Clusters and the onset

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It has been argued in the literature that branching onsets should be dispensed with by introducing complex segments. These were claimed to be obstruents with liquids as their secondary articulation, segments available *as is* in the phonemic inventory of a given language ('Complex Segment Hypothesis'). It is shown that this hypothesis is desirable for phonological theory. Some aspects of CSH are discussed on Russian material by adducing arguments from verbal morphology and from experimental phonetics. Finally, a phonetic study of a speech corpus (British English) renders support to the Complex Segment Hypothesis.

1. Introduction

This paper is devoted to the issue of complex segments in the onset. The central claim considered is that of the so-called 'Complex Segment Hypothesis' first submitted by Hirst (1986). Radically different versions of such hypothesis developed, according to the phonological model assumed: an Underspecification approach (Hirst 1986, 1995), an Aperture Theory approach (Steriade 1993, 1994), a CVCV approach. The latter, represented by Lowenstamm (2003) forms the focus of the present discussion. It is referred throughout this paper as 'CSH'.

According to CSH, onset obstruent-liquid clusters *may* be interpreted as underlying segments forming single units, in other words as complex segments. Not all (onset) obstruent-liquid sequences, however, are complex segments. As Lowenstamm (2003) argues for this point with his analysis of Chaha data (*cf. also section 2*), two competing interpretations are available within CVCV. One candidate representation maps an obstruent X exhibiting a secondary articulation (viz. a palatal approximation or a liquid), onto a *single* C position. The other candidate representation maps X onto a C position while mapping the secondary articulation on the following C position, the two positions being separated by an empty V position. On the segmental level, in the former case, we are dealing with a *single* segment $X^{j/Liquid}$; in the latter case, we are dealing with a {X j/L} complex.

CSH appears to be a straightforward solution to the issue of the complex cluster representation in highly constrained CVCV phonology. That was a less crucial theoretical matter for other theories. For example, standard Government Phonology would syllabify the 'CCL' clusters as heterosyllabic sequences in which the first consonant is in the Coda whereas the following consonant-liquid sequence forms a branching onset. By contrast, such

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interpretation is unavailable in CVCV because of the ban placed by this theory on branching constituents (both Onset and Rhyme) and on Codas. CSH provides then a possible solution.

In this very vein, the aims of this paper are to show that CSH is theoretically desirable because it gives us a simple way of capturing complex consonant patterns and predicting some important, testable phonetic processes.

As noted, the status of phonetic clusters is phonologically ambiguous. The decision about the phonemic status of a cluster may then be a product of concrete methods of phonological analysis. Those exploited in Lowenstamm (2003) are based on the study of templates and reduplicative morphology in relation with various phonological phenomena such as palatalization, vocalic centralization and deaspiration, and of the non-sensitivity of metrical systems to onset structure. These phenomena have been studied on data from Chaha, Ilokano, Greek and Czech.

A related question arises naturally: can CSH be supported by arguments based on data from other languages? Also, could CSH be independently verified via methods of different nature? To illustrate one such method, phonetic treatment of English clusters is proposed addressing the question of effective phonetic duration of consonant clusters in the onsets in British English speech. Evidence bearing on the CSH will come from data concerning susceptibility of clusters to compression. Equally, I will show that CSH is desirable for phonological theory: I will discuss some of its aspects on Russian material adducing arguments from Russian phonotactics and verbal morphology. Regarding these arguments, I will make use of Single-stem theory, a particular framework for modeling Russian morphology. An interesting account of the so-called *l-epentheticum* in Russian will follow from this morphological framework and other considerations.

The structure of the paper is as follows. Section 2 sets forth two of Lowenstamm's (2003) arguments in favor of CSH in order to give the reader some background. Section 3 shows, arguing from Russian data, that CSH is desirable. It will be assessed in the following two sections how well CSH copes with Russian clusters given verbal morphology of this language. Section 5 is an approach to complex segments in English onsets; an experiment on compression of clusters in English is presented, with some of the implications of this experiment for CSH discussed. The conclusion of the paper sums up the results.

2. Some arguments in defense of the Complex Segment Hypothesis[1]

In this section, I briefly present some arguments for CSH drawing heavily on Lowenstamm (2003:2-4). The reader should note that this passage relies on previous results obtained by the same author (Lowenstamm 1996, 1999, 2001).

Compare two perfective verbs in Chaha, a Southern Ethio-semitic language:

(1) a. 3 MASC. SG. fiċänäq-ä 'squash'
b. 3 FEM. SG. q^{w}ıräċ-ä 'take a handful and close the hand'

On the surface, the two verb roots are different in their make-up: the verb in (a) contains four consonants whereas the one in (b) contains three consonants. However, Lowenstamm (1996) shows that the allegedly triliteral roots are mere quadriradicals, if they contain the central

[1] The reader is referred to Lowenstamm (2001, 2003) for detailed explanation and a wealth of details (cf. also the review in Vaxman 2006)

vowel ɪ. (Additionally, some biliteral roots have been proved to be triliteral in Lowenstamm (2001) so that it is easy to see that surface realizations may be one segment shorter than respective underlying forms).

Granted this point, the root in (b) counts as quadriliteral on a par with the root in (a). It is then legitimate to construe of [ċ] as phonetic realization of /ṭ j/ sequence where /j/ is a segment attached to the next C position in the CVCV configuration. On the contrary, what we have in (a) is not a sequence, but a single segment attached to one C position and consisting of /ṭ/ as primary articulation and /j/ as secondary articulation. To put it differently, in (a) we have a cluster while in (b) just one segment.

Part of demonstration runs as follows. If we examine the 1 SG. and 2 MASC. SG. Perfectives of the same two verbs and compare them to (1), we see an [ä] intervening between the final consonant of the root and the *consonant-initial* affix. Lowenstamm's claim is that this vowel results from a metathesis: in this language, a root-final yod and its preceding vowels are reordered:

(2)

	a. UR and realization			b. *Conventional* output notation
	UR		Output	
1 SG	/fiṭ^{j}änäq-x^{w}/	>	[fiṭ^{j}änäqx^{w}]	fiċänäq-x^{w}
2 MASC. SG.	/fiṭ^{j}änäq-xä/	>	[fiṭ^{j}änäqxä]	fiċänäq-xä
1 SG.	/q^{w}ɪräṭäj-x^{w}/	>	[q^{w}ɪräṭjäx^{w}]	q^{w}ɪräċä-x^{w}
2 MASC. SG	/q^{w}ɪräṭäj-xä/	>	[q^{w}ɪräṭjäxä]	q^{w}ɪräċä-xä

Chaha morphology lets the root-final consonant appear in its bare form. Thus, *vowel-initial* suffixes assuming the function of agreement markers trigger root-final yod deletion yielding forms with 'bare' [ṭ]:

(3) a. 3 MASC. PL. /q^{w}ɪräṭäj-o/ > [q^{w}ɪräṭäwo][2]
b. 3 FEM. PL. /q^{w}ɪräṭäj-ma/ > [q^{w}ɪräṭäma]

The [ä] directly follows the last consonant of the root in the output, which brings in partial confirmation of its root-final occurrence when a consonant-initial affix is added. In a word, agreement operations with vowel-initial suffixes opens access to the URs that conventional notation has been obfuscating.

Additional corroboration of CSH comes from Greek reduplicative morphology. Perfect Formation, one of derivational operations involving reduplication in Greek, requires the following ingredients: (i) the phonetic interpretation of a light CV affix in which (ii)V is /e/ and (iii) C is a copy of the root-initial consonant.

Thus, /luo/, after reduplication, yields /le-luka/. However, /grap$_{h}$o/, after reduplication yields /ge-grap$_{h}$euka/, that is the liquid is pruned in order to fit the format of the copy. The process observed has been termed 'decomplexification' in Lowenstamm (2003:10) and defined as deletion of secondary articulation. Now, note that decomplexification is not a

[2] A careful reader will notice a [w] occurring in 3 MASC PL. form. According to Lowenstamm, [w] is inserted after deletion of [j]. Two remarks are due: first, glide insertion is a wide-spread linguistic phenomenon, hence insertion in itself is not problematic phenomenologically speaking. However, there may arise a theoretical question: don't we get a case of intrinsic ordering between deletion of yod and [w] insertion?

universal phenomenon. For example, decomplexification does not operate in Ilokano. In other words, Ilokano does not prune the yod and the liquids.

A uniform account of reduplication in both Greek and Ilokano can be captured straightforwardly through the means of parameterization. Lowenstamm introduces 'a parameter of reduplicative systems' for decomplexification: *"Reduplicate complex segments YES/NO"* (Lowenstamm 2003:10). Then, simply, decomplexification parameter is set to NO for Greek and to YES for Ilokano.

Additionally, in Greek, the pruning of multiple secondary articulations reduplication applies to the copy of the root-initial consonants. Thus, in reduplication, both aspiration and the liquid (be it /$^{l/}$ or /$^{r/}$) are pruned. This fact serves as evidence to the basic claim that liquids are mere secondary articulations. And we conclude with Lowenstamm (2003) that Greek (and Ilokano) *mutæ cum liquidā* do not form branching onsets

I omit the remainder of ample evidence for CSH detailed in Lowenstamm (2003); the reader is referred to the above-mentioned publications by this author.

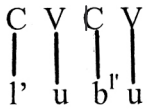
3. The appeal of complex segments

The wide-spread idea of the Russian segment inventory holds that most of consonant phonemes form a certain number of 'palatalized/unpalatalized' pairs: /b/:/b'/, /p/:/p'/, /v/:/v'/, /f/:/f'/, /m/:/m'/ etc. Under the complex segment hypothesis, the plain /b/, previously paired with /b'/, must now be expanded to include the complex /b$^{l'}$/ and this may also be true of all other pairs of consonants. Therefore, a part of the phonemic inventory of Russian should consist of a number of consonants organized in series of three items. (The series can further be extended to include /b^{r}/ and /b$^{r'}$/ and this might be valid for all Russian labials.)

The aim of this section is to show, drawing on Contemporary Russian data, that this approach to consonantal clusters is desirable for phonological theory.

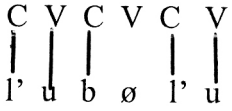
Consider now the form [l'ubl'u] ('love', 1 SG. Pres; Conjugation II). Adopting Lowenstamm's proposal, the appropriate representation for this form would be:

(4)



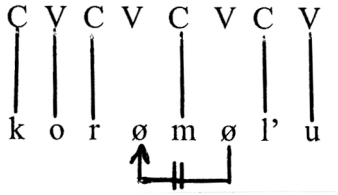
Instead of the traditional representation with an intervening empty nucleus:

(5)



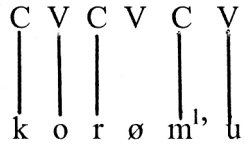
(4) offers the advantage that we can now easily express the patterning of consonants in three-member clusters in CVCV using the Proper Government (henceforth, PG). As an illustration of this, consider the form [korml'u] ('feed' 1 SG. PRES; Conjugation II). This form could be represented as in (6) assuming the standard framework:

(6)



Obviously, this representation violates the Empty Category Principle (ECP) (following Kaye *et al*. 1985 and Charette 1991). On the other hand, ECP is not violated if we accept CSH, /m$^{l'}$/ being then hosted by a single (non-branching) C position without an empty nucleus intervening between *m* and *l'*. As a consequence, we are left with only one empty V position properly governed by the following filled V position:

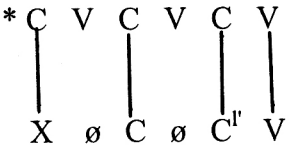
(7)



It follows that CSH allows us to fit a surface sequence of three consonants under two C-nodes. This is important for representing clusters, commonly encountered in Slavic, the complexity of which is otherwise problematic for the CVCV representational format.

There is another reason that makes CSH desirable: CSH predicts the representations (4) (7), precluding at the same time all other ones. In particular, CSH, coupled with the usual principles of CVCV, leads to the prediction that (8) is ill-formed.

(8)



where X is any consonant

This prediction is directly borne out by the data: there are no surface clusters in Russian that would end in [l'] following *three or more* consonantal segments of any kind. In other words, there are …*CCCl'*-type sequences.

In a nutshell, Russian data provide empirical support for CSH. This hypothesis lays the grounds for the modeling of a simple representation for complex clusters without relaxing the CVCV assumptions.

4. A case for the Single-stem theory

4.1. Presentation of the morphological framework

Below, I offer a case study within Single-stem theory showing that not every sequence theoretically qualifying for the complex segment status can effectively be analyzed using the Complex Segment Hypothesis.

The Single-stem theory (Jakobson 1948) is a theory of Russian conjugation that derives all forms of a verb using a single verb stem, as opposed to traditional grammatical theories in which conjugation is based on two different stems: the Present-tense stem and the Infinitive stem.

In order to test CSH on Russian material, I examine a case of alternation in the verbal inflection. The verbs with root-final labials in the Infinitive will be considered. These verbs are treated in a special way within 'two-stem' accounts of Russian morphonology (cf. Čurganova 1973, Reformatskij 1975). These accounts brazenly posit multiple lexical forms for the same word. Such attitude being problematic for a generative model, a different approach is pursued in the present paper.

The reasoning of the two sections below is as follows: (a) a suffix /i/ is added to the stem in the present tense as compared to the Infinitive once the stem-final (so called 'thematic') vowel deletes in the latter; (b) this /i/ is phonetically realized as [l'] in the 1 SG. while realized as [i] in the rest of the forms; hence (c) the obtained sequence *labial+l'* cannot be interpreted as a simplex segment due to phonological and morphological reasons.

4.2. Present Formation

Consider table 1 in which the present-tense forms for the verb [l'ubl'u] 'I love' are listed. (Present-tense endings fuse PERSON and NUMBER categories.) Observe that the thematic suffix /i/ added to the root to form the verbal stem, deletes in 1 SG.

	SG.	**PL.**
1 PERS.	l'ub-l'-u (l'ub'-l'-u)	l'ub'-i-m
2 PERS.	l'ub'-i-š	l'ub'-i-t'e
3 PERS.	l'ub'-i-t	l'ub'-at

Table 1. A Present Formation paradigm

(7) Infinitive: l'ub-i-t' 'love'
Stem: l'ubi
Root: l'ub

As can be seen from table 1, the suffix /l'/ occurring in 1 SG. is palatalized while the preceding labial *may* remain plain (palatalization of the labial being optional, *see below*), and the root-final consonants in all other persons are also palatalized. Another point is that /l'/ of the 1 SG. alternates with ø of 3 PL.

It is possible to account for these observations by postulating an /i/ (tentatively interpreted as marking the fact that the verb is conjugated) added to the right of the stem after the deletion of a homonymous thematic vowel /i/. The deletion of /i/ was traditionally expressed within the Single-stem theory by a 'truncation rule' (cf., in particular, Jakobson 1948 and Coats & Lightner 1975). In fact, /i/ deletes to resolve an ill-formed hiatus. A hiatus is always precluded from forming on the right periphery of the word, that is after the right boundary of the root), as observed in Garde (1970).

For the sake of clarity, the phonological process at hand is represented informally in table 2.

stem	**ending**	**present form.**	**result**
l'ubi-	u	l'ubi+u	l'ubu
kormi-	u	kormi+u	kormu
lovi-	u	lovi+u	lovu

Table 2. Hiatus resolution: thematic suffix + ending

Gloss:
l'ubit' 'love' (Inf)
kormit' 'feed' (Inf)
lovit' 'catch' (Inf)

The conjugative suffix /i/ is then affixed to the right of the root. This results in a new hiatus between the added vocalic suffix and the ending that also begins with a vowel. Compare two derivations for the paradigm in table 2:

(9) 1 SG.l'ub]$_{stem}$ + i + u → l'ubju
3 PL. l'ub]$_{stem}$ + i + at → l'ub'at

Palatalization of /b/ and absence of a surface vowel in 3 PL. is due to hiatus resolution. /i/ and /a/ are both vocalic. Given that in Russian two vowels cannot co-occur in a sequence on the right margin of a stem, /i/ simply deletes. (Observe that in this respect Russian behaves typically: most languages delete some V_1 in a V_1V_2 sequence, not the second.) These processes are informally represented in (10) and (11) in a rule-based format:

(10) /b/-> b'/_____ $V_{[+front]}$

(11) /i/ -> ø / _____ V

In 1 SG, on the contrary, /i/ does not delete, yielding instead /j/: /i/ and /u/ sharing the Place feature [+high] are subject to the OCP-Place. This principle disfavors neighboring segments with at least one place feature being the same. The OCP-place triggers glidification and yields /j/ so that /l'ubju/ is derived.

Summarizing, the differential treatment of /i/ before /u/ and /a/ is determined by the distinction between, on one hand, the phonotactic ban on a morphonologically defined type of hiatus (i+a) and, on the other hand, the OCP-Place (i+u).

Russian provides extensive corroboration for the hypothesis that a yod occurs and exerts an action in the derivation of [l'ubl'u] (1 SG.). Indeed, the regular state-of-affairs for the Russian

verbs in the Present is the palatalization of the stem-final consonant of a verb implying the action of /j/ to the right of a given consonant:

(12)	a. **Infinitive**	b. **1 SG. PR.**	c. **Gloss**	d. **compare**	e. **Gloss**
	xot-e-t’	xoč-u	want	o-xot-a	‘longing’
	gorod-i-t’	gorož-u	put a fence	za-gorod-k-a	‘hurdle’
	zl-i-t’	zl’-u	anger	zl-oj	‘angry’
	vis-e-t’	vi-šu	hang	po-vis	‘hung on’

(12a) shows Infinitives with stem-final segments that are underlyingly non-palatalized. Cognates in (12d) are unpalatalized on the surface, so they evidence that stems in (10a) effectively end in a non-palatalized consonant. By contrast, (12b) shows the result of palatalization.[3] One can easily account for this phenomenon considering then that l’ub’at (3ps. PL.) in table 1 is also a case of palatalization. /j/ palatalizes /b/ in (10) just like it does throughout the 1 SG. PR. forms in (12b) as compared to (12a). (Obviously, back vowels do not palatalize the preceding consonant.) By way of contrast, this does not apply to /b/ in 1 SG l’ubl’u where /b/ is not palatalized obligatorily.

According to Daniel Hirst (pers. comm., 2006), the differential treatment of /j/ may be explained by the phonetic fact that what we have here are precisely sequences consisting of a labial plus a lingual and it is easier to use the tongue to articulate a lingual after a labial than after another lingual. No doubt, this elegant explanation has its appeal. Nevertheless, one might ask why the phonetic output is precisely [l’]. This is the question considered in the remainder of the section 4.

4.3. Fortition?

Above, I have discussed the rationale behind the differential treatment of the marker /i/ and on how yod obtains. Now, the issue boils down to capturing the motivation for the phonetic surface realization of the yod.

The correct explanation for this process had been viewed by some researchers as part of fortition phenomenology. That is why, in this subsection, I willl begin by re-appraising the work of Kristó & Scheer (2005) which takes such point of view. In the following subsection, I shall submit my own interpretation of the facts.

In their talk on the fate of the yod in Slavic, Kristó & Scheer (2005) take the fortition in the postconsonantal position (on which cf. Segeral & Scheer 1999), that is in non-initial onsets, to be the reason behind j -> l’ alternation:

[3] Stem-final velars are not subject to this process in 1 SG. due to their distiribution: in Russian, the palatalized allophones of the velars do not combine with non-front vowels such as /u/ of the 1 SG. present ending (except few loanwords, cf. [ek’u] ‘ an écu’; cf. Paradis 2006). Palatalization in the given Infinitives occurs on the surface. In (10a) we give the forms in the UR, determined by contrasting (10b) with (10c). Palatalization is caused here by the front vowels (cf. Rubach 2002 and references therein).

PSl. *y > l'/ Clab ___

Yod stenghtens to a palatal liquid after (unpalatalizable) labials, elsewhere (= after non-labials) it produces regular palatalization.

Initial Labial + Yod:
PSl *bjudo/bjudъ . dish > OCS bl.ud/bl.udъ, Po bluda, Ru bl.udo
PSl *pjujσ . I spit > OCS plujõ, Sn plújem, Po pluje, Cz pliju, Bu pl'uja.
(Kristó & Scheer 2005)

Note that the authors' claim that labials are unpalatalizable in Slavic does not match phonetics of Russian labials. In this respect, Russian is in sharp contrast with Latin, a language in which labials could not be palatalized (see below). There are abundant examples of secondary articulation in Russian labials, such as:

(13)	b'is	'an encore'	b'es	'demon'
	m'il	'nice' (Attrib.)	m'el	'chalk'
	p'il	'was drinking'	p'el	'was singing'
	sv'iter	'a sweater'	v'et'er	'wind'
	f'int	'a sly trick'	f'en'a	'cronyism'

Further evidence comes from Padgett (2001). This author characterizes the /b'/ vs. /b/ contrast as a 'palatalized' vs. 'velarized' contrast. His argument is based on an experimental study comparing [b] and [b'], [d] and [d'] in speakers of (Moscow) Russian vs. corresponding phones in Donegal (Northern Irish). The experiment focused on the contrast between palatalization and velarization. In particular, Padgett has taken formant measures of the /i/ following relevant labials and dentals, measures that served as acoustic cues to the 'palatalized'/'velarized' contrast.[4] Then, an analysis of variance (ANOVA) measures has been performed on these measures. The results are given in table 3.

Subject	**Russian 1**	**Russian 2**	**Russian 3**	**Irish 1**	**Irish 2**	**Irish 3**
b vs. b'	826 Hz	1189 Hz	1009 Hz	1061 Hz	1842 Hz	1395 Hz
d vs. d'	238 Hz	390 Hz	532 Hz	263 Hz	257 Hz	136 Hz
Result	F(1.32) =161 p<0.001	F(1.32) =529 p<0.001	F(1.32) =249 p<0.001	F(1.16) =218 P< 0.001	F(1.32) =249 p<0.001	F(1.24) =694 P<0.001

Table 3. Results of ANOVA for F2' means of [b]-type vs. [d]-type sounds across 3 Russian and 3 Irish speakers

It is clear from table 3 that for every subject, the difference between the F2' means was much larger following the bilabial consonant, an interaction (velarized/palatalized versus consonant type) that is highly significant. This conclusion provides empirical support for the claim that Russian labials can be palatalized. Phonetically, they are even more palatalizable than dentals knowing that some phonetic properties are not categorical.

[4] F2' at the end-point of a consonant is the major acoustic cue to velarization/palatalization. It is computed with the formula: F2'=F2+0.5(F3-F2)((F2-F1)(F3-F1)).

Since labials are palatalizable in Russian, it is not true, synchronically speaking, that /j/ strengthens into [l'] because it cannot palatalize the preceding labial. The labials, as it has just been seen, palatalize very well. Thus, all types of labial consonants preceding /l'/ in the onset were historically palatalized in Russian, as in [b'l'udo] ('dish'), [p'l'uju] ('I spit') and [lov'l'u] ('I catch'). This pronunciation was prescribed as Standard Russian pronunciation in phonetic textbooks until quite recently (Avanesov 1972 is a good example). It is nowadays a signal that Russian speakers whose speech exhibits palatalized labials in this type of clusters belong to the oldest living generation of Muscovites. This fact implies that Kristo & Scheer's proposal might not be valid synchronically and is probably at least incomplete historically.

In fact, the motivation underpinning their claim may have been the existence of a widely known historical pattern of sound change in which the labials are unpalatalizable, the yod remains and Coda Mirror-induced fortition effectively takes place. Such is, *inter alia*, the formation of French [saš]. It resulted from Latin [sabja-], with the yod obstruentized and [b] ultimately deleted in the coda by lenition (or, for many, lenition targeting an unlicenced C position):

(14)

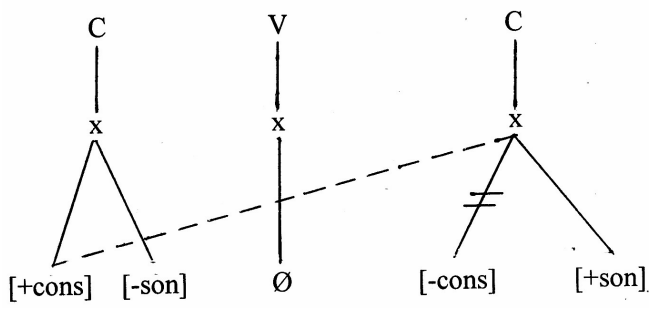
Such sound change observed in many Romance languages (Kaisse 1992, Rankin 1981) typically leads to an obstruent, not to a liquid. Note that in this historical pattern, the coda consonant, which is effectively unpalatalizable as far as Latin is concerned, is lenited to zero. By contrast, the labial in the relevant Russian clusters is never lenited. This fact indicates that the labial is in the onset, not in the coda, and that, in this case, the processes in action are not the same for Russian and for Latin.

Lastly, the authors argue that /j/ strengthens in [l'] because of its syllabic affiliation to the onset, in a way we would then have a mere instance of a positionally-conditioned fortition. It is important to see however, that fortition may not be the operative factor here: explaining our data by fortition is inadequate to account for the phonetic identity of the output, i.e. of the [l']. Nothing in fortition-based approaches explains us why we get precisely a palatalized lateral alveolar liquid.

4.4. A feature-geometrical account

My own solution to these problems is couched in feature-geometrical terms: [l'] results from a rightward spread of the [+consonantal] feature of /b/ onto the palatal glide following the empty nucleus, the [-consonantal] feature of the glide being delinked:

(15)



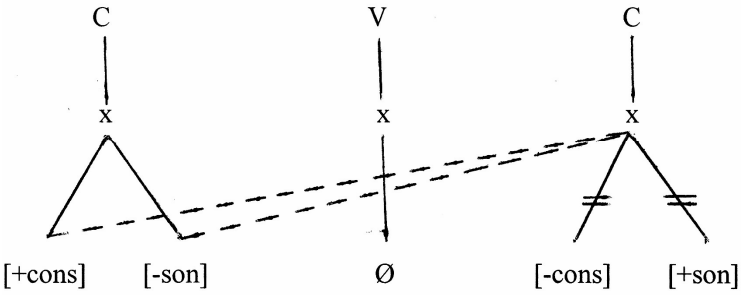
All other features in [j] are maintained, in particular the feature [+sonorant] and the feature [+continuant] of the second consonant. The non-delinking of these two features explains why what we get at the output is not a rhotic.

Feature geometry may provide a uniform account for this type of alternation and the Romance sound change mentioned above. The advantage of this approach is that the obstruentization pattern, like the pattern in (14), can be accounted for using the means of feature-linking/delinking. This is shown in (16). We thus get a unified account for both types of alternations.

(Resort to geometry is dictated by the consideration that in the element theory proper to principle-based frameworks apparently it would have been difficult to offer a complete solution. To operate on the glide with elements, C-to-C relations need to be established, which would explain how the position of /j/ is affected structurally.)

We can therefore conclude that the sequence [bl'] in [l'ubl'u] cannot be interpreted as a complex segment. In the Present forms, [l'] results from /j/ following a labial, as opposed to the Infinitive. The input for [l'ubl'u] being actually /l'ub+i+u/ derived from the root /l'ub/, [bl'] corresponds to an underlying labial-vowel sequence. Thus, a surface cluster that seems to be a realization of a complex segment may well match a genuine cluster in the underlying representation in Russian.

(16)



5. A phonetic case for the Complex Segment Hypothesis

5.1. Compression

Some important phonetic phenomena also point to the validity of the CSH. One of these is compression. Roughly speaking, compression is a shortening in the duration of segments occurring in a given phonetic domain.

Assuming that part of phonological operations should be controlled at the phonetic level, CSH may be tested phonetically. It would in this case predict that compression of consonant clusters would be observed in the onsets, a statement subject to experimental verification.

Hirst & Bouzon (2005), an experimental study of compression as a function of the number of segments in prosodic units, revealed an effect of compression on the levels of the Narrow Rhythmic Unit (NRU), a prosodic unit proposed in Jassem (1952), of the F(oot) and of the Intonational Unit (IU). They found that compression of consonants is successively increasing in the prosodic units from the IU to the F and then to the NRU. Remarkably, no compression was found on the syllable level. These results complement those of J. Allen *et al.* (1987).

In this section, I will present a study of compression *inside* the syllable domain, namely compression in the onset. As a first approximation, our experimental hypothesis is that the more segments occur in an onset, the shorter the duration of each segment in this position.

5.2. Materials

The experiment was carried out on the speech database Aix-MARSEC (Auran *et al.* 2004). The Aix-MARSEC database originally comes from a collection of BBC recordings in British English dating back to the 1980s. It contains approximately five hours and thirty minutes of speech produced by 53 speakers, 17 men and 36 women, in eleven speech styles, from news to poetical recitation. An important feature of the Aix-MARSEC database is that all speech samples are audience-oriented, i.e. produced with the intention of communicating with an audience (by contrast with the laboratory speech corpora, in which speech is not produced with a communicative intention).

Besides recordings, the database contains a broad phonetic transcription in SAMPA aligned with the signal and prosodic category labels, and other material.

5.3. Methods

The Aix-MARSEC database contains 37 speech characteristics organized in columns. The speech characteristics we are interested in are onsets, *phonetically identified* segments, the number of segments in an onset, and the z-scores of these segments.

The z-scores are the normalized durations of segments calculated using the formula:

(15) $$z\text{-}scores(i,p) = \frac{d(p_i) - M(d(p_k)}{SD(d(p_i))}$$

where i is the instance of the segment p, d is the duration of a segment p, M is the mean of durations of the segment p for all of its instances $i, k=1,2,...,n$, n is the number of instances of p, and SD is standard deviation.

5.4. Results

Three sample groups with onsets were considered: one-, two- and three-member onsets. The number of members is designated by *npc* (npc = 1, 2, 3 respectively). The *npc* factor ('npc' refers to 'number (of members) per constituent') has three levels: 1, 2 and 3 that correspond to the number of phonemes in a syllable constituent. Mean z-scores (mean *zp*) were calculated for these three samples as shown in table 4.

npc	1	2	3
mean zp	-0.136297	-0.2742007	-0.193786

Table 4.The mean z-scores ('zp') of consonants in onsets as a function of the number of consonants ('npc') in the onsets

The results given in table 4 show that the mean normalized durations are different and vary with the 'npc' factor, which suggests the following compression hypothesis:

(16) *The 'npc' factor has a significant effect on the mean values of the variable 'zp' in British English speech.*

Note that this statement makes a general prediction for (British) English

An ANOVA was carried out with the statistical software R (Windows NT). The results were very significant: $F(2, 70463) = 100.85$, $p < 2.2\ e\ (-16)$.

5.5. Discussion

In the above experiment, $F = 100.85$ and p is extremely low. This result suggests with a very high probability that the null hypothesis that the means are equal must be rejected. The *npc* factor has an extremely significant effect on the means of the *zp* variable. In other words, this test lends compelling support to the hypothesis that at least one of these three means is different from the others. The duration of consonants in the onset position is shorter for onsets with two or three consonants than for onsets with one consonant.

The relevant phonological interpretation might well be that, in CVCV, the same space is allotted to clusters as to single segments, i.e. segmental sequences of consonants attach to only one C position. If present experimental results prove robust in further experiments, then these findings may be viewed as a phonetic corroboration of the complex segment hypothesis. However, further phonological formalization is needed in order to incorporate the phonetic observations above.

6. Conclusion

The morphological, phonological and phonetic investigation of the plausibility of the Complex Segment Hypothesis leads us to interesting conclusions relative to both phonology and phonetics.

Firstly, it was observed that the *labial+l'* sequences serve as a group to the left of which no consonant may licitly occur. This empirical observation bears out the predictions of the Complex Segment Hypothesis. In other word, this hypothesis is theoretically desirable and matches well with CVCV requirements on representations. On a practical level, however, at least some CL sequences have been shown not to be complex segments.

Secondly, there is clear phonetic evidence for compression in the onset in British English speech (*contra* Allen et al. 1987). I have shown that there is a shortening depending on the number of consonants in the onset. As for phonological value of the phonetic account, compression effect may be taken as an indication that clusters are attached to single non-

branching C positions. Surface consonant sequences occurring in onsets might well then be interpreted as complex segments in the underlying representation. It follows from this interpretation (if it is correct) that *mutæ cum liquidā* are items of the phonemic inventory of English.

Finally, a word of caution is due. Phonetic results presented in this paper might prove non-robust. Non-robustness depends in this case on several factors. These factors are mainly phonetic variation in the database, e.g. inter-speaker variation; sensitivity to sound context; phonotactic restrictions on *sCC* sequences. Further experiments are currently in preparation to control these factors closely.

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