior at the initium is independent of the terminus. The terminus exhibits potential dependency on the initium, in that higher values of the terminus tend to skew towards the high vertical scale. However, this is primarily true of termini preceding the /i/ suffix, which most likely represents an external influence. There is a more relaxed tendency in the termini prior to /u a/ suffixes to be distributed across a broader range horizontally, regardless of the ranking of the initium on the vertical axis.

In the middle column of Figure 4.80, the behavior of the initium of the root is compared to that of the suffix. The initium may occur over the full range of values on the vertical axis, regardless of the suffix on the horizontal axis. Therefore, the behavior at the initium is independent of the suffix. The behavior of the suffix is codified both in position on the horizontal axis and in the iconic marking of each token. Since the suffix behavior is essentially segregated on the horizontal axis, based upon the iconic definition of the suffix, regardless of the behavior by the initium on the vertical axes, the behavior of the suffix is independent of the behavior of the initium.

In the right column of Figure 4.80, the behavior of the terminus of the root is compared to the suffix. There is a direct relationship between the behavior of the terminus and the suffix, although it is not immediately evident which is the dependent variable. However, in Section 4.3.2, it will be shown that the phoneme of the suffix is routinely positioned on-target and on-schedule at the leading edge of the suffix, regardless of the preceding syllable. Furthermore, in this section, it has been shown that the location of the root vowel at the terminus is an intermediate position between the root vowel and the suffix. As such, it is posited that the behavior of the suffix is independent of the behavior of the terminus; however, the behavior of the terminus is conditioned by the behavior of the suffix.

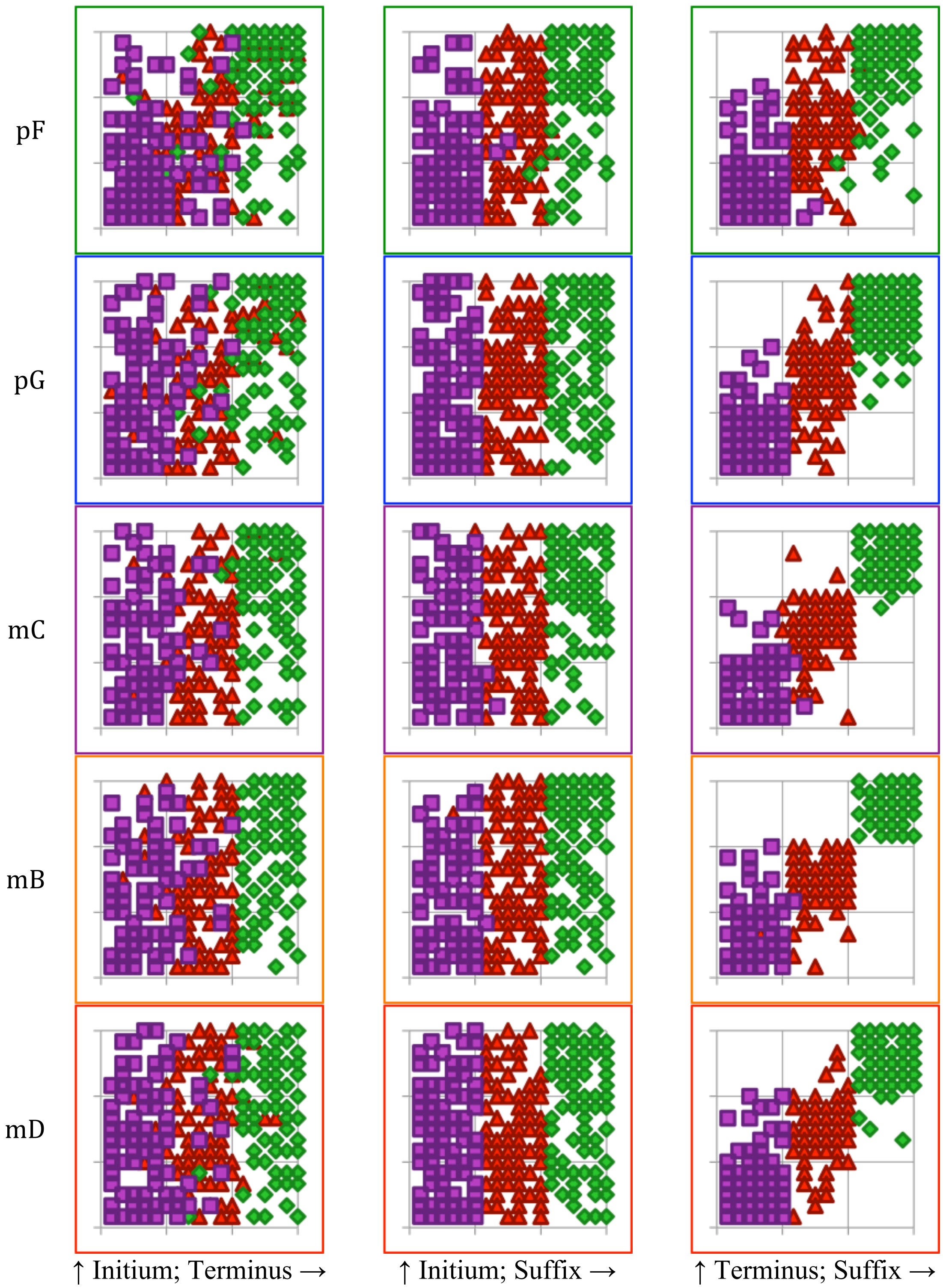


Figure 4.80 Ranked Relationship Between Syllable Edges of Root and Suffix. The icons ◆, ▲, ■, present tokens with the suffix /i a u/, respectively.

The virtually ubiquitous non-conventional differentiation at the terminus of the root is caused by coarticulation between the root and the suffix across the consonant interlude. In general, the kernel of a nucleus is destined to coarticulate with an adjacent lingual target, often forming a tautosyllabic or heterosyllabic diphthong.

Consider the anatomy of the sonorous portion of the root syllables in Figure 4.81. The root vowels consist of three zones: 1) onset effects, 2) momentary attainment of a fronted allophonic loci, and 3) offset effects. The onset effects are further divided into labial effects and onglide transition. The labial damping dissipated shortly after the initium. The onglide transition continues to mid-syllable. The duration of "on-target" allophonic attainment of the kernel is brief. The offset effect begins approximately at mid-syllable.

The syllables depicted in Figure 4.81 represent ÇVÇ sequences, for which DCT conventions assert that the kernels /ɛ a o/ have relocated to fronted allophonic loci /e æ ö/, respectively. The syllables in Figure 4.82 represent ÇVK sequences, and the kernels supposedly have not been relocated to a fronted allophonic locus. However, the tracks in Figure 4.82 reveal that the ÇVK sequences have similar onset effects as their peers in Figure 4.81, namely a short-lived labial effect and a protracted onglide transition. Since similar onset effects occur for ÇVÇ and ÇVK syllables, the behavior of the soft onsets operates independently of the following consonantal context.

In Figure 4.83, KVÇ root syllables prior to high front suffixes exhibit similar offset effects as ÇVÇ syllables in Figure 4.81, in the absence of the initial soft consonant environment. Therefore, since the same offset effects occur with or without a preceding soft environment, the offset effects associated with a following soft environment are independent of the effects associated with a preceding soft environment.

However, onset and offset effects associated with soft consonants operate over a different scope as consonantal effects associated with hard consonants. In Figure 4.82, the onglide transition usually extends completely across the syllable, to the terminus. When compared to the labial portion of the onset effects, the onglide transition is four to five times in duration. This would suggest that the onglide transition is in a different class of transitions than the labial effects.

Furthermore, once tonic suffixes are considered, there will be no labial component of the onset effect (since all roots in this study terminate is velar consonants). And suffixes with tonic /je/, the formant pattern at the initium is routinely maintained as a steady-state /i/ for 40-50 msec. This further shifts the nature of the onset after a soft consonant towards the vocalic end of the continuum of speech sounds from consonant to semi-consonant to vowel in Liberman (1956).

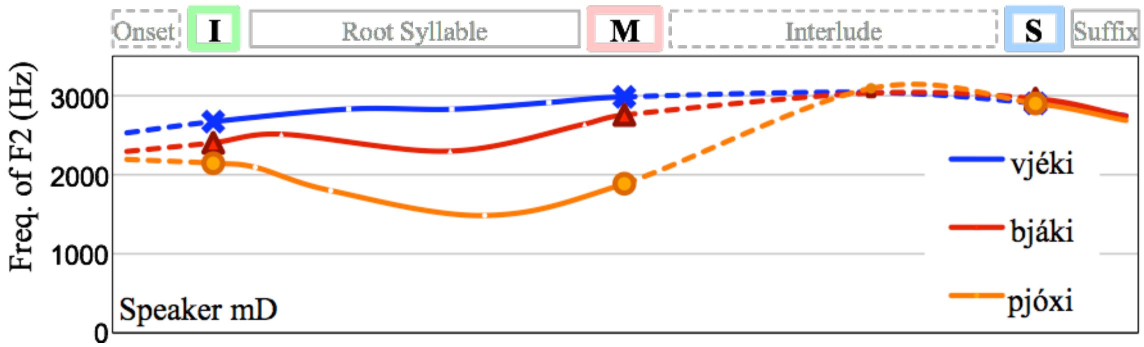


Figure 4.81 The Anatomy of ÇVÇ Sequences. The root vowels consist primarily of three parts: 1) onset effects (labial damping and onglide transition), 2) mid-syllable fronted allophonic locus, and 3) offset effects.

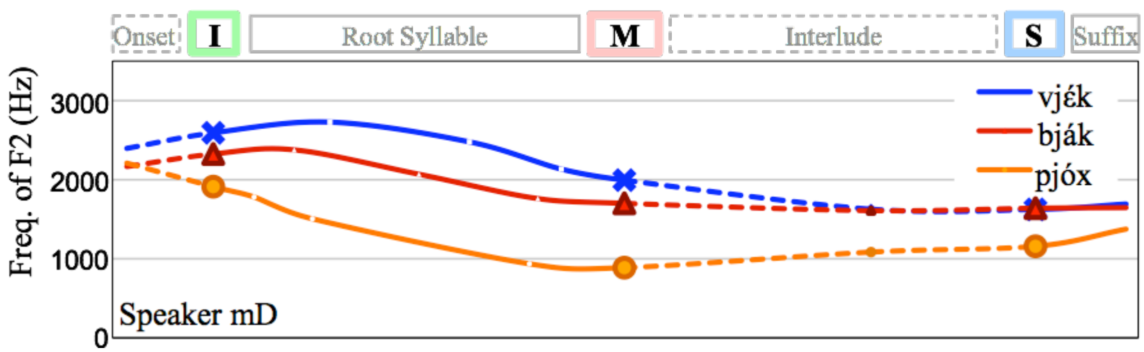


Figure 4.82 The Anatomy of ÇVK Sequences. The root vowels consist primarily of two parts: 1) onset effects (labial damping and onglide transition), 2) terminal allophonic locus. However, the onglide transition extends from the initium to the terminus.

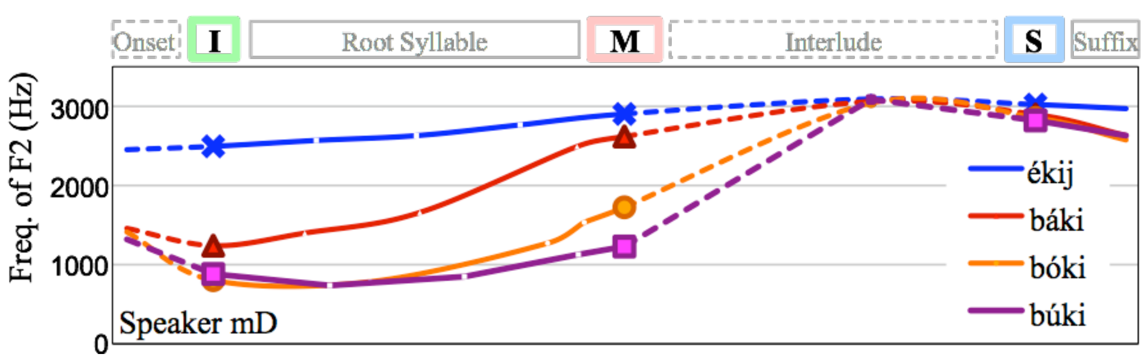


Figure 4.83 The Anatomy of KVÇ Sequences. The root vowels consist primarily of two parts: 1) initial allophonic locus, and 2) offset effects (including offglide). However, the offglide transition begins prior to mid-syllable.

4.3.2 Suffixes and Scheduling of Pre-kernel Targets

In general, coarticulation effects in Modern Standard Russian are primarily anticipatory, because the scheduling and targeting requirements of the pre-kernel position of the nucleus take precedence over the requirements of the kernel position of the nucleus or the post-kernel offglide position in the coda. Anticipatory effects from specified pre-kernel target extend backwards in time into preceding syllables.

Therefore, preservative coarticulation effects will only be registered onto a syllable, if its pre-kernel is underspecified. Underspecified pre-kernel segments cannot project articulatory targeting specifications backwards in time, nor can they be obtained during the preceding interludes, because they do not possess targeting information. As such, underspecified pre-kernel segments only possess scheduling information which is associated with the pre-kernel node of the nucleus, namely, sonorous voicing schedules.

In this section, the behavior of the leading edge of a suffix will be observed. Unlike previous sections, in which the root syllable was held constant, while the suffixes were contrasted, in this section, the suffix will be held constant, and the preceding root will be varied. Comparisons will be made for the interlude prior to the suffix and for the initium of the suffix. Because of low signal-to-noise ratio, and Praat-nominated data-points for the majority of the interlude are deemed unreliable. Therefore, the interlude will be plotted only at three points: the beginning (corresponding to the terminus of the root), middle (corresponding to the release of the stop), and end (corresponding to the initium of the suffix). In the future, with improvements in software or by liberal use of fricatives, data-points from the entirety of the interlude should be reliable.

4.3.2.1 Targeting Schedule for /u/ Suffixes

As shown in Figure 4.84, the pre-kernel of the tonic suffix /ú/ is pre-positioned and anchored during the interlude. In most cases, the acoustic tracks converge to a value of F2 which is on-target, circa the release of the obstruent /k/. This indicates that the articulation of the suffix has arrived on-target at the instant of the release, or prior to this event. The tracks of the vowel remain constant and the vowel is on-target at the initium.

As shown in pane S of Figure 4.84, the consistency of the suffix at its initium is reflected in the equivalent mean values of F2 from type to type within its peer group, regardless of the preceding root vowel. The consistency and stasis of the suffix at the initium is also reflected in the lack of variability from token to token, within a particular type, as indicated by the narrow range of one standard deviation for the tokens of that type.

By comparing Figures 4.84 and 4.85, there appears to be negligible difference in the behavior of tonic and post-tonic suffixes /u/. As with tonic /ú/ in Figure 4.53, the post-tonic /u/ in Figure 4.85 exhibits convergence of the targeting schedule and pre-positioning of the pre-kernel of the suffix, circa the release of the obstruent /k/. The behavior of at the initium of post-tonic /u/ is also consistently on-target from type to type, as indicated by the equivalent mean values of F2, and consistently and statically on-target, as indicated by the narrow range of one standard deviation for tokens within a type.

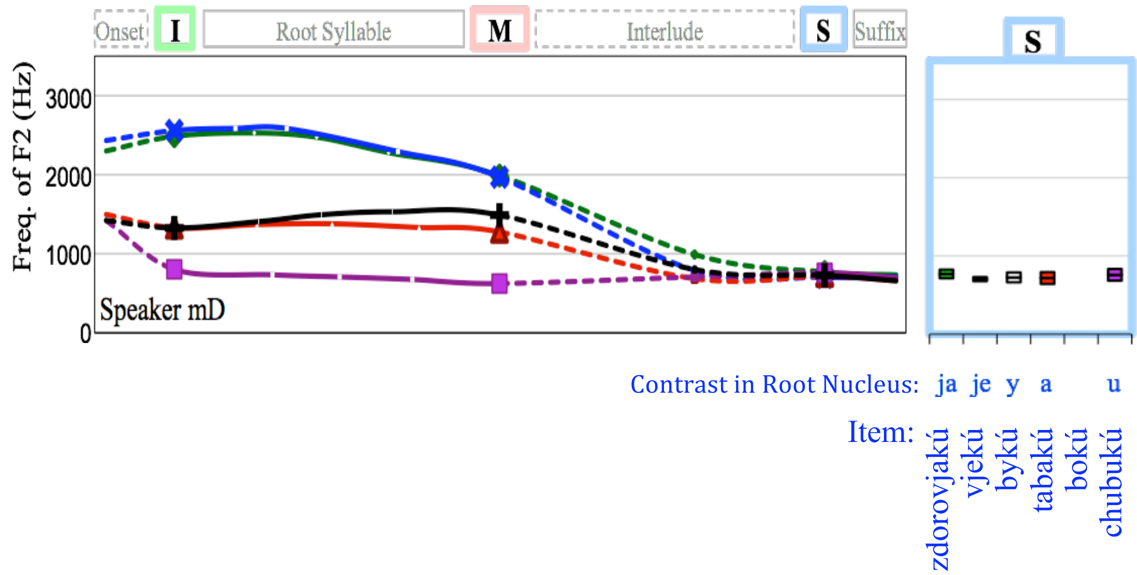


Figure 4.84 Differentiation at Initium of Tonic Suffixes /ú/, Following Various Tonic Vowels. The suffix /u/ is consistently anchored at the stop release, and consistently on-target at the suffix initium.

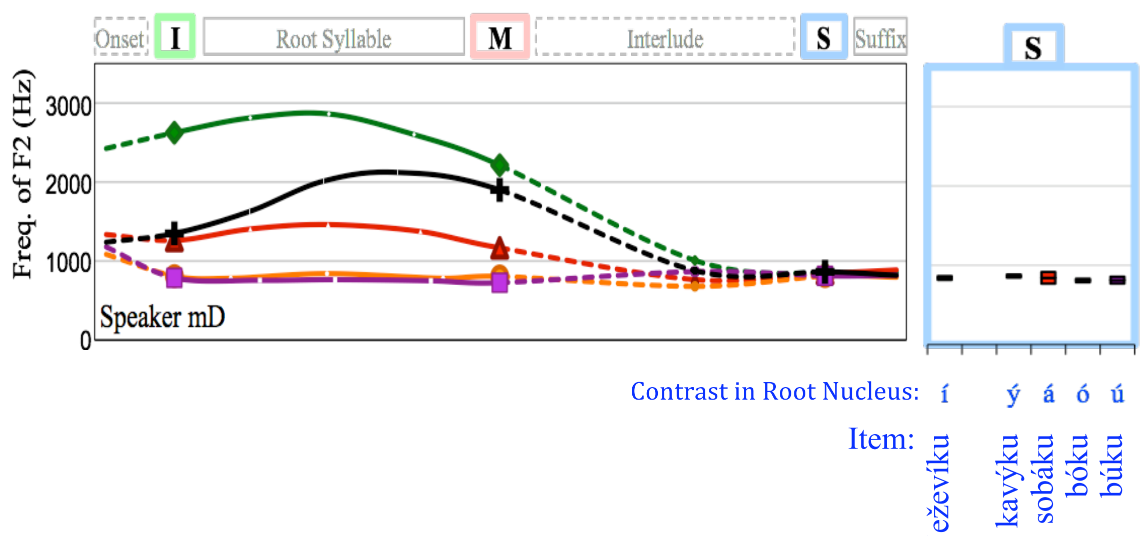


Figure 4.85 Differentiation at Initium of Post-tonic Suffix /u/, Following Various Tonic Vowels. The suffix /u/ is anchored at the stop release, and consistently on-target at the suffix initium.

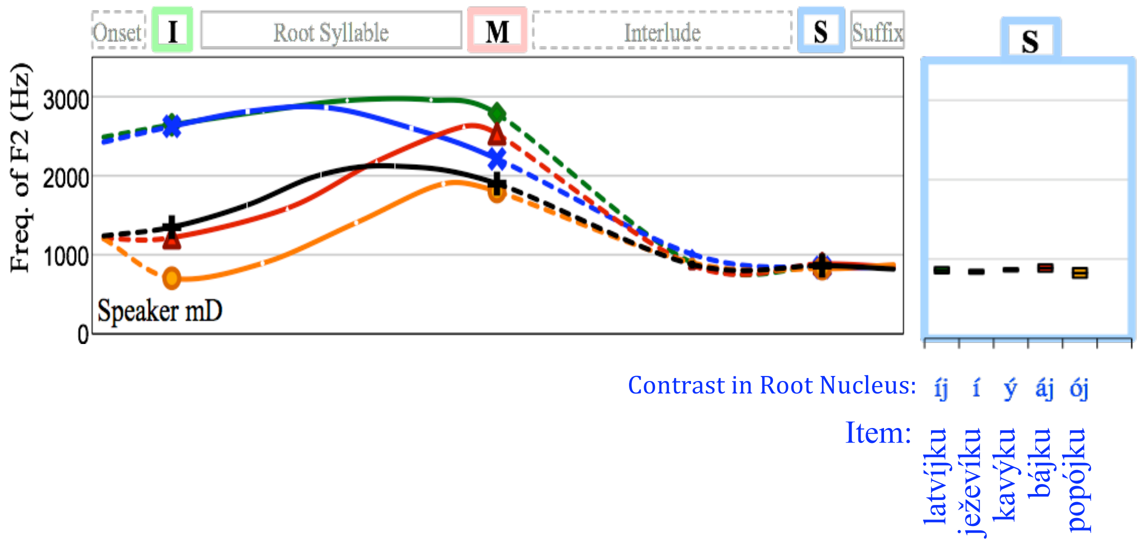


Figure 4.86 Differentiation at Initium of Post-tonic Suffix /u/, Following Tonic Vowels Terminating in /i/ ot /j/. The suffix /u/ is anchored at the stop release, and consistently on-target at the suffix initium.

Since the pre-kernel of /u/ is pre-positioned and anchored during the interlude, the consistency at the anchor-point and at the initium of the suffix is established, regardless of stress on the suffix or the feature specifications of the nucleus of the root vowel. As such, limiting the variability of the root nucleus has little or no effect on the consistency of the pre-kernel of the suffix /u/, as shown in Figure 4.86, in which the pre-kernel and initium behavior of the /u/ suffix is equally consistent, as in Figures 4.84 and 4.85.

However, as shown in Figure 4.86, the imperative for the suffix pre-kernel to be anchored during the interlude has an impact on the terminus of equivalent segments in the preceding syllable. The root syllable of items /latvijku bajku popojku/ all terminate in an offglide /j/. However, the trajectory to the offglide is abandoned prematurely, in response to the imperative to obtain the pre-kernel of the suffix at the appointed anchored time.

4.3.2.2 Targeting Schedule for /o/ Suffixes

As shown in Figure 4.87, the pre-positioning and anchoring of the pre-kernel of the tonic suffix /óv/ is considerably less exact than the behavior for tonic suffix /ú/. In most cases, the acoustic tracks converge towards a value F2, circa the release of the obstruent /k/. However, the convergence is not completed until the initium of the suffix.

In pane S of Figure 4.87, the consistency of the suffix at the initium is reflected in the equivalent mean values of F2 from type to type within the suffix peer group, regardless of the preceding root vowel. The consistency and stasis of the suffix at the initium is also reflected in the lack of variability from token to token, within a particular type, as indicated by the narrow range of one standard deviation for the tokens of any given type.

By comparing Figures 4.87 and 4.88, there appears to be considerable difference in the behavior of tonic and post-tonic suffixes /o/. In Figure 4.88, convergence of transitions to the suffix vowel is separated into two distinct subsets: /oj/ suffix, and elsewhere. While the convergence to /oj/ suffix appears to be anchored during the interlude, the convergence to the suffixes “ogo” /ov om/ is not anchored in the interlude, and the completion of the convergence did not occur until after the initium of the suffix. To verify that this lack of convergence is a result of the vowel of the suffix, and not a result of variability of the overall suffix shape, the data set will need to be restructured to contain only one suffix type (i.e., only /ov/ or only /om/). However, all three of the diversified suffixes share the overall shape /o/ plus labial consonant. At this point, the lack of convergence is tentatively attributed to the underspecified initial suffix vowel /o/.

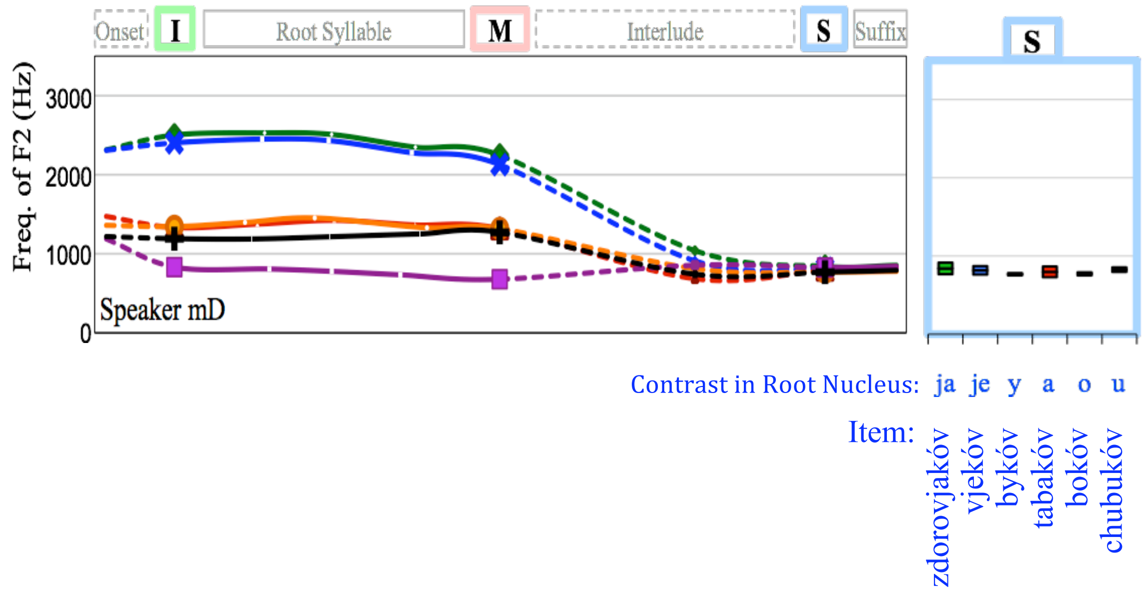


Figure 4.87 Differentiation at Initium of Tonic Suffix /óv/, Following Various Tonic Vowels. The tonic suffix /o/ is consistently on-target at the suffix initium.

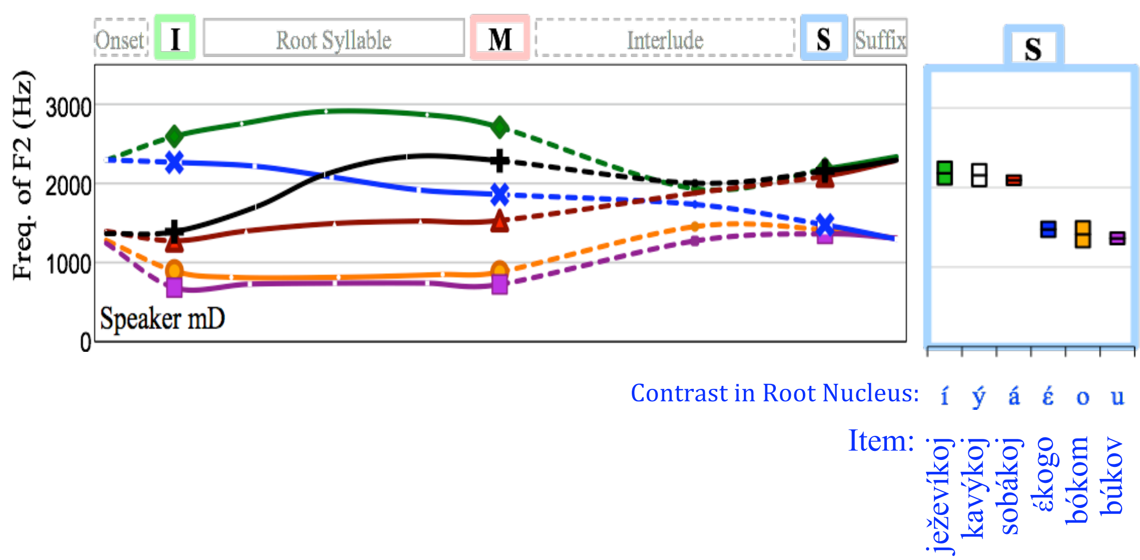


Figure 4.88 Differentiation at Initium of Post-tonic Suffixes with Kernel /o/, Following Various Tonic Vowels. The figure contains two distinctive types of suffixes: /oj o/ plus labial. Each subset has distinctive behavior during the interlude and at the initium. The post-tonic suffix /o/ exhibits discernible degree of variability at the suffix initium.

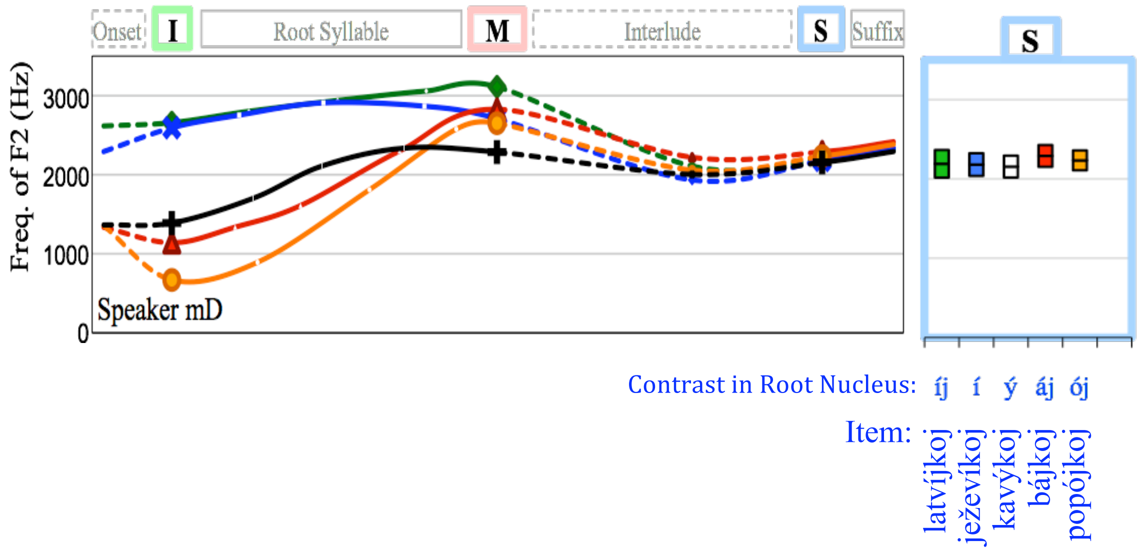


Figure 4.89 Differentiation at Initium of Post-tonic Suffix /oj/, Following Tonic Vowels Terminating in /i/ ot /j/. The suffix /oj is not on-target at the suffix initium, and exhibits a discernible degree of variability at the initium, because the suffix is in transition from the pre-kernel to the offglide.

In Figure 4.89, the degree of variability of the root has been reduced by selecting only roots with /i/ or /j/ as the final vocalic segment of the root; additionally, the variability of the suffix shape have been reduced by selecting only /oj/ suffixes. Despite the decrease in environmental variability, the pre-positioning of the pre-kernel target during the interlude is still more diverse than with the /u/ suffix in the Figure 4.86.

Note, however, in Figure 4.89, that there does appear to be an anchor for the pre-kernel during the interlude, prior to the transition to the offglide of the suffix. As such, the pre-kernel's time-on-target is contained within the interlude. (This is similar to the containment of the time-on-target of pre-kernel /j/ after back vowels in Figure 4.94.)

At the time of the initium, the suffix /oj/ is already in transition to its offglide, as indicated by the greater range of standard deviation for tokens within a particular type.

4.3.2.3 Targeting Schedule for /a/ Suffixes

As shown in Figure 4.90, the pre-positioning and anchoring of the pre-kernel of the tonic suffix /á/ is considerably less exact than the behavior for tonic suffix /ú/. In most cases, the acoustic tracks converge towards a value F2, circa the release of the obstruent /k/. Only the track from the /u/ root syllable exhibits preservative effects onto the suffix, and only this track is not on-target at the anchor-point of the release of the /k/.

In pane S of Figure 4.90, the consistency of the suffix at the initium is reflected in the equivalent mean values of F2 from type to type within the suffix peer group, regardless of the preceding root vowel (excluding the suffix initium for /u/ root). The consistency and stasis of the suffix at the initium is also reflected in the lack of variability from token to token, within a particular type, as indicated by the narrow range of one standard deviation for the tokens of any given type.

By comparing Figures 4.90 and 4.91, there appears to be considerable difference in the behavior of tonic and post-tonic suffixes /a/. In Figure 4.91, convergence of transitions to the suffix vowel is still diverse at the customary anchor-point at the stop release, because the post-tonic /a/ has an underspecified pre-kernel target. Without specificity of the pre-kernel, the convergence to /a/ suffix did not appear to be completed until after the suffix initium.

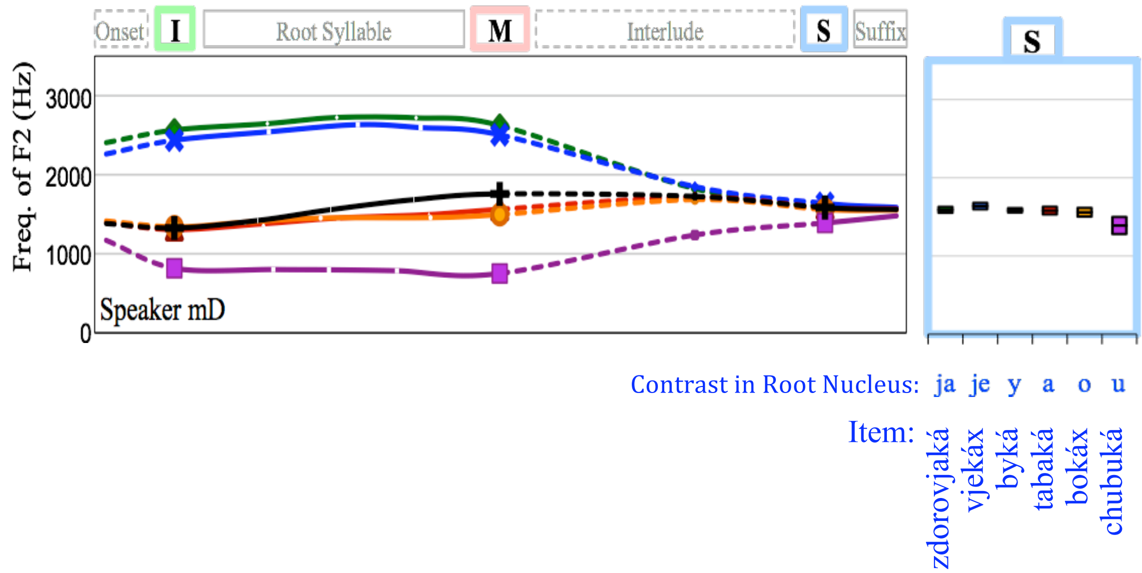


Figure 4.90 Differentiation at Initium of Tonic Suffixes /á áx/, Following Various Tonic Vowels. The suffix is anchored at the stop release, and consistently on-target at the suffix initium in most cases (except for /u/ root).

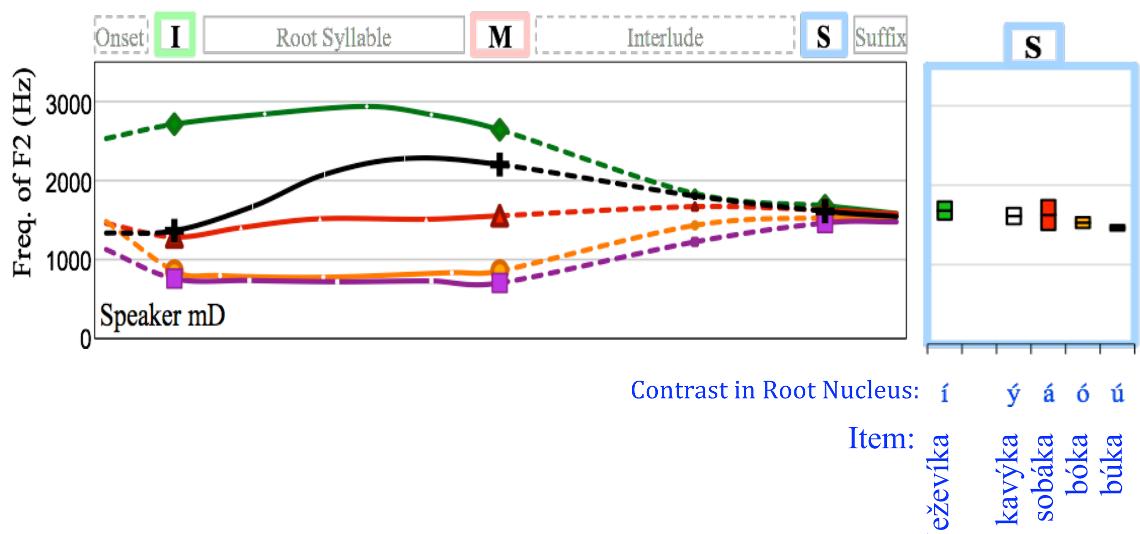


Figure 4.91 Differentiation at Initium of Post-tonic Suffix /a/, Following Various Tonic Vowels. The suffix is neither anchored at the stop release, nor on-target at the suffix initium.

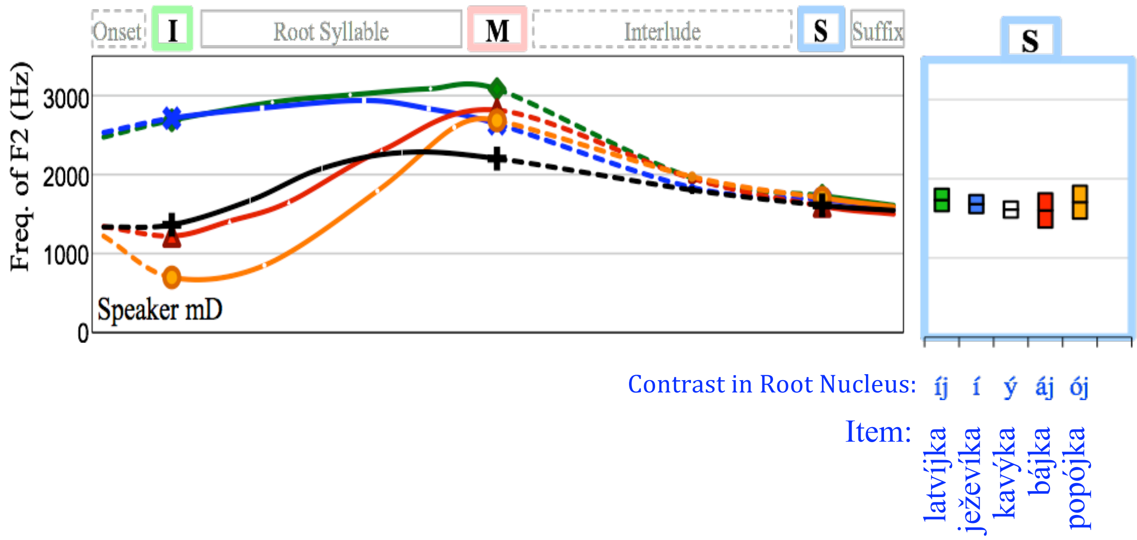


Figure 4.92 Differentiation at Initium of Post-tonic Suffix /a/, Following Tonic Vowels Terminating in /i/ ot /j/. The suffix is neither anchored at the stop release, nor on-target at the suffix initium.

In Figure 4.92, the degree of variability of the root has been reduced by selecting only roots with /i/ or /j/ as the final vocalic segment of the root; therefore, the overall agreement in the contour of the transitional onset to the suffix has been increased. This agreement in contour circumstantially gives the illusion that the pre-kernel of the post-tonic suffix /a/ is anchored at the stop release. However, the apparent anchored point at the stop release is not an allophonic locus associated with post-tonic /a/, but rather is merely an intermediate position on the fronting axis of schwa.

Lastly, without specificity of the pre-kernel, the variability from token to token at the initium is still great, as indicated by the greater standard deviation of each type, in pane S of Figure 4.92. Furthermore, the underspecified post-tonic /a/ exhibits a slight degree of preservative effects from the preceding fully specified /i/ target.

4.3.2.4 Targeting Schedule for /je/ Suffixes

As shown in Figure 4.93, the pre-positioning and anchoring of the pre-kernel of the tonic suffix /jé/ is consistently on-target with /j/. The acoustic tracks of transitions to the suffix converge towards a value F2, circa the release of the obstruent /k/, and the prototypical locus of [i] is obtained. This locus is maintained through the initium. In other words, the pre-kernel locus of the tonic suffix /je/ is maintained as a steady-state position.

In pane S of Figure 4.93, the consistency of the suffix at the initium is reflected in the equivalent mean values of F2 from type to type within the suffix peer group, regardless of the preceding root vowel. The consistency and stasis of the suffix at the initium is also reflected in the lack of variability from token to token, within a particular type, as indicated by the narrow range of one standard deviation for the tokens of any given type.

By comparing Figures 4.93 and 4.94, there appears to be discernible difference in the behavior of tonic and post-tonic suffixes /je/. In Figure 4.94, the pre-kernel /j/ is still anchored circa the stop release, and convergence of transitions to the suffix vowel still obtains the locus of [i]. However, the locus at the anchor-point is not maintained in the post-tonic suffix, and transition to the kernel /e/ begins immediately. As such, the post-tonic suffix is in transition at the initium, and the variability from token to token (indicated by the greater spread in standard deviation in pane S of Figure 4.94) indicates a lack of precise coordination between the lingual gesture and the beginning of sonorous phonation.

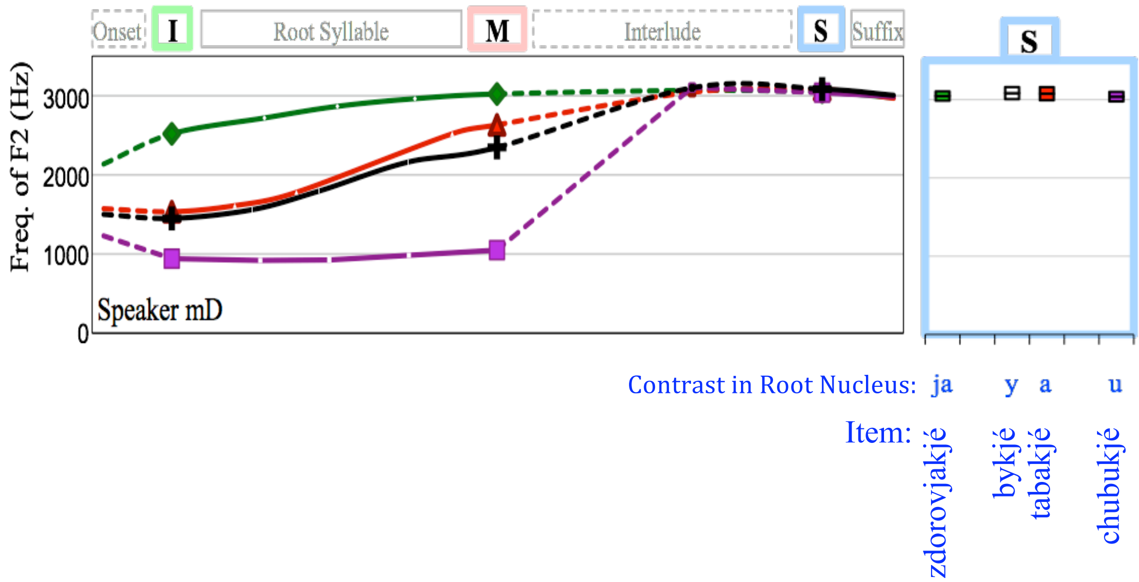


Figure 4.93 Differentiation at Initium of Tonic Suffix /jé/, Following Various Tonic Vowels. The pre-kernel of the suffix is consistently anchored at the stop release, and consistently on-target to the pre-kernel target at the suffix initium.

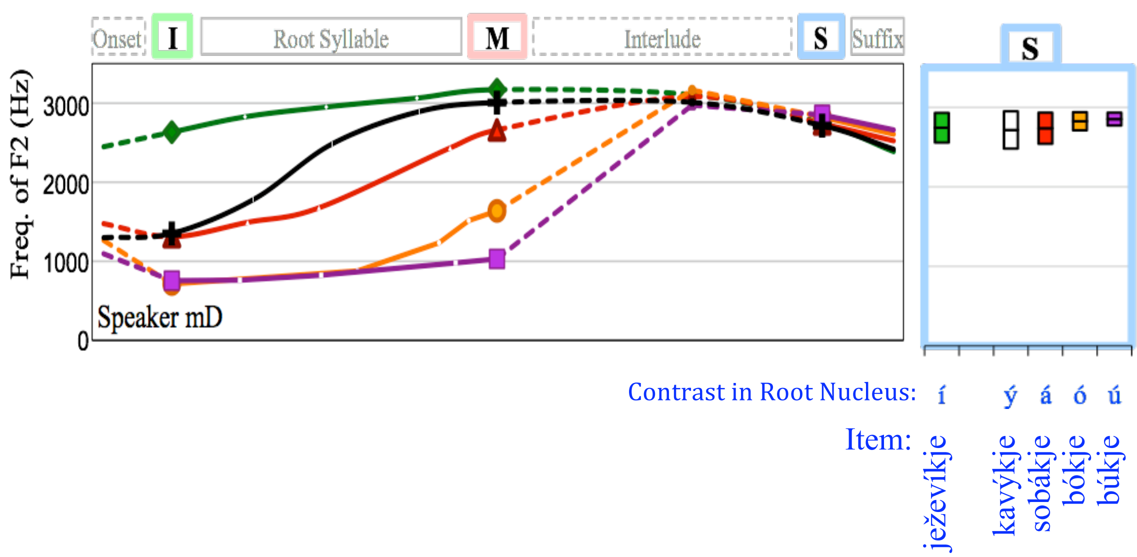


Figure 4.94 Differentiation at Initium of Post-tonic Suffix /je/, Following Various Tonic Vowels. The pre-kernel of the suffix is consistently anchored at the stop release; however, the suffix is in transition from the pre-kernel to the kernel at the suffix initium.

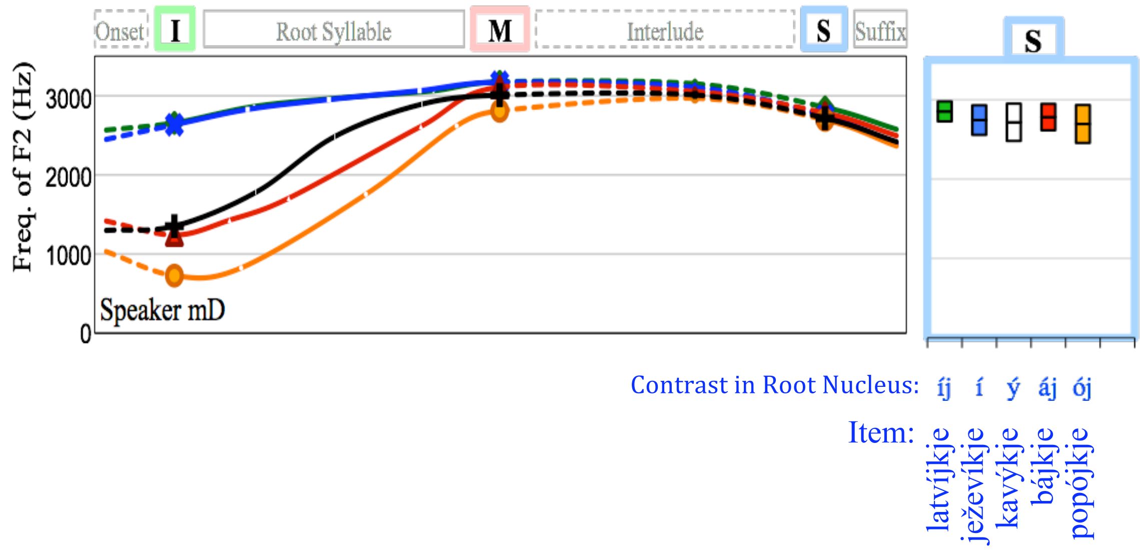


Figure 4.95 Differentiation at Initium of Post-tonic Suffix /je/, Following Tonic Vowels Terminating in /i/ ot /j/. The pre-kernel of the suffix is consistently anchored at the stop release; however, the suffix is in transition from the pre-kernel to the kernel at the suffix initium.

Since the pre-kernel of /je/ is pre-positioned and anchored during the interlude, the consistency at the anchor-point is established, regardless of stress on the suffix or the feature specifications of the nucleus of the root vowel. As such, limiting the variability of the root nucleus offers little to no improvement on the consistency of the pre-kernel of the suffix /je/. As shown in Figures 4.95 and 4.94, the pre-kernel and initium behavior of the /je/ suffix is equally consistent, regardless of the degree of variability of the preceding vowel segment.

4.3.2.5 Targeting Schedule for /i/ Suffixes

As shown in Figure 4.96, the pre-positioning and anchoring of the pre-kernel of the tonic suffix /í/ is consistently on-target. The acoustic tracks of transitions to the suffix converge towards a value F2, circa the release of the obstruent /k/, and the prototypical locus of [i] is usually obtained. This locus is maintained through the initium.

In pane S of Figure 4.96, the consistency of the suffix at the initium is reflected in the equivalent mean values of F2 from type to type within the suffix peer group, regardless of the preceding root vowel (excluding the suffix initium for /u/ root). The consistency and stasis of the suffix at the initium is also reflected in the lack of variability from token to token, within a particular type, as indicated by the narrow range of one standard deviation for the tokens of any given type.

By comparing Figures 4.96 and 4.97, there appears to be a discernible difference in the behavior of tonic and post-tonic suffixes /i/. In Figure 4.97, the pre-kernel /i/ is still anchored circa the stop release, and convergence of transitions to the suffix vowel still obtains the locus of [i]. However, the locus at the anchored-point is not maintained, and transition towards centralized vowel-space begins immediately. As such, the suffix is in transition at the initium, and the variability from token to token (indicated by the greater spread in standard deviation in pane S of Figure 4.94) indicates a lack of precise coordination between the lingual gesture and the beginning of sonorous phonation. Only the lexical item /ekij/ maintains the pre-kernel position as a steady-state vowel, owing to the non-contrastive target /j/ in the offglide of the adjectival suffix.

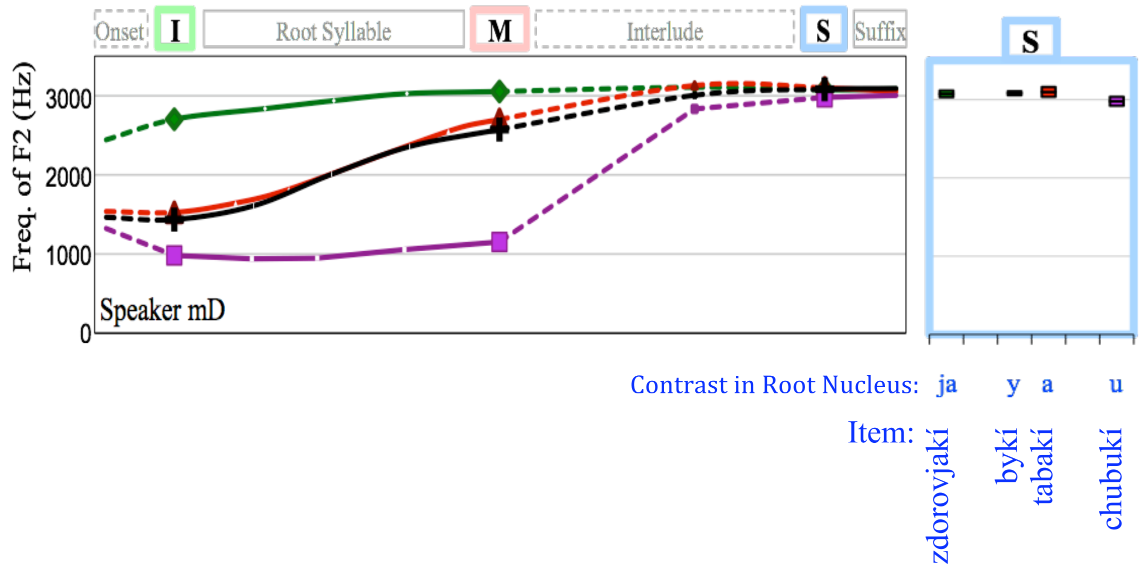


Figure 4.96 Differentiation at Initium of Tonic Suffix /í/, Following Various Tonic Vowels. The pre-kernel of the suffix is consistently anchored at the stop release, and consistently on-target to the pre-kernel target at the suffix initium.

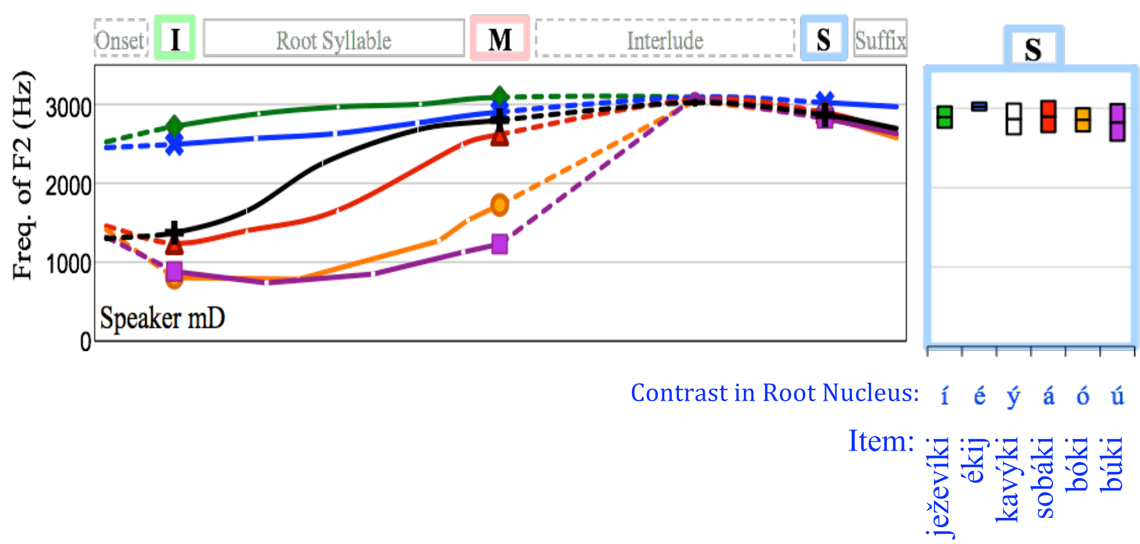


Figure 4.97 Differentiation at Initium of Post-tonic Suffix /i/, Following Various Tonic Vowels. The pre-kernel of the suffix is consistently anchored at the stop release; however, the suffix is in transition at the suffix initium.

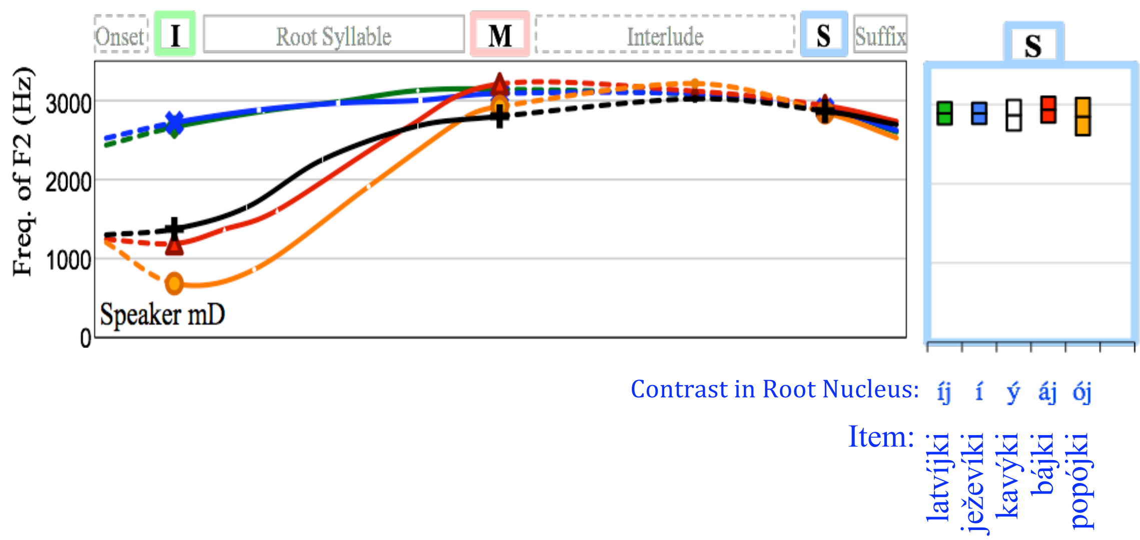


Figure 4.98 Differentiation at Initium of Post-tonic Suffix /i/, Following Tonic Vowels Terminating in /i/ ot /j/. The pre-kernel of the suffix is consistently anchored at the stop release; however, the suffix is in transition at the suffix initium.

The post-tonic suffix /i/ was usually performed as the diphthong [jɪ]. Since the only occurrences of post-tonic /i/ in the current data set were these word-final, open syllables of the suffixes, it was unclear whether all post-tonic /i/ would be performed as [ji]. Expansion of the data set to include post-tonic (and pre-tonic) /i/ in closed syllables, would be necessary to determine if an unstressed /i/ is habitually performed as [jɪ]. If future research reveals that only the word-final open syllable /i/ is performed as [jɪ], then it seems feasible that the suffix has only a pre-kernel /i/ with no specified kernel. As such, the unstressed suffix would travel the trajectory from /i/ to centralized schwa, and the portion of the trajectory of the suffix that occurs during sonorous phonation will cross the region of vowel-space assigned to [ɪ] is not especially characteristic of either target, but rather a portion of the fronting axis for schwa.

4.3.2.6 Targeting Schedule for "Zero" Suffix

As shown in Figure 4.99, the interlude prior to zero suffix usually exhibits the same behavior as the interlude prior to an underspecified non-zero suffix, such as /a/, shown in Figure 4.100. The tracks of F2 prior to the "zero" suffix loosely converge to centralized vowel-space, on the same schedule as post-tonic /a/.

As shown in pane S of Figure 4.99, the consistency of the "zero" suffix appears to be considerably less than non-zero /a/. However, this apparent high degree of variability is primarily a factor of low signal-to-noise ratio.

By overlaying a vast number of multiple tokens of "zero" suffix, the alignment of Praat-nominated data-points along a contour similar to the non-zero, post-tonic underspecified suffix emerges. In the future, with improvements in acoustic analysis software, hopefully the signal-to-noise ratio of non-sonorous regions of a waveform will be sufficiently enhanced, that reliable measurements can be extracted from these regions of the waveform as well.

At the current time, the only criterion which distinguishes the behavior of "zero" suffix from other underspecified vowel suffixes is sonorous voicing. As such, there is potentially a centralized pre-kernel of a word-final syllable lurking in the final consonant interlude of "consonant-final" forms. If so, this would correspond to the position and behavior of the historical back jer-u.

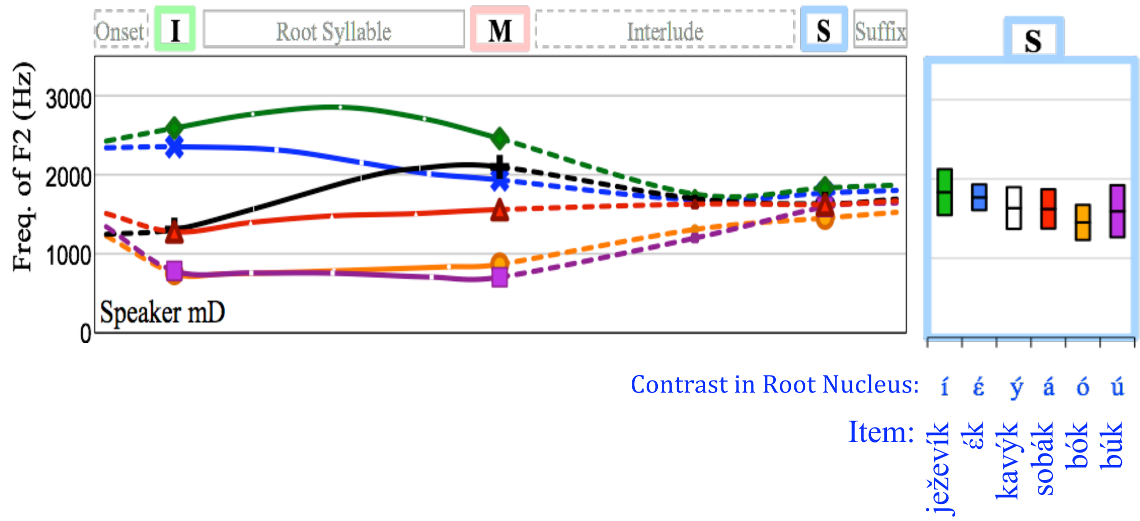


Figure 4.99 Interlude Behavior Prior to "Zero" Suffix, Following Various Tonic Vowels. The suffix is consistently on-target at the suffix initium.

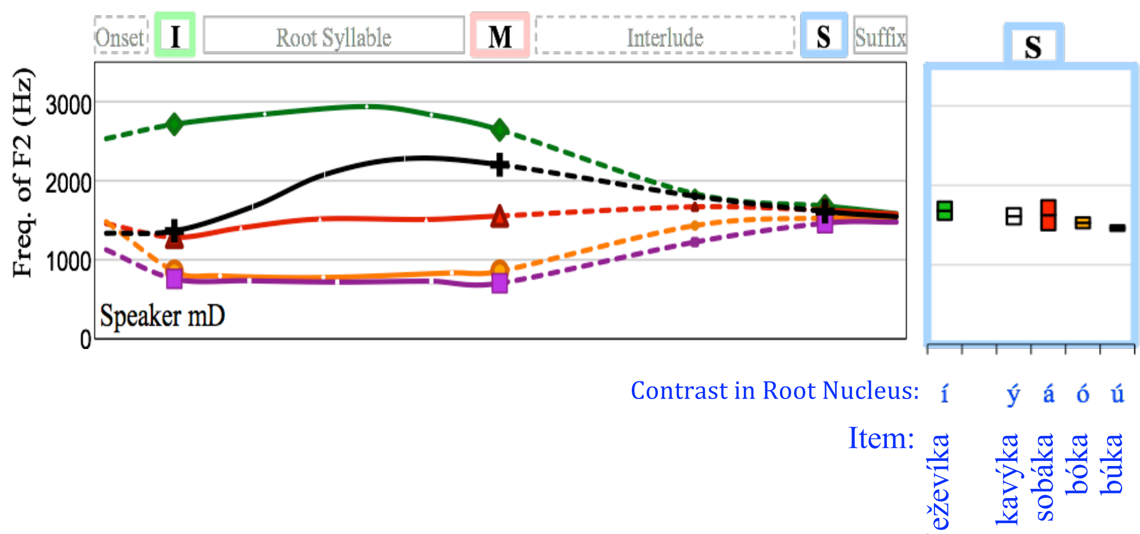


Figure 4.100 Differentiation at Initium of Post-tonic Suffix /a/, Following Various Tonic Vowels (4.91 revisited). The suffix is neither anchored at the stop release, nor on-target at the suffix initium.

4.3.2.7 Summary of Suffixes and Scheduling of Pre-kernel Targets

The pre-kernel of all fully specified suffixes (which excludes only underspecified post-tonic suffixes) is obtained during the consonant interlude at approximately the time of the stop release. The invariable scheduling and the consistently on-target behavior of the pre-kernel target during the interlude indicate that the timing of the pre-kernel is firmly anchored to a point in the interlude. This on-target behavior of the pre-kernel at its anchor-point is not influenced by the tractive force of another vowel target, whether that may be a preceding kernel vowel or offglide, or a following kernel vowel or offglide. As such, the pre-kernel is both anchored and intractable.

In parallel fashion, the post-kernel offglide is anchored at the moment of the terminus, and the locus of offglide is often fully obtained. However, in cases for which the needs of the anchored pre-kernel of the following syllable take precedence, the locus of the offglide will not be fully obtained. Such cases arise if the following pre-kernel (and the preceding kernel) is a back vowel, and there is insufficient time to complete the gesture to the offglide, prior to obligations to arrive on-target at the anchored and intractable locus for following (back) pre-kernel. Therefore, the post-kernel is deemed anchored in time, but tractable with regard to targeting.

In contrast, the kernel is neither anchored nor intractable. The (fully obtained) on-target behavior of a kernel in an offglide diphthong occurs circa the initium; the (partially attained) "on-target" behavior of the kernel in an onglide diphthong occurs circa the terminus; and the (fronted) "on-target" behavior of a kernel in a triphthong occurs circa mid-syllable. Therefore, the scheduling of a kernel's "on-target" behavior is not anchored. Moreover, the allophonic locus attained by the kernel is highly dependent on the surrounding vowel targets, whether they are tautosyllabic or heterosyllabic. Therefore, the kernel is highly tractable.

As evidenced by the scheduling behavior of the stressed and unstressed suffixes /je oj/, the on-target behavior of the first element of a diphthong is contained within the consonant interlude.

To account for this observed behavior, the following explanation is posited. The first mora of a nucleus is devoted to the pre-kernel. This pre-kernel mora begins at the approximate position of the stop release in the interlude, at which point the targeting information of the pre-kernel segment is anchored. And the pre-kernel mora extends into the zone of sonorous phonation for approximately 50 msec. The first half of this pre-kernel mora is jointly governed by the consonant of the interlude. The initial marginal effects of the consonantal articulation are typically registered on this first half of the pre-kernel mora. The first half of the pre-kernel mora has a variable duration of sonorous phonation, governed by the voice-onset-time associated with the consonant. The second half of the pre-kernel mora is always sonorous.

The second mora of a nucleus is devoted to the kernel, and is only manifested if the syllable is stressed and the kernel has not been deleted. Transitions from the tautosyllabic pre-kernel are projected into the kernel mora, from the scheduled anchor-point of that pre-kernel. Transitions from the following vowel target (either a tautosyllabic offglide or the pre-kernel of the following syllable) are projected backwards in time into the kernel mora. The entirety of the kernel mora is sonorous.

A third mora might occur in an open syllable or a syllable with a post-kernel offglide. Further study will reveal if the entirety of this third mora is sonorous. Since the offglide was observed to be voiceless after it was obtained at the terminus, it appears that only the first half of the third mora is sonorous, and the second half is devoted to aspects of the sonorant in the first position of the coda.

According to DCT doctrine, palatalized "soft" consonants contrast with "hard" consonants, in that, for "soft" consonants, the tongue is raised to the front of the palate, and maintained there for the duration of the consonant. According to this current research, however, the tongue is always pre-positioned for a vowel during the preceding consonant interlude. Therefore, the only contrast for tongue position for "soft" and "hard" consonants is the contrast in feature specifications for the following vowel.

Although not specifically recorded in DCT documents, the assumption is that the raised tongue position inherent in "soft" consonants is contained only during the consonants, and as such, falls under the jurisdiction of the interlude, and not the subsequent vowel. In terms of "soft" consonants, this is generally observed in the current study. However, the same scheduling behavior is also observed with hard consonant interludes. For both the nucleus /y/ and the suffix /oj/ (as shown in Figure 4.89), the first target of each diphthong is on-target during the interlude. By the time of the initium, the diphthong is already departing the first target and is in transition to the second target. If behavior of the tongue being on-target in a raised position only during the interlude is grounds to create a separate class of for "soft" consonants, then it should be required that two additional separate classes of consonants be established before /y/ nucleus and the

/oj/ suffix, since each of these have on-target behaviors which exist only during the interlude, and are contrastive to the tongue position of consonants which are not followed by these two nuclei.

In other words, it is not warranted to create a separate unique class of consonants for a localized scheduling behavior which is not unique to "soft" environments. Likewise, it is not warranted to create a separate unique class of consonants because of the pre-positioning of targets during the interlude, when this behavior is not unique to "soft" consonants either.

Vowels 4.3.3 Preservative Effects on Underspecified Suffixes

Anticipatory effects are registered at the terminus for virtually every root kernel followed by a contrastive unreduced suffix vowel. If the suffix vowel is non-contrastive, then the terminal portion of the root kernel behaves like a steady-state vowel. If the suffix vowel is contrastive, then the terminal portion of the root kernel begins to diphthongize to the following specified target. If the following target is underspecified (i.e., reduced), then the terminal portion of the root kernel tends to remain on-target at the kernel, and this position in vowel-space is carried into the following syllable.

As shown in Figure 4.101, preservative effects can be registered on a suffix, for which the first target is an underspecified vowel. Effectively, the suffix syllable is performed as [kja] or [kjə]. However, this surface form is prohibited as an underlying form. Velar /k/ can only be converted to [k̡] prior to /i/ or /e/. Therefore, the sequence /k̡a/ is ungrammatical. Since the sequence is ungrammatical, the occurrence of the surface form must have an underlying form other than /k̡a/.

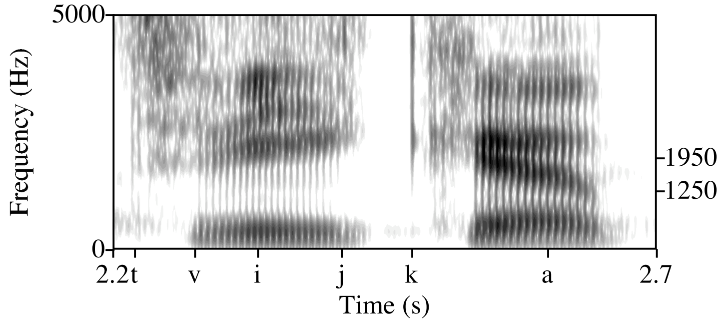


Figure 4.101 Spectrogram of the Final Root Syllable and Suffix of /latvíjka/, by Speaker pF. The suffix exhibits onglide from the preceding /j/ target obtained at the terminus of the root syllable. F2 for the suffix is 1950 at its initium, and 1250 at its terminus.

The solution is a preservative coarticulation of adjacent lingual targets, in the underlying sequence /jka/. The velar /k/ of the interlude is not a lingual gesture, and hence, it does not interfere with adjacency of the two lingual targets /j/ and (reduced) /a/, if the targets are organized by articulatory tiers.

Preservative coarticulation is the solution which permits the observed surface form [kja] and also permits the continued prohibition of the ungrammatical underlying sequence /k̦a/. Thus, the existence of this preservative coarticulation is yet another piece of evidence that coarticulation across a consonant interlude is an active process in Modern Standard Russian, and it provides for the parallel existence of the anticipatory coarticulation effects, which have been posited for virtually every pairing of two contrastive adjacent vowel targets in most of the previous examples.

4.3.4 Radical Coarticulation Across an Intervening Vowel

Further evidence of coarticulation and tier-oriented adjacency is provided by speakers pG and kK, who routinely articulated the front of the tongue independently from the back of the tongue in their performance of tonic /y/ and adjectivals suffixes /aja uju/. All speakers exhibited the ability to articulate the front of the tongue independently from the back of the tongue, and perform a flap without disturbing the formant pattern of the first two syllables of any inflected form of здоровяк /zdorovjak/ 'healthy person.' Thus, the only aspect of pG and kK's behavior, which was innovative, is the inclusion of high front vocalic target /i j/ into the set of coronal gestures.

As shown in Figure 4.102, speaker pG performs the suffix /uju/ by maintaining the back vowel /u/ for the duration of the suffix. The intervocalic /j/ is accomplsihed by a minute adjustment in the height of the tongue tip, at the locus of /j/, thereby disqualifying /j/ as a point of closure at the initial edge of the suffix, re-qualifying it at the middle, and disqualifying it again at the terminal edge of the suffix.

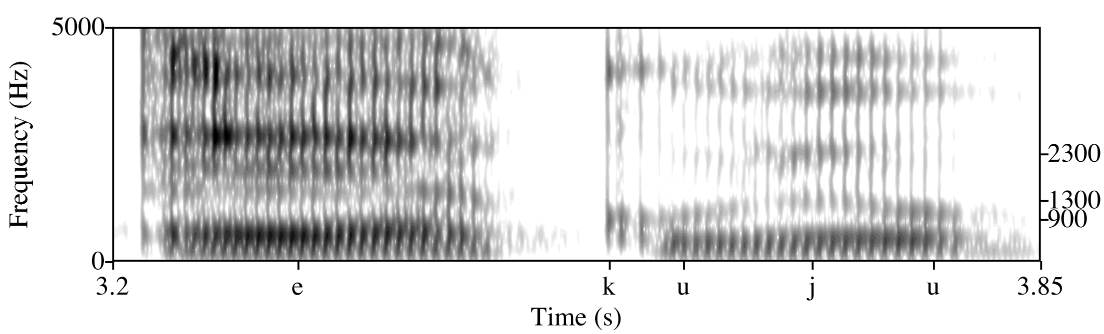


Figure 4.102 Spectrogram of the Root Syllable and Suffix of /ékuju/, by Speaker pG. The intervocalic glide of the suffix is performed independently from the back of the tongue. Although the track of the /u/ across the suffix does become slightly fronted, the sustained /u/ is fronted no further forward than pG's F2 value for prototypical [ɨ] or [a].

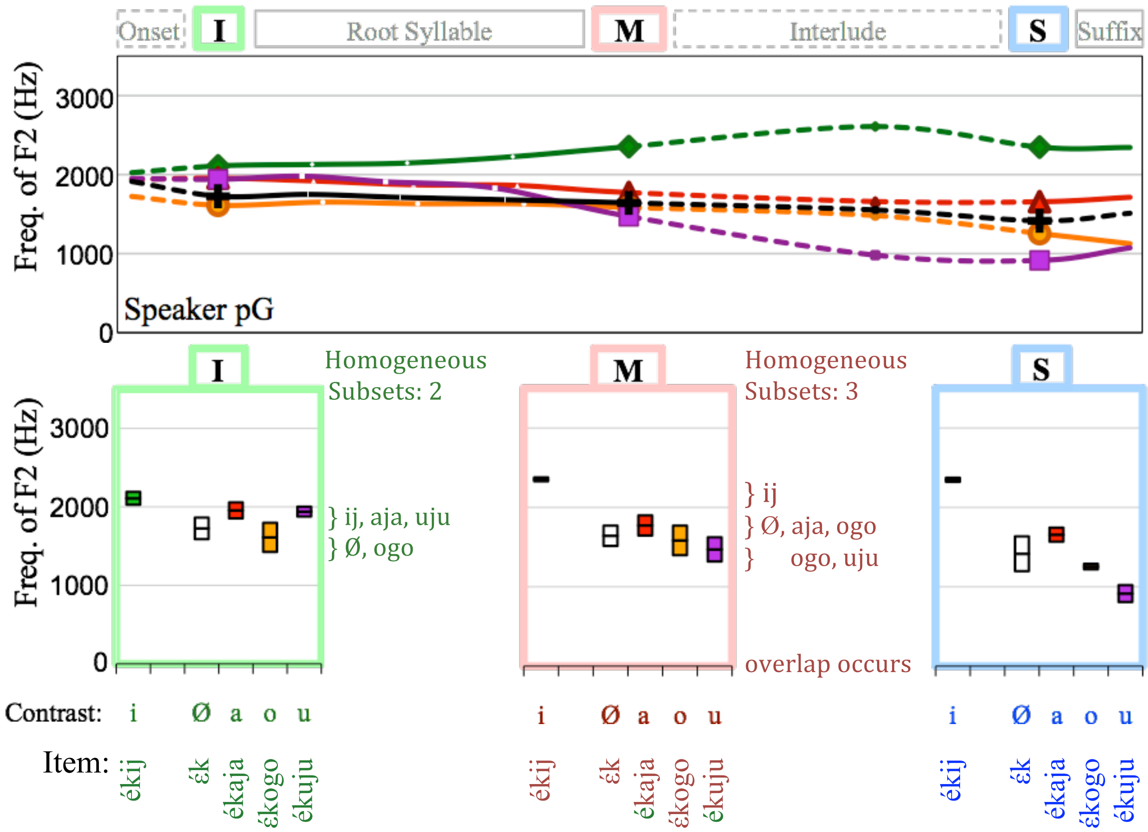


Figure 4.103 Differentiation at Initium of Tonic Root of экий /ekij/ 'what a.' The initium is divided into two sub-sets, according to the presence/absence of a high front element in the suffix. This is a violation of DCT convention that fronting of the kernel /e/ occurs only before soft consonants.

Table 4.40 Results of Univariate ANOVA for F2 at the Initium of Tonic Root /ek/. Speaker pG differentiates the initium of the root, based on the presence of /i/ or /j/ anywhere in the suffix. The remaining speakers differentiate the initium of the root, based upon the first vowel of suffix: front vs. non-front. Speaker pF further differentiates prior to non-front suffix targets.

Subset / Speaker	Number of Subsets	DCT Violations	Homogeneous Subsets		
pF	3	1	ij	Ø, aja, ogo	ogo, uju
pG	2	2	ij, aja, uju		Ø, ogo
mC	2	0	ij	Ø, aja, ogo, uju	
mB	2	0	ij	Ø, aja, ogo, uju	
mD	2	0	ij	Ø, aja, ogo, uju	

The relevance of the suffix in this example is that the onsetless root vowel /e/ is conditioned by the following soft environment. As such, speaker pG performs the items /ék ékogo ékij/ as [ɛ́k], [ɛ́kəvə], and [ékij], respectively, in accordance with DCT conventions. This demonstrates that speaker pG has correctly acquired the process which differentiates the distinct allophonic loci of /e/ as [e] and [ɛ].

However, in contradiction to DCT conventions, speaker pG did not perform the items /ékaja ékuju/ as [ɛ́kəjə] and [ɛ́kuju], with the prototypical locus of [ɛ] for the root kernel (Figure 4.103). Instead, speaker pG performed these items as [ékəjə] and [ékuju], with the fronted allophonic locus [e], which was conditioned by a following soft environment.

As shown in Figure 4.102, the initial edge of the suffix was clearly a hard KV onset [ku], and not a soft ÇV onset [kju] or [k̡u]. Therefore, the element fronting the kernel vowel /e/ of the root was not the consonant. The only possible element in the entire sequence /ekuju/ belonging to the set of phonemes that could cause the allophonic fronting of /e/ was /j/.

Yet, in order for /j/ to cause the fronting of the root kernel, coarticulation must not only span the intervening consonant interlude, but must also span an intervening vowel as well. If adjacency is organized by articulatory tier, then no conflict arises. Speaker pG routinely articulates the front of the tongue and the back of the tongue independently, and thereby, apparently has separated the articulation of lingual gestures into two tiers: a front tier for tongue tip, and a back tier for tongue body.

As such, the targets /e j/ are on the same tier and relatively proximal in terms of the timing chain. The non-lingual consonant /k/ does not constitute competition for articulators, and does not interfere with the anticipatory coarticulation from /j/ in the suffix backwards to /e/ in the root. Likewise, /u/ is on a separate tier for tongue body gestures, and does not constitute competition for articulators, and does not interfere with the anticipatory coarticulation from /j/ backwards to /e/.

If speaker pG can routinely replicate vocalic coarticulation across an intervening vowel in addition to a consonant interlude, then clearly, it is feasible for speaker pG to perform coarticulation across a consonant interlude alone. If speaker pG can perform coarticulation across a consonant interlude, then it is feasible for any speaker of Modern Standard Russian to do so as well.

CHAPTER 5

CONCLUSIONS, IMPLICATIONS, AND FUTURE CONSIDERATIONS

5.1 Conclusions

Given the recurring phenomena observed in the data, the following conclusions have been drawn regarding the syllable structure, phonemic inventory, vowel reduction processes, and tautosyllabic and heterosyllabic coarticulations in Modern Russian. These conclusions have been enabled by capitalizing on advances in computer software that permit the rapid extraction of numerous data-points across the duration of a syllable, by observing the longitudinal behavior of the acoustic shape of a syllable, and by taking the innovative approach of characterizing the formants of a syllable as a series of behavioral change-points, rather than sampling the formant structure of a syllable only once or even a small number of times at fixed intervals, such as every quarter-syllable.

5.1.1 Coarticulation vs. Cyclical Transference of Feature Specifications

The traditional method of characterizing the behavior of a vowel by measuring the formant structure of the vowel only once near mid-syllable is inadequate in establishing the behavior of contours. Furthermore, the Dual Consonant Tradition's (DCT) reliance on a binary phonemic feature of the consonantal inventory to explain the allophonic surface variants of vowels is inadequate to describe the degree of differentiation that routinely occurred at a root terminus in the current data set.

The inadequacy of a single measurement of formant structure circa mid-syllable can be corrected with longitudinal change-point modeling of the formant contours. Furthermore, this longitudinal change-point modeling can accommodate vowel-to-vowel coarticulations, which (in conjunction with the pre-positioning of the pre-kernel of the bifurcated nucleus during the consonant onset) can account for all of the formant contours and the replicable differentiation at the terminal edge of the root vowel prior to contrastive suffixes that were observed in the current data set.

In the data, the most frequent and most readily discernible differentiation at the root terminus involved a contrast between front vs. non-front vowel suffixes. Due to the application of SPR Rule P1a, a neutralization occurs between the initial edge of /-i/ and /-e/ suffixes. This neutralization generates a numerical gap in the distribution of the values of F2, if the suffix vowel is varied from front to back vowels, in the progression i > e > ɨ > a > o > u of Figure 5.1, and yields i/je >> ɨ > a > o > u as shown in Figure 5.2.

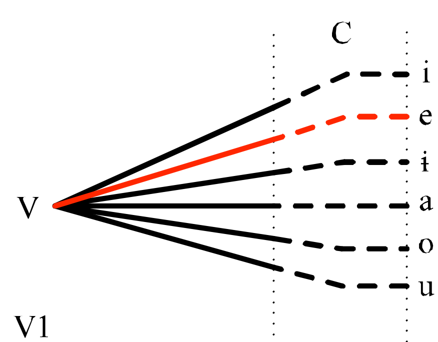


Figure 5.1 Stylized Differentiation of F2 at the Terminus of V1 With Hypothetical Even Distribution of Contours. SPR Rule P1a is operative on consonants prior to /e/.

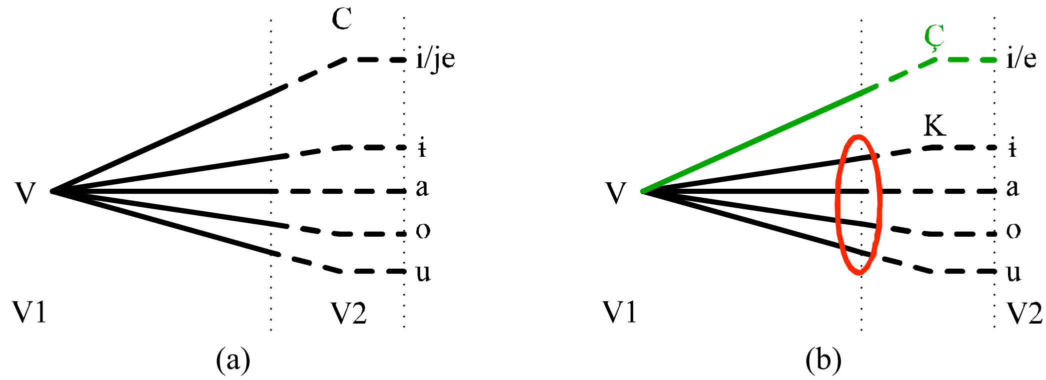


Figure 5.2 Stylized Differentiation of F2 at Terminus: Current and SPR. (a) Current account with pre-kernel V2 pre-positioned during interlude. (b) SPR account with binary division between soft (Ç) and hard (K) consonants. Hard/soft binary contrast cannot accommodate further differentiation at the terminus of V1 prior to hard consonants (K).

If SPR Rule P1a is re-formulated to insert an epenthetic /j/ before /e/, effectively positing equivalent targets /i j/ as the initial segments of /-i/ and /-je/ suffixes, then this numerical gap in the value of F2 can be accounted for in terms of vowel-to-vowel coarticulation, as shown in pane (a) of Figure 5.2.

This gap in the value of F2 can also theoretically be accommodated by a binary phonemic feature [±sharped], as posited by Halle (1959) in *The Sound Pattern of Russian*, as shown in pane (b) of Figure 5.2. Using Halle's model, the differentiation at the terminus of the root syllable before front vowel suffixes can be expressed as a marginal [+sharped] consonantal effect registered on the preceding vowel.

However, the binary phonemic feature [±sharped] cannot accommodate further differentiation at the root terminus when the following consonant is [+sharped], i.e., it cannot accommodate a differentiation between /-i/ and /-e/ suffixes, nor can it accommodate further differentiation at the root terminus when the following consonant is

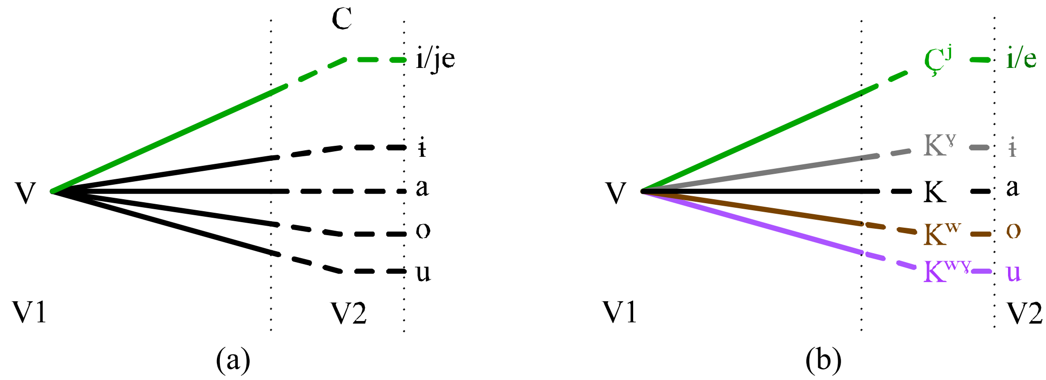


Figure 5.3 Stylized Differentiation of F2 at Terminus: Current and Keating. (a) Current account with pre-kernel V2 pre-positioned during interlude; (b) Application of Keating's account of phonetic feature spreading after SPR framework of binary division between soft (Ç) and hard (K) consonants.

[–sharped] i.e., it cannot accommodate differentiation between /-a -o -u/ suffixes, circled in pane (b) of Figure 5.2 (/-ы/ suffixes were not observed in the data).

The inability of DCT's phonemic contrast to accommodate further differentiation beyond the binary contrast attributed to soft vs. hard consonants can theoretically be improved by the application of a second wave of the transference of feature specifications, in the form of phonetic features that will spread a feature onto a segment if the segment is underspecified for that feature (Keating 1988). As such, the consonant of the interlude between the root vowel and the suffix vowel can act as an intermediate and provide the context in which the contrast of the suffixes can be transferred onto the terminus of root syllable. As shown in pane (b) of Figure 5.3, each non-front suffix V2 spreads a different set of phonetic features to the preceding consonant. These phonetically contrastive consonants can potentially account for the differentiation noted on the preceding vowel V1.

Jones and Ward (1969) noted that hard consonants have special allophones prior to non-front vowels. Hard consonants are labialized before the rounded vowels /o u/, and hard consonants are velarized before /ɨ u/ (Jones and Ward 1969: 79-81). Therefore, four allophonic variants of hard consonants exist: plain (before /a/ or schwa), velarized (before /ɨ/), labialized (before /o/), and labio-velarized (before /u/). Since differentiated "specified" phonetic allophones within the hard consonant set exist (per Jones and Ward), differentiation at the root terminus can be accounted for by means of feature spreading at the phonetic level (per Keating) from the suffix vowel onto the consonant interlude, and then in turn from the consonant interlude onto the terminus of the root vowel.

However, as shown in pane (b) of Figure 5.4, this phonetic modification to the binary phonemic contrast of DCT still cannot account for further differentiation within the soft consonant set (i.e., it cannot accommodate differentiation before /-i/ and /-e/ suffixes), because the supposed phonemic feature of the consonant interlude is set to [+sharped], and the /-e/ suffix does not impart any of the identified phonemic or phonetic features, other than [+sharped]. As such, the terminal interface of the roots of both /VÇi/ and /VÇe/ sequences should be identically /VÇ/, and differentiation before /-i/ and /-e/ should not be possible. However, as shown in Table 4.39, replicable differentiation before the front suffixes /-i/ and /je/ often occurs at the terminus of root vowels /o u/.

By spreading phonetic features from the suffix to the consonant interlude, and then in turn from the consonant to the preceding root vowel, the Keating account of feature spreading at the phonetic level can accommodate more of the observed data than the DCT account, which only posits spreading of a binary feature at the phonemic level.

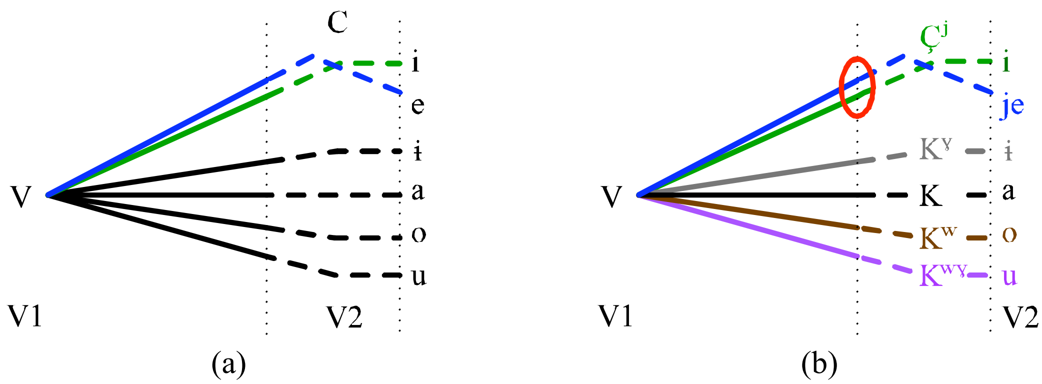


Figure 5.4 Stylized Differentiation of F2 at Terminus With Maximum Number of Contrasts. (a) Current account with pre-kernel V2 pre-positioned during interlude. (b) Application of Keating account of phonetic feature spreading after SPR framework of binary division between soft (Ç) and hard (K) consonants. The likelihood that the terminus will differentiate before /i/ vs. /je/ increases the further back the vowel V1 is.

However, since the feature spreading does not skip a segment, the Keating account still treats segments as discrete elements that must be addressed linearly, in the sequential order of the underlying phonemic string. The Keating account does not consider that the possibility that underlying phonemic sequence might theoretically be parsed by articulatory tier, which might result in portions of two (or more) segments on different tiers occurring simultaneously.

The Keating account also cannot accommodate the behavior of the unstressed /-oj/ suffix. As was shown in Figure 4.83, for speaker mD, the value of F2 at the release of the stop /k/ prior to the unstressed suffix /-oj/ is approximately 2000 Hz. Similarly, in Figure 4.86, the same approximate value of F2 at the release of the stop /k/ prior to the unstressed suffix /-a/ is 2000 Hz. In contrast, in Figure 4.92, the value of F2 at the release of the stop /k/ prior to the /-i/ suffix is 3000 Hz. Hence, there is parity in the stop /k/ before /-a/ and /-oj/ suffixes, but contrast in the stop before /-a -oj/ vs. /-i/ suffixes. This parity and contrast is also registered on the root terminus in Figures 4.60, 4.62, 4.63, and 4.64. Based on this replicable parity and contrast, the stop /k/ before the suffix /-i/ is "soft" and the stop /k/ before the suffixes /-a -oj/ is "hard".

However, if the formant tracks in these figures must be considered purely as sequential segments without temporal overlap, then the beginning of the vowel of the suffix /-oj/ does not occur until the beginning of sonorous phonation, and evaluation of the formant track of sonorous portion of the /-oj/ suffix indicates that the phonetic realization of the suffix is either [i] or [ɨj], both of which are prohibited here, since the consonant /k/ prior to the suffix /-oj/ has been established to be a "hard" /k/. If the /-oj/ suffix has a phonetic surface form of [i], then the preceding stop must be "soft", which it is not. If the /-oj/ suffix has a phonetic surface form of [ɨj], then it cannot occur after the velar /k/, which it does. Therefore, the /-oj/ suffix cannot have a phonetic surface form [i] or [ɨj]. The suffix can only have the surface form [əj], after the "hard" /k/.

However, if the phonetic surface form of the suffix is [əj], then the first segment [ə] must be pre-positioned prior to sonorous phonation, and must occur within the preceding consonant interlude, in order to fulfill the formant contour that is observed in the data. If this suffix requires pre-positioning of the initial segment of its nucleus during the preceding consonant onset, then such pre-positioning should be available to other nucleus types as well.

Consider the following representation in Figure 5.5, re-created from Fant (2004: 150), with d) described as "A continuously varying importance function for each phoneme describing the extent of its dependency of particular events within the speech wave. Overlapping curves without sharp boundaries." (Fant 2004: 149)

Regarding Fant's explanation of the schematic and the overlap of consonant and vowel phonemes, Fant observes:

> "The number of successive sound segments within an utterance is greater than the number of phonemes. Fully developed unvoiced stops, for instance, contain at least two sound segments, the occlusion and the burst, and the latter may be subdivided into an explosion transient and a short fricative. The first part of a vowel following the burst generally assimilates the voicelessness of the preceding sound. It is a matter of convention whether this sound segment is to be assigned to the vowel, or to the preceding 'aspirated' consonant." (Fant 2004: 150)

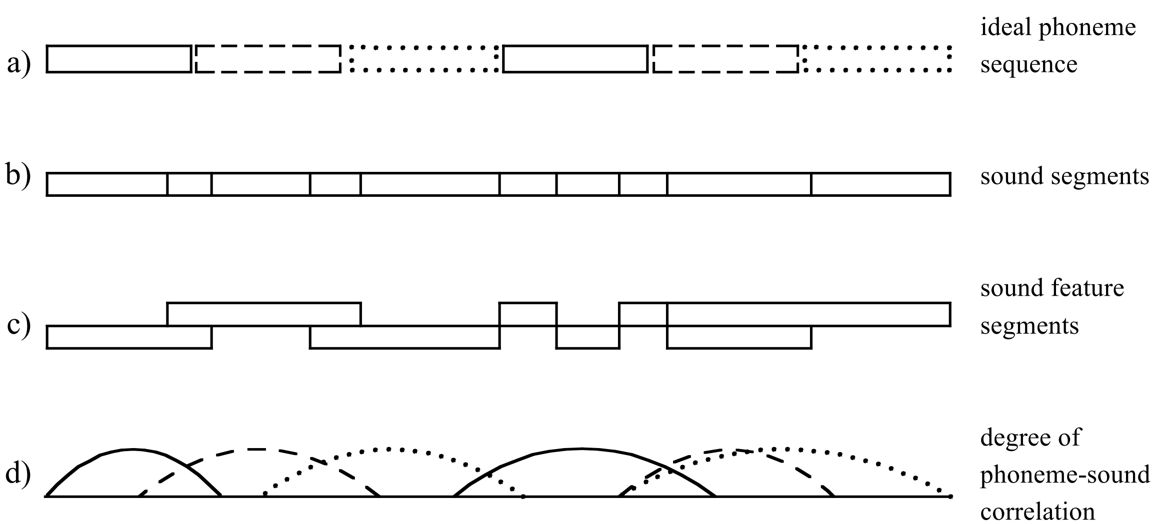


Figure 5.5 Fant's Schematic Representation of Sequential Elements of Speech. a) is the phonemic aspect, b) and c) represent acoustic aspects, and d) shows the degree of phoneme-sound correlation. Re-created from Fant (2004: 150; Figure 2).

This “first part of the vowel following the burst” is precisely the “sound segment” that the current account is assigning to the pre-kernel of the nucleus. In contrast, DCT assigns this portion of the vowel to the preceding consonant, along with the ongoing vocalic transition of the onglide extending into the sonorous vowel (if the pre-kernel is the onglide /j/), which usually continues completely across the vowel to its terminus.

Adapting Fant’s schematic to Modern Russian, in Figure 5.6 the pre-kernel is pre-positioned to be on-target circa the consonant burst (at point ‘g’). If the pre-kernel is the segment /j/, then the lengthy transitions necessary to obtain the position of /j/ in vowel-space extend for equivalent durations on either side of the pre-kernel’s arrival during the obstruent. To the right, the transition for the onglide /j/ can extend to the terminus of the kernel (to point ‘m’). To the left, the transition for the onglide /j/ can extend backwards into the preceding vowel (to point ‘d’).

If the pre-kernel is unoccupied underlyingly, then features from the kernel node can be copied to the pre-kernel node, thereby creating a steady-state formant pattern from points ‘g’ forward to ‘i’ (if another /j/ is encountered), or to ‘m’ (if the next vocalic target after the kernel is not a /j/).

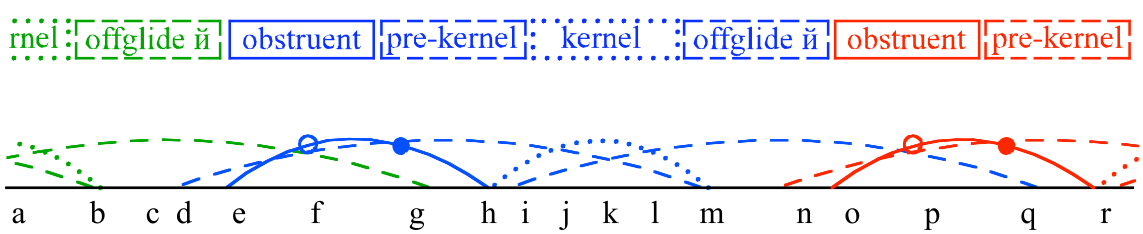


Figure 5.6 Adaptation of Fant’s Schematic Representation of Sequential Elements of Speech to Simplified Sequences of Modern Russian. In this diagram, consonant clusters have been reduced to a single consonant, and only the offglide is permitted in the sonorant node of the coda.

Within this framework, the mora assigned to the pre-kernel always begins circa the burst of the obstruent, and, as a result, the marginal consonantal effects of the obstruent onset are always registered on the pre-kernel. These consonant effects include both transitional coarticulations (observed as formant contours) and changes in sonority associated with the voicing of the consonant.

In pane (a) of Figure 5.7, temporarily considering only the issue of voicing, if the syllable is onsetless, the entire mora μ_j of the pre-kernel is sonorous from points 'j' to 'k.' If the onset contains a voiced obstruent, then the first sliver of mora μ_j from 'j' to 'b' is devoiced, and the remainder from 'b' to 'k' is sonorous. If the onset contains a voiceless obstruent, then the first half of mora μ_j from 'j' to 'p' is voiceless, and the second half of mora μ_j from 'p' to 'k' is sonorous. The entire mora μ_k of the kernel is always sonorous; however, the kernel mora μ_k is only manifested in stressed syllables.

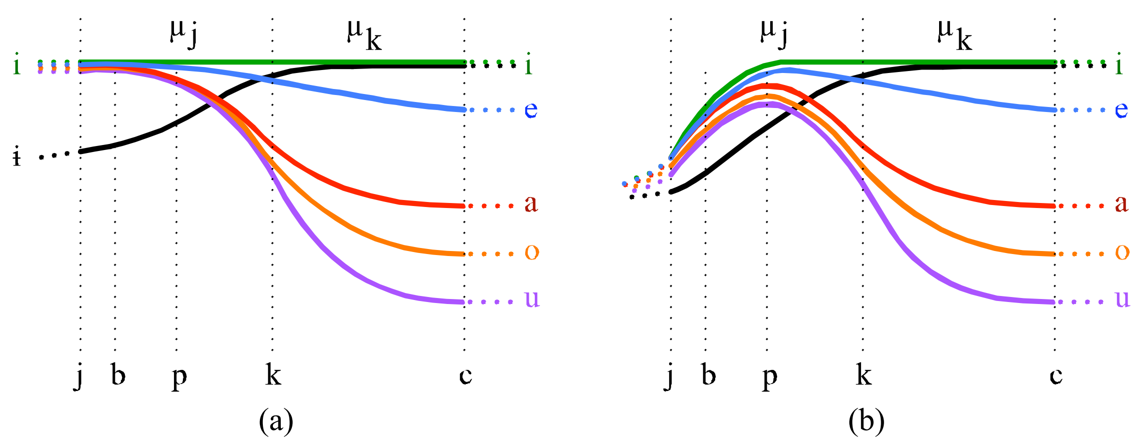


Figure 5.7 Stylized Formant Tracks of F2 for the Two Mora of a Stressed Syllable with a Single Obstruent in the Onset. (a) Tracks are devoid of discernible marginal consonant coarticulations; (b) Tracks are characteristic of labial damping from the onset. In both panes, voice onset times are represented by: 'j' if the syllable is onsetless, 'b' if the onset is voiced, and 'p' if the onset is voiceless. The kernel begins approximately at 'k', and terminates at the coda 'c'.

In pane (b) of Figure 5.7, temporarily considering only the issue of marginal consonantal effects on vocalic formant patterns, if the onset contains a voiced obstruent, then the first portion of the consonantal transition occurs prior to the initium at 'b,' but the majority of the consonantal transition is registered on the vowel, most noticeably from 'b' to 'p.' If the onset contains a voiceless obstruent, then the majority of the consonantal transition occurs prior to the initium at 'p,' and the transition registered from 'p' to 'k' will most likely only resemble that of a glide.

In summary, by positing that pre-positioning of the pre-kernel occurs during the consonant onset, then a single account can accommodate all of the differentiation at the root terminus observed in the data, and the allophonic variants of the consonants of Modern Russian (whether they be "phonemic" contrasts between soft and hard consonants per DCT, or phonetic contrast between plain, labialized, velarized and labio-velarized hard consonants per Jones and Ward), and the observed timing of gestures that are contained with the consonant interlude associated with /j/, /ɨ/ and [ə], when they occur in diphthongs /je ja jo ju/, /ɨi/ and [əj], respectively. This account is made possible by positing a bifurcated nucleus within the syllable structure of Modern Russian, by separating the phonemes of the underlying sequences into articulatory tiers (as in line 'c' of Fant's schematic in Figure 5.5), and by permitting coarticulations between adjacent segments on a particular tier, even if "intervening" segments occur on a different tier. As such, adjacency can also be applicable within an articulatory tier, and not solely within the linear sequential order of the underlying phonemic string.

5.1.2 Syllable Structure

Adoption of the bifurcated nucleus grants Modern Russian a two-position nucleus, and permits a single, unified comparison of the Modern Russian syllable structure with other Modern Slavic languages such as Czech, Slovak, etc., which retain contrastive vowel length. It also permits a single, unified description for the syllable structure of the Russian language throughout its evolution from Proto-Indo-European, via Proto-Slavic and Slavic, to Modern Russian.

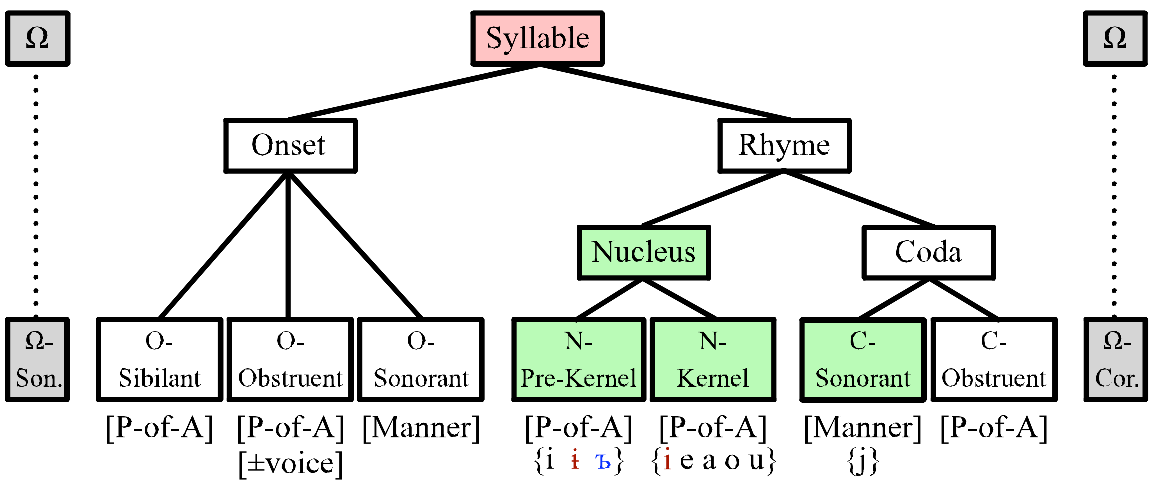


Figure 5.8 Proposed Syllable Structure for Modern Russian. The leaf nodes that contain segments responsible for vocalic contours have been highlighted in green. The set of permissible underlying (semi-)vocalic segments has been listed beneath each node. If the pre-kernel node is unoccupied, the features of the kernel can potentially be copied to the pre-kernel to create a steady-state "contour".

Adoption of the bifurcated nucleus and a robust /j/ pre-kernel also eliminates the need for any sort of "palatalization" feature in the phonemic system, be it [±sharped] or

[±palatalized] or [±soft]. This, in turn, eliminates any consideration for such a feature and its licensing within the syllable structure. It then follows that the only nodes within the syllable structure that are licensed to generate the effect of palatalization are those nodes which can legitimately contain /j/.

As such, the source of palatalization for the onset can be isolated into a single pre-kernel node, between the onset and the kernel vowel. This, in turn, provides a single, unified description to account for palatalization (or lack thereof) affecting previous syllables. Those segments that are sufficiently proximal to the following pre-kernel in terms of timing will be exhibit palatalization effects. In contrast, those segments that are sufficiently distant, either by number of intervening segments or by slower speaking rate or artificial syllable breaks, will not exhibit palatalization effects.

5.1.3 Distribution of Sonorants

Adoption of the bifurcated nucleus permits a separate node for the /j/ onglide within a nucleus. In so doing, both the onglide and the kernel vowel can be present in the underlying form of phonemic sequence. This permits /j/ in placements within phonemic sequences, in parallel with other sonorants /m n r l/ and /v/. Thus, a single, unified description of the distribution of all sonorants, including /j/, can be established.

5.1.4 Vowel Reduction

Adoption of the bifurcated nucleus permits a transparent explanation for determining the allophonic value of unstressed vowels. After the kernel vowel is deleted in an unstressed syllable, the nucleus will exhibit the feature specifications of the surviving pre-kernel. If the pre-kernel is /j/, the nucleus will be expressed as [i]. If the pre-kernel is /ɨ/, the nucleus will be expressed as /ɨ/. If the pre-kernel contains feature specifications copied from the kernel V_{ω}, the nucleus will be expressed as V_{ω}. If the pre-kernel is underspecified, the nucleus will expressed as a (centralized) coarticulation between the surrounding lingual targets. Thus, a single, unified description of the surface form of an unstressed nucleus can be established, regardless of the presence or absence or of the features of consonants in the onset.

5.1.5 Double Articulation in the Onset

Double articulation of the consonant onset can be explained as simultaneous geestures, involving the "plain" consonant of the underlying phonemic sequence and the pre-kernel of the nucleus. The pre-kernel of the nucleus is scheduled to arrive on-target during the preceding consonant interlude. In the case of the pre-kernel /j/, this pre-positioning, in conjunction with the observed fact that the pre-kernel /j/'s on-target behavior is contained within the onset, is considered by DCT as evidence of the specialized articulation of palatalized consonants, by DCT. However, parallel pre-positioning and on-target containment during the onset was observed for the pre-kernel of /y/ and the unstressed suffix /oj/. Thus, the targeting behavior of the onset of the suffix syllables of папе /papje/ 'papa' prep.sg., папы /papy/ 'papa' nom.pl., папой /papoj/ 'papa' instr.sg., and папа /papa/ 'papa' nom.sg. are all contrastive; however, the scheduling of specified pre-kernel on-target behavior for /papje/, /papy/ and /papoj/ is the same. If the scheduling of the pre-kernel of /papje/ is denoted as [pap^{j}e], then the scheduling of /papy/ should be denoted as [pap^{y}i], and /papoj/ as [pap^{ə}j]. Granting the onset of /pje/ special phonemic status due to scheduling should require parallel granting of special phonemic status to both /py/ and /poj/, all of which contrast to the onset of /pa/. As such, granting phonemic status due to scheduling will result in four (or more) consonants sets, and not merely the conventional dual hard vs. soft sets of DCT.

Therefore, adoption of the bifurcated nucleus and the pre-positioning of the pre-kernel node within the onset not only permits a single, unified description of the interaction of the pre-kernel and the consonant of the onset, regardless of the feature specifications of the pre-kernel, but also eliminates the need for a specialized feature within the phonemic system. As such, all modified articulatory gestures for consonants, due to contrastive pre-kernels, are allophonic variants of the basic set of phonemic consonants, and are not underlying contrastive phonemic consonants.

5.1.6 Dialectal Differences

Although dialectal differences may arise from a variety of sources, the bifurcated nucleus model permits a single, unified underlying representation of phonemic sequences, and a single set of phonological rules to account for the system of vowel reduction within various dialects. The identity of those vowel phonemes that will or will not reduce can potentially be isolated into a single phonological rule, which is dialect specific.

5.1.7 Jers

The bifurcated nucleus model provides a node within the syllable structure by which jers can be accommodated without the creation of any special architecture or methods. The primary constraint is that jers can be positioned only into the pre-kernel node during syllabification. With this constraint in place, nuclei solely containing jers are processed no differently than syllables which contain a jer /j/ in the pre-kernel and a kernel vowel (/ja/, /juj/, etc.), and no differently from syllables containing only an underlying kernel vowel (/a/, /u/, etc.).

Furthermore, the bifurcated nucleus provides a mechanism by which word-final jers can be posited as syllables that can bear stress in the underlying lexical form. The ability for a word-final jer to bear stress underlyingly allows all nominal forms to be recorded in the lexicon as vowel-final; subsequently, this word-final syllable can be brought to bear on determining the grammatical class of the lexical item, and the word-final nucleus can be used in determining the stress paradigm of the item.

As such, adoption of the bifurcated nucleus permits a single, unified description for all lexical nominal items (i.e., all nominal items can be recorded in the lexicon as nucleus-final), and a single, unified description of the two largest stress paradigms for the nominal system (i.e., immobile stress on the root, or immobile stress on the suffix, except for the "zero" suffix, in which case a phonological process deletes the kernel of the word-final jer, and relocates stress placement one syllable to the left).

The bifurcated nucleus and the placement of jers into the pre-kernel position also permits a single, unified description of palatalization effects involving a syllable with a front jer-i, regardless of whether the syllable containing the front jer-i contains a kernel, or bears stress, or is allocated a mora, or receives sonorous phonation.

Finally, adoption of the bifurcated nucleus and the placement of jers into the pre-kernel position of word-final syllables also permits a single, unified description of a word-final voiceless fricative /j/, regardless of whether this /j/ is positioned in the offglide (sonorant) position in the coda of the final syllable (e.g., бой /boj/ ‘battle’) or is positioned in the pre-kernel position of the nucleus of the final syllable (e.g., мать /matj/ ‘mother’). In both cases, the word-final /j/ is a voiceless fricative/approximant.

5.1.8 Coarticulations in Modern Standard Russian

Coarticulations abound in Modern Standard Russian. Coarticulations can be classified based upon the nodes of the syllable structure which the participating segments occupy. Coarticulations can also be classified based upon the feature specification (or lack thereof) of the segments at these nodes.

5.1.8.1 Classification of Vocalic Coarticulations

Tautosyllabic diphthongal coarticulations involving pre-kernel /j/ and the kernel vowels /e a o u/ account for the distinctive onset associated with preceding palatal environments, and correspond to the use of <е я ё ю> in the Cyrillic orthographic system. In certain circumstances, the kernel /i/ will also create a diphthongal trajectory through vowel-space, hence, justifying the inclusion of <и> with the preceding kernels.

However, tautosyllabic onglide diphthongs are not limited to palatalized environments. The same structural configuration exists with the pre-kernel /ɨ/ (corresponding to the use of orthographic <ы>), which creates a tautosyllabic coarticulation with the kernel /i/.

Furthermore, the tautosyllabic diphthongal coarticulations with the kernel vowels and the offglide occur. This corresponds to the use of orthographic <й> (e.g., байка /bajka/ 'fable'). Heterosyllabic diphthongal and triphthongal coarticulations with the pre-kernel /j/ of the following syllable account for the distinctive offset associated with following palatal environments (e.g., собаке /sobakje/ ‘dog’ prep.sg. or бяке /bjakje/ ‘nasty thing’ prep.sg., in which the heterosyllabic sequences [aj] and [jaj] arise, respectively, across the consonantal interlude /k/). The heterosyllabic offglide and the tautosyllabic offglide are equivalent lingual gestures, and differ only in scheduling, with regard to sonorous phonation and syllable boundaries. Heterosyllabic or tautosyllabic triphthongs account for the fronted allophonic loci of the kernel vowels, regarded as ÇVÇ sequences by DCT.

Coarticulations occur routinely within a syllable to form tautosyllabic formant contours (e.g., [ja] in бяка /bjaka/ ‘nasty thing’ or [aj] in байка /bajka/ 'fable'). Coarticulations also occur routinely across a consonant interlude to form heterosyllabic formant contours (e.g., собаке /sobakje/ ‘dog’ prep.sg.). On rare occasion, heterosyllabic coarticulations can occur across an intervening vowel, if a separate articulatory tier is posited for the tongue tip, which can operate independently from the tongue body (e.g., экую [ekuju] hyperbole ‘what a!’, as opposed to the surface form [ɛkuju], if the influence of /j/ in the suffix does not skip the intervening /ku/).

5.1.8.2 Differentiation of Root Terminus in Anticipatory Coarticulations

The number of differentiations registered at the terminal edge of the root vowel can be determined from the number of contrastive suffixes that follow the root. If there are S number of suffixes, the root terminus M will be differentiated into a number of distinction locations, equal to or less than the number of suffixes ($1 \leq M \leq S$). The value of M will be determined by the number of contrasts for the initial vocalic element of the suffixes within S, and the degree of contrast between the final vocalic target of the root syllable and the initial vocalic element of the suffix. The value of M will also be affected by the anchoring schedule of the final vocalic target of the root.

The value of M is affected by vowel reduction processes, which may neutralize contrast in leading edge of certain suffix vowels. For instance, in the standard dialect, post-tonic /a o/ both reduce to the same feature matrix (schwa), which decreases the possible number of contrasts for the suffix vowel. Also, with the application of SPR Rule P1a, an epenthetic /j/ is inserted before /e/ suffix. Doing so neutralizes the contrast between the first vocalic segment of /i/ and /e/ suffixes. As such, in the standard dialect, only three initial contrasts exist for the five suffixes /-i -e -a -o -u/, namely, [i ə u].

Also, the application of SPR Rule P1a, effectively leaves a gap in the frequency range of F2 at the terminus, which would have been associated with the phoneme /e/. This gap is created because the epenthetic /j/ changes the initial target of the suffix from [ɛ] to [i]. This gap in the frequency range of F2 gives the appearance that the initial edge of the suffixes is divided into two groups: front vs. non-front. However, the division is actually [i] vs. non-[i].

It is conjectured that this gap could be repopulated, if phrasal constructions such as <TOKEN этого типа> [TOKEN ɛ́təvə típə] ‘TOKEN of this type’ can concatenate the final syllable of TOKEN and the first syllable of the genitive phrase with the same timing as suffixation. The phrasal construction should not trigger application of SPR Rule P1a. And thus, perhaps coarticulation between the root vowel and /e/ might occur, without the epenthetic /j/.

The value of M is also affected by the contrast of the final vocalic segment of the root and the initial vocalic segment of the suffix. With regard to the root vowel, if the suffix is non-contrastive, then the root vowel will remain on-target until the terminus, and continue on-target into the suffix. This constancy can be viewed as non-coarticulation, or as simultaneous anticipatory and preservative effects being applied vacuously. If the suffix is contrastive with regard to the root vowel, but the suffix is underspecified, then the root vowel will remain on-target until the terminus, and preservative effects will likely be registered on the suffix. If the suffix is contrastive with regard to the root vowel, and the suffix is fully specified, then anticipatory effects will be registered on the root vowel.

If the final vocalic target of the root syllable is anchored at the terminus (only the offglide /j/ qualifies for this condition), then the likelihood that the root vowel will remain on-target is considerably greater than if the final target of the root syllable is an unanchored kernel.

Thus, M, which is the number of differentiated termini for the root syllable, is affected by the anchoring schedule of the final vocalic target of the root, by the relative contrast between the root and the suffix, and by the number of actual surface contrasts that the suffix can generate. In this framework the value of M is predicted to be closer to 1 if the root syllable contains an offglide, and closer to S if the suffixes generate the maximum number of contrasts possible – as is the case for tonic suffixes, or dialects in which vowels do not reduce.

Only one instance of a lexical root that generated one subset of termini (M=1) was observed in the data, the lexical item /bájka/ 'fable'. It was more common for the terminus to differentiate into two subsets (M=2), which can be categorized by the relationship of the root to the suffix: {contrastive and specified} vs. {non-contrastive or underspecified}.

If the differentiation resulted in a binary grouping of 1 terminus vs. 4 termini, then the lone differentiated suffix was usually /u/, and the root terminated in a front vowel. If the differentiation resulted in a binary grouping of 2 termini vs. 3 termini, then the subset of 2 was the suffixes /i/ and /je/, and the subset of 3 was /a o u/, and the root terminated in a rounded back vowel. If the differentiation resulted in a trinary or quaternary grouping, then the subsets of suffixes of the previous two conditions tended to be sub-divided further.

The termini of the root were ranked by the values of F2, in parallel to the ranking of the value of F2 of the initial edge of the suffix (i.e., the higher the value of the suffix, the higher the value of the terminus). This principle was operative collectively over types of syllables, and individually over tokens within a type grouping.

Lastly, the value of F2 at the terminus of a root tended to be a value numerically between the value of F2 of the final target of the root and the value of the initial target of the suffix, indicating that the value of F2 at the root terminus is a point on a contour from the two vocalic targets on either side of the terminus.

5.2 Implications

The discoveries of this study and the application of mathematical equations to model entire spans of vocalic contours have ramifications that reach beyond the study of Russian phonology.

5.2.1 The Study of Vowel-Consonant Transitions

This study verifies that vowel-to-vowel coarticulations across a consonant interlude can occur. Therefore, if one were interested in isolating vowel-consonant transitions, one would be well served to ensure that the vowel on opposite side of the consonant is as non-contrastive as possible. This will help to eliminate the confounding effects of having formant contours due to vowel-to-vowel coarticulations.

5.2.2 Multiple Simultaneous Vowel Tracks

On occasion, the Praat acoustic software nominated erroneous results, if more than the expected number of formants were encountered. This unexpected number of formants apparently occurred when the tongue tip was articulated independently of the tongue body, and two simultaneous points of closure in the oral cavity were maintained.

Speaker pG routinely articulated the front of the tongue independently from the tongue body, especially in cases in which tautosyllabic diphthongs and triphthongs presented challenges to obtain all targets during a brief schedule. As such, speaker pG often tended to maintain positions for both the tongue tip and the tongue body, and alternate the prominence of the two points of closure by minute changes in height of the tongue tip. Even though prominence between targets was accomplished by disqualifying and re-qualifying the point of closure associated with the tongue tip, the sustained formant pattern associated with the position of tongue tip did not completely dissipate, when the high front vowel was not prominent. As such, simultaneous dual formant patterns for both the front and the back of the tongue (i.e., $F1_f/F2_f$ and $F1_b/F2_b$) were present in the spectrogram of many diphthongs and triphthongs.

Under the parameter settings for the spectrogram, the Praat software was instructed to find a fixed number of formants within a certain frequency range. The default settings is to find 5 formants within the lower 5500 Hz of the spectrogram. However, with dual formant patterns within the same frequency range, the Praat software often incorrectly nominated formant pattern for a single, misshapened composite vowel (i.e., $F1_f/F2_b$ or $F1_b/F2_f$). As such, for the suffix depicted in Figure 5.9, the Praat-nominated formant pattern for the beginning and end of the suffix was 700 Hz for F1 and 2000 Hz for F2. This location is outside of the vowel-space for the speaker.

The over-riding principle of an ordinal formant structure, within generalized frequency ranges for each successive formant, created difficulties for the Praat software. Working within the constraints of an ordinal formant structure, the Praat software erroneous nominated formant frequencies. Under the current system, correction of the problem requires multiple captures with contrastive configurations of the spectrogram settings, and then weeding out the extraneous data-points from each capture and building a separate formant pattern for each of the simultaneous vowels.

The system of labeling formants with ordinal numbers proved to be a minor handicap in this situation, in which more than two formants occurred below F3. Labeling formants with independent labels rather than ordinal numbers will alleviate this handicap.

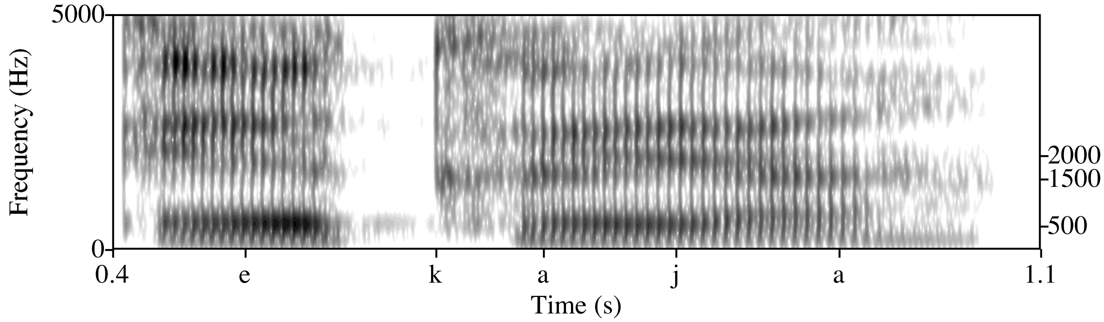


Figure 5.9 Spectrogram of Simultaneous Vowels in the Suffix of /ékaja/, Performed by Speaker pG. F2 for the intervocalic /j/ is approximately 2000 Hz. F2 for the post-tonic /a/'s is approximately 1500 Hz. In the spectrogram, the combined energy of F1 for /j/ and F1 for /a/ is centered around 500 Hz. This wide band of energy contains F1 for the /j/ at approximately 400 Hz, and F1 for the /a/ at approximately 700 Hz.

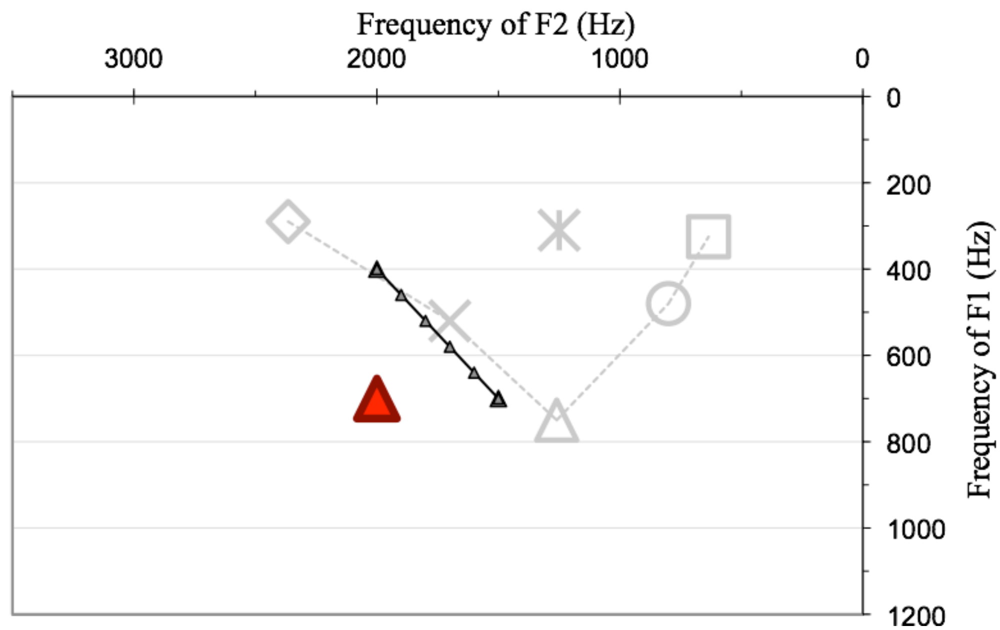


Figure 5.10 Erroneous Configuration of Location in Vowel-space Caused by Mis-matching Formant Values for Simultaneous Vowels. The generalized trajectory of the suffix /aja/ is indicated by the data-points between /i/ and /a/. The erroneous location is created by pairing F1 of /j/ with F2 of /a/. The resultant composite location is outside of the vowel-space of the speaker.

5.2.3 Collision of F2 with F3

Coarticulations with /j/ as the onglide or offglide abounded in the data. In many cases of diphthongs with the /j/ offglide, F2 appeared to collide into F3, displacing F3 to a frequency range approximately 500 Hz higher, as shown in pane (a) of Figure 5.11. This collision created an abrupt change in the contour of F2, effectively causing F2 to become instantaneously asymptotic without any curvature associated with deceleration. However, the geometry of the curvature of the displaced F3 suggests that F2 crosses F3, and the observed curvature in "F3" is actually the sigmoid deceleration of F2, as shown in pane (b) of Figure 5.11.

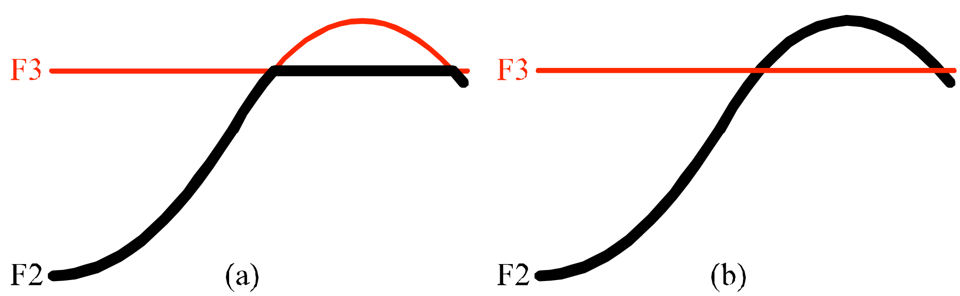


Figure 5.11 Collision of F2 with F3. (a) F2 displaces F3 to a higher frequency; (b) F2 theoretically crosses F3 and violates the ordinal numbering of formants.

If the value of F3 is not associated with the point of closure in the oral cavity, then this crossing of F3 by F2 seems reasonable. However, if F3 is a phenomenon associated with the point of closure in the oral cavity, then the abrupt right-angle change to asymptotic behavior of F2 can potentially be explained by a collision of (at least a portion of) the tongue with the hard palate, which would account for the lack of deceleration. However, the displacement of F3 as a curvilinear pattern, while the change in F2 is a square step-function warrants further investigation.

The system of labeling formants with ordinal numbers might prove to be a major handicap in this situation, if it is determined that F2 actually exceeds F3. Labeling formants with independent identifiers would accommodate instances in which one formant crossed another.

5.2.4 Merger of F2 with F3

In offglide diphthongs, in which F2 did not collide with F3 and/or displace it, F2 often merged with F3, to form a single band of energy at the terminus, in Figure 5.4.

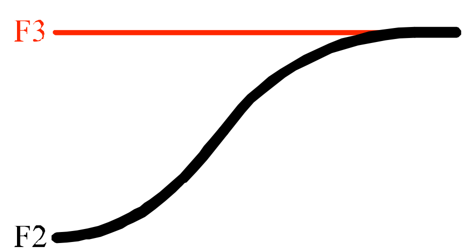


Figure 5.12 Merger of F2 with F3.

The system of labeling formants with ordinal numbers proved to be a minor handicap in this situation, in which fewer than three formants occurred below F4. Labeling formants with independent identifiers, rather than ordinal numbers, will prevent discontinuities in higher formants caused by the “loss” of a formant due to merger.

5.2.5 Location of F2 at Usual Location of F3

For monophthongal /i/, the value of F2 usually occurred at the value normally associated with F3 for most other vowels. The effect of this overlain formant is that the Praat software then indicated that F3 for /i/ occurred higher than F2, in the range of 3500 to 4000 Hz.

In the settings menu for spectrograms in the Praat software, the default parameters instruct the Praat software to isolate 5 formants in the lower 5500 Hz of the spectrogram. As such, for most individuals, F1-F3 usually occurred below 3000 Hz, and two formants (indicated as F4 and F5) occurred at the higher end of the default range. For convenience sake, let F4 be 4000 Hz, and F5 be 5000 Hz. For any given individual, two formants always occurred at these two frequency values, which suggests that these two formants represent constant (permanent) behavior.

However, the system of labeling formants with ordinal numbers does not treat these two formants as constant behavior. If fewer than three formants are detected below 4000 Hz, then the formant at 4000 Hz will be labeled as F3 or F2, even though it represents the same phenomenon as when it is labeled F4.

Likewise, if more than four formants are detected below 4000 Hz, then the formant at 4000 Hz will be labeled as F5 or F6, even though it represents the same phenomenon as when it is labeled F4.

Labeling formants with a subscript related to behavior, rather than an ordinal number will alleviate this problem. For instance, F1 could be relabeled FH for height; F2 relabeled as FD for distance or FB for backness: F3 relabeled as FZ for Helmholtz, or whatever behavior it is found to represent; FL for lateral formant; FN for nasal formant; FP for pitch/fundamental frequency; etc. As such, labeling of related behavior will not shift, regardless of the number of formants detected.

5.2.6 Asymmetry in the Sigmoid Curve Associated with /j/ Coarticulations

Coarticulations with /j/ were asymmetrical in two respects. As previously noted, when /j/ was the offglide, F2 tended to collide with F3 (or the tongue collided with the hard palate), creating a square step-function. As such, the curvature of the contour prior to the point-of-inflexion was asymmetrical with the square change in contour after the point-of-inflexion.

When /j/ was the onglide, then both spans of curvature of F2 before and after the point-of-inflexion were curvilinear; however, the radius of the initial curvature associated with leaving the point of closure of the onglide was tighter than the radius of the terminal curvature associated with approaching the point of closure of the kernel vowel. As such, it appears that the tip of the tongue had accelerated faster than the body of the tongue had decelerated. This asymmetry of the radii of curvature of the two halves of the sigmoid curve increases the suitability of the Gompertz curve over the hyperbolic tangent. Since the curvature with the tighter radius is the initial half of the sigmoid curve, special re-ordering of the data to accommodate the Gompertz curve is not necessary. One need only ensure that the coefficient of magnitude is negative, so that the Gompertz curve is recording decay in time, and not growth.

5.2.7 Application for Synthetic Formant Patterns

The application of change-point mathematical models performed admirably in constructing composite formant tracks, which were representative of the behavior of multiple tokens of the same syllable type. The coefficient structure of the hyperbolic tangent and the Gompertz curves are easy to control, to produce the desired contours. As such, either of these two functions could be use to produce carefully controlled synthetic formant patterns for perception tests, or for commercial use in producing more natural-sounding synthetic speech patterns from sequences of symbols.

5.2.8 Unification of Studies on Diphthongs and Formant Contours

The use of change-point mathematical models can be applied to many of the previous strategies for observing formant contours. Consider the stylized sigmoid curve in Figure 5.13, representing F2 of a diphthong. The model has five points of interest:

1) I is the initium, and represents the observed beginning of the first steady-state.

2) J is the end of the first steady-state and the beginning of the transition.

3) K is the point of inflexion for the sigmoid curve.

4) L is the end of the transition and the beginning of the second steady-state.

5) M is the terminus, and represents the observed end of the second steady-state.

The following studies analyzed glides and diphthongs, by observing a variety of behaviors. The basic parameters for each of these behaviors are all contained in the model in Figure 5.13. As such, each of the following studies could have theoretically made use of the standardized model in Figure 5.13.

Bond (1978) compared the duration of transition in a diphthong, which is represented in the stylized model as the span JL. Gay (1968) compared the ratio of steady-states and transition in diphthongs, which are represented by the spans IJ and JL. Gay (1970) compared the rate of change of F2 in diphthongs, which is represented by the slope μ.

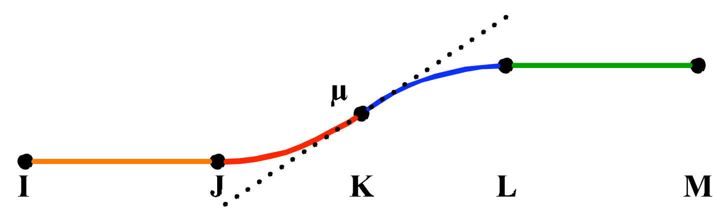


Figure 5.13 A Stylized Sigmoid Curve as a Model of a Diphthong. Span JL represents the transition between steady-states IJ and LM. K represents the point of inflexion of the sigmoid curve, and μ represents the slope of the sigmoid curve at the point of inflexion.

Jha (1985) compared the duration of steady-states and transition and the rate of change of the transition in diphthongs, which are represented by the spans IJ, LM, JL, and μ, respectively. Lehiste (1961) compared the duration of the steady-states of diphthongs, which are represented as IJ and LM. Liberman (1956) compared the duration of transition of diphthongs, which is represented as the span JL.

Thus, a standardized tool can be applied to studies of diphthongs, even if the tool is used to focus on a variety of different aspects.

5.3 Future Considerations

The technique of modeling formant contours, which was employed in this research study, could be improved dramatically, if access to additional reliable data-points were possible. These additional data-points include:

1) F1 at the margins, since F1 at the margins was largely ignored, because the Praat software had difficulty disambiguating F1 from F0, for high vowels;

2) The separation of F0, F1 and F2 for high back vowels; and

3) Measurements for F1, F2 and F3 during non-sonorous zones.

Access to additional data-points (especially during non-sonorous zones) would permit a beneficial change of perspective, and eliminate the restricted field of selection, which was associated with observing sonorous zones only. Incorporating data-points from adjacent non-sonorous zones would permit a more contiguous view of the vowel, to include its behavior during the consonant onset, and the scheduling and targeting of its pre-positioning during the onset. With the incorporation of data from these surrounding zones, contiguous coarticulation of lingual targets is expected to be even more apparent.

Furthermore, instead of aligning the initium and the terminus, and noting the (vertical) variable nature of the formant frequency at these points in time, the contours (which were remarkably consistent) could be aligned to each other, and the initium and terminus could be noted as (horizontal) variable points in time on the normalized contours. Access to additional data-points would also permit access to change-points which occur outside of the sonorous zone, and hence permit more consistent and complete modeling of the formant contours.

A continuation of this study should also include coronal consonants in the onset of the root syllables, to determine if vowel-to-vowel coarticulation can occur across a coronal consonant interlude. One such potential coarticulation was observed in the data with the intervocalic flap in the pre-tonic syllables of <здоровяк> /zdorovjak/ ‘healthy person’, in which the flap did not disturb the sustained articulation of the two pre-tonic schwa vowels. It would be interesting to see if the coarticulation in a sequence with contrastive vowels (e.g., the /i u/ coarticulation in <пируэт> /pirúɛ́t/ ‘pirouette’) reveals that the vowel coarticulation is planned, prior the insertion of the flap gesture.

Future study should also include an expansion of the participant base. Such an expansion would permit better control of variables associated with regional dialect, gender and age. Ideally, data collection in Russia itself would also help remove considerations regarding second language skills, if monolingual speakers of Russian participated.

APPENDIX A

LANGUAGE BACKGROUND QUESTIONNAIRE

Анкета для участие
Language Background Questionnaire

Родной язык ______________________________
Native Language

Родной язык отца ______________________________
Native Language of father

Родной язык матери ______________________________
Native Language of mother

В детстве, на каком языке Вы общались дома?
Русском или каком либо другом? ______________________________
As a child, what language did you speak at home? Russian or another language?

Какие языки Вы знали до 18 лет? ______________________________
What languages did you speak before age 18?

Какие другие языки Вы знали после 18 лет? ______________________________
What additional languages did you learn after age 18?

В каком городе Вы выросли? ______________________________
What city did you grow up in?

В каком году и месяце Вы родились? ______________________________
Date of birth (month and year)

Какая у Вас специальность? ______________________________
Level of Education

Table A.1 Compilation of Language Background Questionnaire Data.

Speaker[1]	п[2,3]	Gender	Age[4]	Hometown	Country	Education[5]	Languages[6]
pF	pɛ	M	45	St. Petersburg	Russia	PhD	English French
pG	pɛ	M	20	St. Petersburg	Russia	(B.A.)	English
mC	pʷɛ	F	48	Moscow	Russia	(M.A.)	English
mB	pʷɛ	F	22	Moscow	Russia	(B.A.)	English
mD	pʷɛ	F	46	Sverdlovsk	Russia	M.A.	English German
uS	pə	F	34	Zaporozhye	Ukraine	M.A.	English
uT	pə	F	34	Odessa	Ukraine	B.A.	English Ukrainian Romanian
uR	pʷi	F	33	Berdyansk	Ukraine	B.A.	English Ukrainian Polish
kK	pʷɛ	F	30	Kerch	Crimea, Ukraine	PhD	English Ukrainian
bZ	pɛ	F	40	Orsha	Belarus	B.A.	English

1 Speaker tags included the participant's dialectal group tag plus a unique speaker tag. p = St. Petersburg; m = Moscow; u = Ukraine; k = Crimea; b = Belarus.
2 Pronunciation of the name of the letter "п" of the Cyrillic alphabet. Although table entries indicate [ɛ] as the nucleus of the name, the actual value of the nucleus may include allophones similar to [e ɛ ə] for the various tokens by a particular speaker. Entries listed as [ə] were centralized. Entries listed as [i] were high front.
3 Entries listed as containing a labial onglide [ʷ] exhibited a distinctive transition from the onset to the nucleus. This transition is labeled as [ʷ]; however, it may actually have been a labial onglide [ʷ], a lengual onglide [ᵊ], or perhaps pharyngeal constriction. Since the sequence obstruent+[ɛ] does not occur in lexical items in Modern Standard Russian, determining the exact nature of this onset transition was not the focus of this research; however, recognition of this distinctive onset transition was useful is categorizing speakers by dialect.
4 Age at the date of recording.
5 All participants indicated some amount of college education. The two youngest participants were currently pursuing their degrees. Credentials are generically listed as BA/MA, since the questionnaire was non-specific to B.A/M.A., B.S./M.S. or B.C.S.E/ M.C.S.E. programs. Speaker mC is listed as M.A., although this entry in the questionnaire was unfilled; the participant's education level was indicated verbally during the recording session.
6 Additional languages spoken, beyond native Russian.

APPENDIX B

PROTOTYPICAL LOCI OF VOWEL PHONEMES

The values of F1 and F2 for the prototypical loci of the phonemic vowels for the five primary speakers are provided in Table B.1. These values are used in the construction of a reference frame for each speaker's vowel-space, which are compared in Figure 4.1. The values for SPR-D were extracted from the Appendices of SPR.

Table B.1 Prototypical Loci for Vowel Phonemes.

	i		e		a		o		u		ɨ	
Speaker	F1	F2	F1	F2	F1	F2	F1	F2	F1	F2	F1	F2
mB	285	2915	575	2210	920	1280	445	700	320	620	375	1110
mD	330	3120	660	2385	945	1405	445	715	375	655	450	1630
mC	270	2630	555	1760	730	1245	445	745	300	600	360	1110
pG	290	2365	520	1700	750	1260	480	800	325	635	310	1250
pF	280	2260	440	2075	680	1105	435	715	305	605	345	1150
SPR-D	250	2100	400	1875	700	1375	400	900	250	675	200	1475

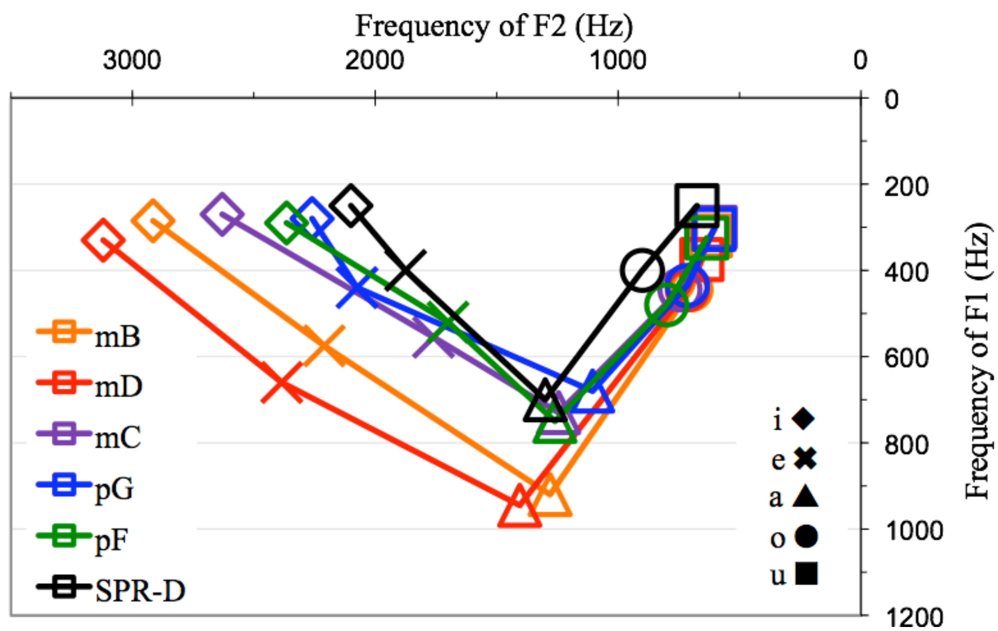


Figure 4.1 (revisited) Comparison of Vowel-space for m-Group, p-Group, and Subject SPR-D.

APPENDIX C

HOMOGENEOUS SUBSETS OF UNIVARIATE ANOVA FOR SYLLABLE EDGES

This appendix contains tables of comparisons of the homogeneous subsets from univariate ANOVA tests conducted on the initial edge of the root vowel, the terminal edge of the root vowel, and the initial edge of the suffix vowel, for all inflected lexical items of the study.

C.1 Notes for Table C.I

C.1.1 Table C.I Configuration

Differentiation at the root initium, which is required by DCT, is shaded pale green for front vowel suffixes vs. white for non-front vowel suffixes.

Differentiation at the root initium, which is not required, but can be accommodated by DCT, is shaded dark green for front vowel suffixes vs. white for non-front vowel suffixes.

Non-differentiation at the root initium, which can be accommodated by DCT, is shaded pale yellow.

Differentiation at the root initium, which cannot be accommodated by DCT, is shaded blue for front vowel vs. pale red for non-front vowel suffixes.

C.1.2 Table C.I Observations

1. Only onsetless /é/ is required by DCT to differentiate at the root initium, before front vowel suffixes. Required differentiation is denoted by pale green shading (for front vowel suffixes) vs. white (for non-front vowel suffixes).

2. Differentiation of the root /ék/ by speaker pG is a violation of DCT, since the differentiation is not front vs. non-front vowel suffixes.

3. Onsetful /é/ might also be expected to differentiate at the root initium, before front vowel suffixes; however, onsetful /é/ should have a transitional onglide, which should obscure differentiation. Differentiation for onsetful /é/ is primarily noted at mid-syllable, by DCT.

4. Kernels /á ó ú/ are not required to differentiate at the root initium by DCT; however, differentiation is usually noted at mid-syllable, as allophones [æ ö ü].

5. Differentiation at the root initium for kernels other than /é/ is not required, but also not prohibited by DCT.

6. Systematic differentiation tends to occur with tonic kernel /é/, and with pre-tonic syllables.

7. Systematic non-differentiation at the root initium tends to occur if the root contains an offglide, which blocks the anticipatory effect of the suffix, or if the kernel is tonic /i/.

8. Sporadic differentiation occurs elsewhere.

9. The post-tonic suffix /om/ containing a nasal exhibited the least amount of consistency.

Table C.I Univariate ANOVA Test Homogeneous Subsets, Denoting Contrast at Root Initium Before Soft/Hard Consonants Associated With Suffixed Vowels.
S=Speaker; L=Lexical Item; R=First Root Target; 1-5=Terminus Before Suffix; H=Subsets; V=Violations

S	L	R	1	2	3	4	5	H	V
pF	ježevíka	í	je	a	i	oj	u	1	
pG	ježevíka	í	a	i	je	oj	u	1	
mC	ježevíka	í	i	u	a	je	oj	2	1
mB	ježevíka	í	i	a	oj	je	u	1	
mD	ježevíka	í	i	a	je	u	oj	1	
pF	píka	í	oj	a	i	je	u	2	1
pG	píka	í	a	u	i	oj	je	1	
mD	píka	í	i	je	a	u	oj	2	
pF	ɛ́k	ɛ́	ij		aja	ogo	uju	3	1
pG	ɛ́k	ɛ́	ij	uju	aja		ogo	2	2
mC	ɛ́k	ɛ́	ij		aja	ogo	uju	2	
mB	ɛ́k	ɛ́	ij		aja	uju	ogo	2	
mD	ɛ́k	ɛ́	ij		aja	uju	ogo	2	
pF	vjɛ́k	j	i	o	je	ax	u	2	1
pG	vjɛ́k	j	je	i	ax	u	o	2	
mC	vjɛ́k	j	je	i	o	u	ax	1	
mB	vjɛ́k	j	je	i	ax	u	o	2	
mD	vjɛ́k	j	i	o	ax	u	je	1	
pF	uzbjɛ́k	j	i	je	a	u	ov	2	
pG	uzbjɛ́k	j	i	je	a	u	ov	2	
mD	uzbjɛ́k	j	je	a	ov	i	u	1	
pF	kavýka	ɨ	je	a	i	oj	u	1	
pG	kavýka	ɨ	u	oj	a	i	je	1	
mC	kavýka	ɨ	i	oj	je	a	u	1	
mB	kavýka	ɨ	i	je	u	a	oj	2	
mD	kavýka	ɨ	oj	i	a	je	u	1	
pF	bjáka	j	oj	i	a	u	je	3	2
pG	bjáka	j	i	u	oj	je	a	1	
mC	bjáka	j	i	je	u	a	oj	3	
mB	bjáka	j	oj	je	a	i	u	1	
mD	bjáka	j	i	je	oj	a	u	1	
pF	sobáka	á	i	a	oj	u	je	1	
pG	sobáka	á	i	je	a	oj	u	2	
mC	sobáka	á	a	i	je	u	oj	1	
mB	sobáka	á	oj	i	je	u	a	2	1
mD	sobáka	á	je	a	oj	u	i	1	
pF	bók	ó	om	je	i		u	2	1
pG	bók	ó	om	je	u	i		2	
mC	bók	ó	je	i	om	u	a	1	
mB	bók	ó	a	om	je	i	u	1	
mD	bók	ó	om	a	u	i	je	2	
pF	ljepjëxa	j	i	je	a	oj	u	3	
pG	ljepjëxa	j	je	i	u	a	oj	2	
mC	ljepjëxa	j	je	i	a	oj	u	3	1
mB	ljepjëxa	j	i	a	je	u	oj	1	
mD	ljepjëxa	j	je	i	u	a	oj	3	1
pF	búk	ú	i	ov	u	je	a	1	
pG	búk	ú	i	ov	je	u	a	1	
mC	búk	ú	a	i	je	ov	u	1	
mB	búk	ú		a	u	je		1	
mD	búk	ú	i	u	a	je	oj	2	

S	L	R	1	2	3	4	5	H	V
pF	latvíjka	í	a	je	i	oj	u	1	
pG	latvíjka	í	a	i	je	oj	u	1	
mC	latvíjka	í	a	i	je	u	oj	1	
mB	latvíjka	í	oj	je	a	i	u	1	
mD	latvíjka	í	a	i	oj	je	u	1	
pF	bájka	á	je	i	a	u	oj	1	
pG	bájka	á	a	je	i	u	oj	1	
mC	bájka	á	a	i	oj	je	u	1	
mB	bájka	á	je	a	oj	u	i	1	
mD	bájka	á	je	a	u	i	oj	2	
pF	popójka	ó	je	i	a	u	oj	2	
pG	popójka	ó	je	oj	a	i	u	1	
mC	popójka	ó	je	a	u	oj	i	1	
mB	popójka	ó	je	i	u	oj	a	1	
mD	popójka	ó	je	u	a	i	oj	1	
pF	vjek	j			áx	óv	ú	2	1
pG	vjek	j			áx	óv	ú	1	
mC	vjek	j			ú	áx	óv	1	
mB	vjek	j			ú	áx	óv	1	
mD	vjek	j			ú	áx	óv	2	1
pF	zdorovjak	j	í	jé	á	u	óv	2	
pG	zdorovjak	j	í	jé	á	óv	ú	2	
mC	zdorovjak	j	í	jé	ú	á	óv	2	
mB	zdorovjak	j	á	í	jé	ú	óv	2	1
mD	zdorovjak	j	í	á	jé	óv	ú	2	1
pF	byk	ɨ	jé	í	á	óv	ú	3	1
pG	byk	ɨ	í	á	óv	ú	jé	1	
mC	byk	ɨ	jé	í	óv	á	ú	2	
mB	byk	ɨ	jé	í	á	óv	ú	2	
mD	byk	ɨ	jé	í	ú	á	óv	2	
pF	tabak	ɐ	í	jé	á	óv	ú	3	1
pG	tabak	ɐ	í	jé	á	óv	ú	2	1
mC	tabak	ɐ	í	jé	á	ú	óv	1	
mB	tabak	ɐ	í	jé	óv	á	ú	2	1
mD	tabak	ɐ	jé	í	óv	ú	á	2	1
pF	bok	ɐ	í		áx	ú	óv	2	1
pG	bok	ɐ	í		óv	ú	áx	2	1
mC	bok	ɐ			óv	áx		1	
mB	bok	ɐ	í		óv	áx		2	1
mD	bok	ɐ			óv	áx		1	
pF	čubuk	u	í	jé	á	óv	ú	2	1
pG	čubuk	u	í	jé	ú	á	óv	2	
mC	čubuk	u	jé	í	á	óv	ú	2	
mB	čubuk	u	jé	í	óv	ú	á	1	
mD	čubuk	u	í	jé	óv	á	ú	3	2

Subset overlaps subset to its right
Unstressed Root
/e/ Differ before front vs. Differ before non-front
Differ within front set
Differ within non-front
Non-differentiated before front/non-front suffix
Differentiation before front, but not /e/ initium

C.2 Notes for Table C.M

C.2.1 Table C.M Configuration

Differentiation at the root terminus, which is not required, but can be accommodated by DCT, is shaded pale green for front vowel suffixes vs. white for non-front vowel suffixes.

Non-differentiation at the root terminus, which can be accommodated by DCT, is shaded pale yellow.

Differentiation at the root initium, which is cannot be accommodated by DCT, is shaded: blue for front vowel vs. pale red or orange for non-front vowel suffixes.

C.2.2 Table C.M Observations

1. Systematic non-differentiation at the root terminus tended to occur if the root contains an offglide, blocking anticipatory effects of the suffix, or if the kernel is tonic /i/.

2. The least amount of differentiation before front vowel suffixes occurred for tonic front kernels /í/.

3. The greatest amount of differentiation before front vowel suffixes occurred for tonic back round kernels /ó ú/.

4. The greatest amount of differentiation before back vowel suffixes occurs for tonic kernel /é/ and for pre-tonic syllables with an onglide /j/.

5. The least amount of differentiation before back vowel suffixes occurs for tonic back round kernels /ó ú/.

6. The most balanced differentiation before suffixes occurs with tonic kernel /á/ and with centralized pre-tonic kernels /y a o/, after nucleus reduction.

Table C.M Univariate ANOVA Test Homogeneous Subsets, Denoting DCT Conformity to Potential Contrast at Terminus Before Soft/Hard Consonants Associated With Suffixed Vowels.
S=Speaker; L=Lexical Item; R=Last Root Target; 1-5=Terminus Before Suffix; H=Subsets; V=Violations

S	L	R	1	2	3	4	5	H	V
pF	ježevíka	í	je	~~a~~	~~i~~	~~oj~~	u	2	
pG	ježevíka	í	je	a	i	oj	u	3	2
mC	ježevíka	í	i	je	a	oj	u	3	1
mB	ježevíka	í	i	je	a	oj	u	3	1
mD	ježevíka	í	je	i	oj	a	u	3	1
pF	píka	í	a	~~je~~	i	~~oj~~	u	3	2
pG	píka	í	i	a	je	oj	u	2	1
mD	píka	í	i	je	oj	a	u	3	1
pF	ɛ́k	ɛ́	ij		aja	ogo	uju	3	1
pG	ɛ́k	ɛ́	ij		aja	~~ogo~~	uju	3	1
mC	ɛ́k	ɛ́	ij		aja	ogo	uju	2	
mB	ɛ́k	ɛ́	ij		aja	ogo	uju	4	2
mD	ɛ́k	ɛ́	ij		aja	~~ogo~~	uju	3	1
pF	vjɛ́k	ɛ́	i	je	a	o	u	3	1
pG	vjɛ́k	ɛ́	i	je	a	o	u	3	1
mC	vjɛ́k	ɛ́	i	je	a	o	u	3	1
mB	vjɛ́k	ɛ́	i	je	a	o	u	4	2
mD	vjɛ́k	ɛ́	je	i	a	o	u	3	1
pF	uzbjɛ́k	ɛ́	i	je	a	~~ov~~	u	3	1
pG	uzbjɛ́k	ɛ́	i	je	a	ov	u	4	2
mD	uzbjɛ́k	ɛ́	i	je	a	ov	u	3	1
pF	kavýka	í	je	i	a	~~oj~~	u	3	1
pG	kavýka	í	i	je	oj	~~a~~	u	3	1
mC	kavýka	í	i	je	a	oj	u	2	
mB	kavýka	í	i	je	a	oj	u	2	
mD	kavýka	í	je	i	oj	a	u	4	2
pF	bjáka	á	i	je	oj	a	u	2	
pG	bjáka	á	i	je	a	~~oj~~	u	3	1
mC	bjáka	á	i	je	oj	~~a~~	u	3	1
mB	bjáka	á	i	je	a	oj	u	3	1
mD	bjáka	á	i	je	a	oj	u	3	1
pF	sobáka	á	i	je	a	oj	u	3	1
pG	sobáka	á	je	i	a	oj	u	2	
mC	sobáka	á	i	je	oj	a	u	2	
mB	sobáka	á	i	je	oj	~~a~~	u	3	1
mD	sobáka	á	i	je	a	oj	u	3	1
pF	bók	ó	je	i		om	u	4	2
pG	bók	ó	i	je		om	u	4	2
mC	bók	ó	i	je	a	om	u	2	
mB	bók	ó	i	je	a	om	u	2	
mD	bók	ó	i	je	a	om	u	2	
pF	ljepjëxa	ó	i	je	a	oj	u	2	
pG	ljepjëxa	ó	je	i	a	oj	u	3	1
mC	ljepjëxa	ó	i	je	a	oj	u	2	
mB	ljepjëxa	ó	i	je	a	oj	u	3	1
mD	ljepjëxa	ó	i	je	oj	a	u	2	
pF	búk	ú	i	je	a	ov	u	2	1
pG	búk	ú	i	je	a	ov	u	2	
mC	búk	ú	i	je	a	ov	u	2	
mB	búk	ú		je	a	ov	u	2	
mD	búk	ú	i	je	u	ov	a	3	1

S	L	R	1	2	3	4	5	H	V
pF	latvíjka	j	i	a	oj	je	u	2	1
pG	latvíjka	j	i	je	oj	a	u	2	1
mC	latvíjka	j	i	oj	je	a	u	2	1
mB	latvíjka	j	i	je	oj	~~a~~	u	3	1
mD	latvíjka	j	je	i	oj	a	u	2	1
pF	bájka	j	i	je	a	oj	u	1	
pG	bájka	j	i	~~je~~	oj	a	u	3	1
mC	bájka	j	i	je	oj	~~a~~	u	3	1
mB	bájka	j	i	je	oj	a	u	3	1
mD	bájka	j	i	je	oj	a	u	3	1
pF	popójka	j	je	a	i	oj	u	2	1
pG	popójka	j	je	i	a	oj	u	2	1
mC	popójka	j	i	je	a	oj	u	3	1
mB	popójka	j	i	je	a	oj	u	3	1
mD	popójka	j	i	je	a	oj	u	2	1
pF	vjek	j			áx	óv	ú	3	2
pG	vjek	j			áx	óv	ú	2	1
mC	vjek	j			áx	óv	ú	2	1
mB	vjek	j			áx	óv	ú	2	1
mD	vjek	j			áx	óv	ú	3	2
pF	zdorovjak	j	í	jé	á	ú	óv	3	1
pG	zdorovjak	j	í	jé	~~á~~	~~óv~~	ú	3	1
mC	zdorovjak	j	í	jé	á	óv	ú	3	1
mB	zdorovjak	j	í	jé	á	óv	ú	3	1
mD	zdorovjak	j	í	jé	á	óv	ú	4	2
pF	byk	ɨ	í	jé	á	óv	ú	3	1
pG	byk	ɨ	í	~~jé~~	á	óv	ú	2	
mC	byk	ɨ	í	jé	á	óv	ú	2	
mB	byk	ɨ	í	jé	á	óv	ú	2	
mD	byk	ɨ	í	jé	á	~~ú~~	óv	3	1
pF	tabak	ɐ	í	jé	á	óv	ú	2	1
pG	tabak	ɐ	í	jé	á	óv	ú	2	1
mC	tabak	ɐ	jé	í	á	~~óv~~	ú	4	2
mB	tabak	ɐ	í	jé	á	óv	ú	2	
mD	tabak	ɐ	í	jé	á	óv	ú	3	1
pF	bók	ɐ	í		á	óv	ú	3	1
pG	bók	ɐ	í		á	óv	ú	2	
mC	bók	ɐ			á	óv		1	
mB	bók	ɐ	í		á	óv		2	
mD	bók	ɐ			á	óv		2	1
pF	čubuk	u	í	~~jé~~	~~á~~	óv	ú	3	1
pG	čubuk	u	jé	í	á	óv	ú	2	
mC	čubuk	u	í	jé	á	óv	ú	2	
mB	čubuk	u	í	jé	á	óv	ú	2	
mD	čubuk	u	í	jé	á	~~óv~~	ú	3	1

Subset overlaps subset to its right	Unstressed Root
Non-violations to DCT for contrast before suffix	Violations to DCT for contrast before suffix
Non-differentiated before front/non-front suffix	Differ within non-front / Differ within non-front
Differ before front vs. / Differ before non-front	Differ within front set

C.3 Notes for Table C.S

C.3.1 Table C.S Configuration

Shading in Table C.S does not denote violations to DCT conventions. However, trends in suffix behavior suggest influences can be attributed to the preceding root syllable, which does represent a violation of DCT conventions.

For the standard dialect of Modern Russian, post-tonic /a o/ should pattern together, and post-tonic /i je/ suffixes may or may not pattern together, since post-tonic /je/ suffix may be realized as [jə].

Non-differentiation at the initial edge of the suffix is shaded pale yellow.

Differentiation at the initial edge of the suffix is shaded: blue or pale green for front vowel suffixes vs. white, orange, gold or pale red for non-front vowel suffixes.

C.3.2 Table C.S Observations

1. The greatest degree of differentiation occurred when the suffixes were tonic, since vowel reduction has not occurred, and the vowels retain full specifications.

2. The suffix /je/ tended to differentiate from /i/ more regularly, if the root syllable terminated in a non-front vowel.

3. The suffixes /je i/ did not differentiate, after syllable containing an offglide /j/.

4. The post-tonic suffix /oj/ patterned with post-tonic /a/ during the pre-suffix interlude; however, by the initial edge of the suffix /oj/ tended to differentiate from /a/. For speakers of p-Group, /oj/ tended to overlap the subsets of /je i/. For speakers of m-Group, /oj/ tended to pattern similarly to /je i/, but with greater separation of homogeneous subsets.

Table C.S Univariate ANOVA Test Homogeneous Subsets for the Initial Edge of Suffix Vowels. S=Speaker; L=Lexical Item; R=Last Root Target; 1-5=Suffix; H=Subsets

S	L	R	1	2	3	4	5	H
pF	ježevíka	í	i	je	oj	a	u	3
pG	ježevíka	í	i	oj	je	a	u	3
mC	ježevíka	í	i	je	oj	a	u	4
mB	ježevíka	í	i	je	oj	a	u	4
mD	ježevíka	í	i	je	oj	a	u	4
pF	píka	í	i	je	oj	a	u	4
pG	píka	í	i	je	oj	a	u	4
mD	píka	í	i	je	oj	a	u	5
pF	ɛ́k	ɛ́	ij		aja	ogo	uju	4
pG	ɛ́k	ɛ́	ij		aja	ogo	uju	4
mC	ɛ́k	ɛ́	ij		aja	ogo	uju	4
mB	ɛ́k	ɛ́	ij		aja	ogo	uju	4
mD	ɛ́k	ɛ́	ij		aja	ogo	uju	4
pF	vjɛ́k	ɛ́	i	je	o	ax	u	3
pG	vjɛ́k	ɛ́	i	je	ax	o	u	3
mC	vjɛ́k	ɛ́	je	i	o	ax	u	3
mB	vjɛ́k	ɛ́	i	je	ax	o	u	4
mD	vjɛ́k	ɛ́	i	je	o	ax	u	3
pF	uzbjɛ́k	ɛ́	i	je	a	ov	u	4
pG	uzbjɛ́k	ɛ́	i	je	a	ov	u	3
mD	uzbjɛ́k	ɛ́	i	je	a	ov	u	3
pF	kavýka	í	je	i	oj	a	u	3
pG	kavýka	í	oj	i	je	a	u	3
mC	kavýka	í	i	je	oj	a	u	4
mB	kavýka	í	i	je	oj	a	u	4
mD	kavýka	í	i	je	oj	a	u	4
pF	bjáka	á	i	je	oj	a	u	4
pG	bjáka	á	i	je	oj	a	u	3
mC	bjáka	á	i	je	oj	a	u	4
mB	bjáka	á	i	je	oj	a	u	5
mD	bjáka	á	i	je	oj	a	u	4
pF	sobáka	á	i	je	oj	a	u	4
pG	sobáka	á	i	je	oj	a	u	3
mC	sobáka	á	i	je	oj	a	u	4
mB	sobáka	á	je	i	oj	a	u	4
mD	sobáka	á	i	je	oj	a	u	4
pF	bók	ó	i	je		om	u	3
pG	bók	ó	i	je		om	u	3
mC	bók	ó	i	je	a	om	u	3
mB	bók	ó	i	je	a	om	u	5
mD	bók	ó	i	je	a	om	u	3
pF	ljepjëxa	ó	je	i	oj	a	u	4
pG	ljepjëxa	ó	i	je	oj	a	u	3
mC	ljepjëxa	ó	i	je	oj	a	u	3
mB	ljepjëxa	ó	i	je	oj	a	u	5
mD	ljepjëxa	ó	i	je	oj	a	u	4
pF	búk	ú	i	je	a	ov	u	5
pG	búk	ú	i	je	a	ov	u	5
mC	búk	ú	i	je	a	ov	u	3
mB	búk	ú		je	a		u	3
mD	búk	ú	je	i	a	ov	u	3

S	L	R	1	2	3	4	5	H
pF	latvíjka	j	i	je	oj	a	u	3
pG	latvíjka	j	i	je	oj	a	u	3
mC	latvíjka	j	i	je	oj	a	u	4
mB	latvíjka	j	i	je	oj	a	u	4
mD	latvíjka	j	i	je	oj	a	u	4
pF	bájka	j	i	oj	je	a	u	3
pG	bájka	j	i	oj	je	a	u	3
mC	bájka	j	je	i	oj	a	u	4
mB	bájka	j	i	je	oj	a	u	4
mD	bájka	j	i	je	oj	a	u	4
pF	popójka	j	je	i	oj	a	u	3
pG	popójka	j	i	je	oj	a	u	3
mC	popójka	j	i	je	oj	a	u	4
mB	popójka	j	i	je	oj	a	u	4
mD	popójka	j	i	je	oj	a	u	4
pF	vjek	j			áx	óv	ú	3
pG	vjek	j			áx	óv	ú	2
mC	vjek	j			áx	óv	ú	2
mB	vjek	j			áx	óv	ú	3
mD	vjek	j			áx	óv	ú	3
pF	zdorovjak	j	í	jé	á	óv	ú	5
pG	zdorovjak	j	í	jé	á	óv	ú	3
mC	zdorovjak	j	í	jé	á	óv	ú	3
mB	zdorovjak	j	í	jé	á	óv	ú	4
mD	zdorovjak	j	í	jé	á	óv	ú	3
pF	byk	ɨ	í	jé	á	óv	ú	4
pG	byk	ɨ	í	jé	á	óv	ú	4
mC	byk	ɨ	í	jé	á	ú	óv	4
mB	byk	ɨ	í	jé	á	óv	ú	4
mD	byk	ɨ	jé	í	á	óv	ú	3
pF	tabak	ɐ	í	jé	á	óv	ú	3
pG	tabak	ɐ	í	jé	á	óv	ú	5
mC	tabak	ɐ	í	jé	á	óv	ú	3
mB	tabak	ɐ	í	jé	á	óv	ú	3
mD	tabak	ɐ	í	jé	á	óv	ú	3
pF	bok	ɐ	í		áx	óv	ú	3
pG	bok	ɐ	í		áx	óv	ú	4
mC	bok	ɐ			áx	óv		2
mB	bok	ɐ	í		áx	óv		3
mD	bok	ɐ			áx	óv		2
pF	čubuk	u	í	jé	á	óv	ú	4
pG	čubuk	u	í	jé	á	óv	ú	5
mC	čubuk	u	í	jé	á	óv	ú	4
mB	čubuk	u	í	jé	á	óv	ú	5
mD	čubuk	u	jé	í	á	óv	ú	3

Subset overlaps subset to its right	Unstressed Root	Non-front Vowel Suffix
/oj/ Grouping with Front Vowel Suffixes	Front Vowel Suffix	Differ within non-front
/oj/ Patterning with Front Vowel Suffixes	Differ within front set	Differ within non-front

APPENDIX D

SIGN CONVENTIONS AND TERMINOLOGY

D.1 Sign and Symbol Conventions

In this document, the modified version of IPA, which is similar to that employed in *The Sound Pattern of Russian* (Halle: 1959, p. 16) is as follows:

1) The symbols for palatal and dental consonants č, š, ž, and c instead of IPA ʧ, ʃ, ʒ, and ʦ, respectively, in parallel with Halle;

2) The symbol y has been chosen to represent the phonemic nucleus corresponding to the Cyrillic character ы. First, this usage is consistent with other Modern Slavic languages which use a modified Latin orthography (such as Modern Czech), and use the symbol y to represent the historical segment(s) ы. Second, the usage of the Latin symbol y for the Cyrillic symbol ы is also traditional in many transliteration practices for Modern Russian. Third, the Latin symbol y is ASCII-friendly, and its usage permits a consistent representation of the phoneme, across the variety of software packages used in this research (some of which do not support Unicode). The various phonetic allophones of ы will be represented as [ɨ], [ɨi], [^{ɯ}ɨ], [^{y}ɨ], [^{y}i] as necessary. The Latin symbol y will not be used to represent a high front rounded vowel, as is the convention of IPA. Instead, when the need arises to refer to a high front rounded vowel, the symbol ÿ will be used.

The major drawback to using the symbol y to represent the underlying segment(s) for Cyrillic ы or any of its allophones is that the Latin symbol y is very similar visually to the Cyrillic symbol у (/u/).

3) Palatalized consonants will be represented as a single glyph with a hook (e.g. ƫ), when pre-defined glyphs are available in the Font library, or as a single glyph which is

created by the superposition of the unpalatalized glyph over a cedilla (e.g. ç̌), when pre-defined glyphs are not available, whereas Halle represented palatalized consonants as a sequence of two glyphs: a comma following the symbol of the unpalatalized sound (e.g., t,);

4) Stressed vowels will be represented as a single glyph with an acute accent mark (e.g. ú), whereas Halle represented stressed vowels as two glyphs: an apostrophe preceding the symbol for the unaccented vowel (e.g. ’u). When necessary, secondary stress will be represented with a single glyph with a grave accent mark (e.g. ò). Thus, in the phrase “бок о бок” /bòk ó bok/ ‘side by side’, the first vowel bears secondary stress, the second vowel bears primary stress, and the third vowel is unstressed. Table D.1 includes all of the symbols employed in this presentation and the contexts in which these symbols are used.

Table D.1. Vocalic Symbols Which Occur in Various Contexts in this Document.

Cyrillic Symbol	Stressed (Phonemic)	Stressed (Phonetic)	Unstressed (Phonemic)	Unstressed (Phonetic)
и	j, í	^{j}, j, í	j, i	^{j}, j, i, ɪ
э	é	é, ɛ́	e	e, ɛ
а	á	á, ɑ́	a	a, ɑ, ɐ, ə, ɘ
о	ó	ó	o	o, a, ɑ, ɐ, ə, ɘ
у	ú	ú	u	u, ʊ
ы	ý	^{y}, ɯ̵, ɨ̂, í	y	^{y}, y, ɨ, i
е	j, é	^{j}, j, ɛ́, é	j, e	^{j}, j, e, ɛ, i
я	j, á	^{j}, j̗, á, ǽ	j, a	^{j}, j, a, i
ё	j, ó	^{j}, j, ó, ö, ɵ́, ǿ̗, œ́	j, o	^{j}, j, o, i
ю	j, ú	^{j}, j, ú, ǘ, ʉ́, ÿ	j, u	^{j}, j, u, i, ü
ь			j	j
ъ			ɘ	ɘ, ^{ə}

5) Symbols for Variable Sets:

Table D.2. Symbols Representing Variable Sets. The majuscule symbols in the left column will represent any member of the sets defined in the second and third columns.

Variable Set	Members of Set	Description of Set
C	{p, t, k, …, p̡, t̡, k̡, …, č, š, ž, …, č̡, š̡, ž̡, …}	any Consonant
Č	{j, č, š, ž}	any Palato-alveolar Consonant
Ç	{p̡, b̡, v̡, f̡, m̡, t̡, d̡, s̡, z̡, n̡, r̡, l̡, ç, č̡, š̡, ž̡, k̡, g̡, x̡}	any DCT "Soft" Palatalized Consonant
K	{p, b, v, f, m, t, d, s, z, n, r, l, k, g, x}	any DCT "Hard" Unpalatalized Consonant
B	{p, b, v, f, m, p̡, b̡, v̡, f̡, m̡}	any Labial Consonant
D	{t, d, s, z, n, r, l, t̡, d̡, s̡, z̡, n̡, r̡, l̡}	any Alveolar Consonant
G	{k, g, x, k̡, g̡, x̡}	any Velar Consonant
V	{i, y, e, a, o u, …}	any Vowel
W	{i, y, e, a, o, u, je, ja, jo, ju, ij, yj, ej aj, oj, uj, jej, jaj, joj, juj}	any Tautosyllabic Vocalic Sequence
X	any of the above	any Segment or Sequence

6) The following diacriticals will be used, as they occur in Hamilton 1980:

´ (accent acute) to denote primary stress.

` (accent grave) to denote secondary stress.

˘ (breve) to unstressed vowels.

¨ (umlaut/dieresis) to denote centralized allophones.

D.2 Terminology

D.2.1 Hard and Soft Features

The terms "hard" and "soft" are used liberally, because they are:

1) Traditional in many Russian studies; and

2) Non-committal, with regard to stance on palatalization (segment/feature, sequential/co-articulated/double-articulated/modified point-of-articulation, etc.).

D.2.2 Initium and Terminus

A substantial portion of this document addresses the behavior of the syllable at the leading edge and trailing edge of the sonorous portion of the vowel. For brevity, the label "initium" refers to the "initial edge of the sonorous portion of the syllable", and the label "terminus" refers to the "terminal edge of the sonorous portion of the syllable". In general, most attention in this study is paid to the final syllable of a root, prior to the suffix (if any). Unless otherwise indicated, the labels "initium" and "terminus" refer only to the edges of the final syllable of the root of the token currently under consideration.

D.2.3 Three Types of Inflection

Three distinct definitions of "inflection" are encountered in this document:

1) Intonational pitch contour.

2) Declension of grammatical cases, resulting in suffixation.

3) The change in the slope behavior of a mathematical curve.

To reduce confusion, the term "intonation" is limited to issues involving pitch. The spelling "inflection" is limited to grammatical declension. And finally, the spelling "inflexion" is employed with regard to mathematical curves.

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