# Sonorant Voicing Transparency in Russian*

Karen E. Robblee and Martha W. Burton
The Pennsylvania State University

## 0. Introduction

Many languages have rules of voicing assimilation whereby adjacent sound segments share the same voicing feature. The targets, triggers and directionality of assimilation vary from language to language. Jakobson (1978) describes an unusual type of voicing assimilation in Russian occurring in clusters of three or more consonants that include an intermediate sonorant. The data are complex and have therefore been the topic of several phonological studies (cf. Halle and Vergnaud 1981; Berendsen 1983; Hayes 1984; Kiparsky 1985). Jakobson's description is based primarily on his own listener judgements, and is inconsistent with other accounts (Ševoroškin 1971, Shapiro 1993). In this paper we use acoustic analyses in an attempt to resolve discrepancies in the various descriptions of Russian phonological voice.

## 1. Descriptions of Russian voicing assimilation

Russian voicing assimilation is usually regressive, with the voicing of obstruent clusters conditioned by the final obstruent in the chain.[1] It generally occurs at a morpheme boundary, including the prepositional boundary. Thus, the final obstruents of prepositions are voiceless when attached to lexemes with initial voiceless consonants, and voiced when attached to lexemes with initial voiced consonants.

| | | | | | |
|---|---|---|---|---|---|
| (1a) | ot soli | 'from salt' | /ts/ | → | [ts] |
| (1b) | pod sol'ju | 'under salt' | /ds/ | → | [ts] |
| (2a) | s taktom | 'with tact' | /st/ | → | [st] |
| (2b) | bez takta | 'without tact' | /zt/ | → | [st] |
| (3a) | ot zolota | 'from gold' | /tz/ | → | [dz] |
| (3b) | pod zolotom | 'under gold' | /dz/ | → | [dz] |
| (4a) | s dannymi | 'with facts' | /sd/ | → | [zd] |
| (4b) | bez dannyx | 'without facts' | /zd/ | → | [zd] |

In examples (1) and (2) the cluster-initial obstruents precede voiceless obstruents and are voiceless, while in (3) and (4) the cluster-initial obstruents precede voiced obstruents and are voiced.

Sonorants generally do not participate in voicing assimilation. For instance, /r'/ does not trigger voicing of the preceding /s/ in (5); nor does /l'/ undergo voicing assimilation to the following /t/ in (6).[2]

| | | | | | |
|---|---|---|---|---|---|
| (5) | s riskom | 'with risk' | /sr'/ | → | [sr'] |
| (6) | pal'to | 'coat' | /l't/ | → | [l't] |

Voicing assimilation may thus be characterized by an α-rule, like the one shown in (7).

(7) *Russian voicing rule*:

$$[-\text{ sonorant}] \longrightarrow [\alpha \text{ voice}] \;/\; \underline{\qquad\quad} \begin{bmatrix} \alpha \text{ voice} \\ -\text{ sonorant} \end{bmatrix}$$

In a cluster of more than two obstruents this rule applies iteratively beginning from the right of the chain, thereby accounting for voiced [d] instead of [t] in (8), and voiceless [t] for /d/ in (9).

| | | | | | |
|---|---|---|---|---|---|
| (8) | ot sbornika | 'from [a/the] collection' | /tsb/ | → | [dzb] |
| (9) | pod stolom | 'under [a/the] table' | /dst/ | → | [tst] |

The voiced labials /v, v'/ have special status with respect to rules of voicing assimilation. They behave as sonorants when occuring before a vowel, but as obstruents in other positions. The voiced labial fricative fails to trigger voicing assimilation in (10) but undergoes voicing assimilation in (11), as well as (12) (Jakobson 1971; Andersen 1969b; Reformatskij 1975; Hayes 1984; Shapiro 1966, 1993). Note that in (12) the cluster-initial /z/ is also voiceless.[3]

| | | | | | |
|---|---|---|---|---|---|
| (10) | tvoj | 'your' | /tv/ | → | [tv] |
| (11) | vtoroj | 'second' | /vt/ | → | [ft] |
| (12) | bez vpuska | 'without admittance' | /zvp/ | → | [sfp] |

Jakobson (1956) asserts that in examples like (12) the labials /v, v'/ play no role in the voicing of the initial obstruent; rather, the voicing of the initial obstruent is determined by the cluster-final consonant. For instance, in (12) the voicing properties of /z/ are affected by the cluster-final /p/, and not by /v/. He later extends his analysis to include nonsyllabic sonorants, stating that an initial obstruent in an OBSTRUENT + SONORANT + OBSTRUENT cluster assimilates to the final obstruent as if there were no intervening sonorant (Jakobson 1978). The sequence /zmc/ in (13) may be realized with a syllabic [m̩] and no assimilation, or it may be realized with the /z/ assimilating to the /c/ found after the nasal /m/.

(13) iz Mcenska /zmc/ → [zm̩c] ~ [smc]
'from Mcensk'

(14) s rdejuščim /srd'/ → [sr̩d'] ~ [zrd']
'with glowing'

The sequence /srd'/ in (14) may similarly be produced with a syllabic [r̩] or with /s/ assimilating to the /d'/ found after the liquid /r/. Jakobson does not discuss the phonetic properties of the nonsyllabic sonorant in these clusters.

Ševoroškin's (1971) account of Russian voicing assimilation conflicts with the Jakobsonian description in two respects. He argues that when assimilation occurs, the nonsyllabic sonorant is an active participant in voicing assimilation. Sequences of OBSTRUENT + SONORANT + OBSTRUENT may be implemented in one of two ways. Either the sonorant is syllabic and thus blocks assimilation, or it is nonsyllabic and produced as a fricative. As a nonsyllabic fricative it functions as a target and trigger of assimilation. These two phonetic variants are depicted in (15). In contrast to the Jakobsonian analysis, Ševoroškin thus views voicing assimilation of /z/ in (12) and (13) as the result of an iterative process.

(15) iz Mcenska /zmc/ → [zm̩c] ~ [sm̥c]

Ševoroškin cites (16)-(17) as further evidence that sonorants play an active role in assimilation. He claims that assimilation does not occur in (16) and (17) because the sonorants block it. Note that both examples have cluster-final voiced obstruents. His description suggests an asymmetry in assimilation depending on the voiced or voiceless nature of the cluster-final obstruent.[4]

(16) Prževal'skij [prž]
(17) Kržižanovskij [krž]

Although he provides several examples of voicing assimilation involving clusters with a cluster-final voiceless obstruent, for instance (13), he provides no examples like (14), in which assimilation is triggered by a cluster-final voiced obstruent. His examples with cluster-final voiced obstruents are like (16) and (17), in which assimilation fails to occur.[5]

The α-rule in (7) can account neither for Jakobson's description of examples such as (13), nor for Ševoroškin's description. For this reason, several rules have been proposed in other frameworks.

This study explores whether the sonorant in these clusters is transparent. If it is, we should be able to predict voicing characteristics of initial obstruents in OBSTRUENT + SONORANT + OBSTRUENT clusters without reference to the intervening sonorant. We also consider whether the voiced or voiceless nature of a cluster-final obstruent limits assimilation. Is it the case, as Ševoroškin suggests, that clusters ending in voiceless obstruents allow voicing assimilation across an intermediate sonorant, while those ending in voiced obstruents do not? Generally stated, we want to learn whether the final obstruent affects the voicing of the first obstruent regardless of the sonorant's phonetic properties, and whether the voiced or voiceless nature of a cluster-final obstruent affects the operation of voicing assimilation. We limit our targets to clusters with liquid sonorants. We consider voicing assimilation first in clusters with initial fricatives, and then in clusters with initial stops.

## 2. Phonetic analysis

Jakobson, Fant and Halle (1976) describe voicing, using two pairs of phonetic oppositions. The VOICED/VOICELESS opposition describes the glottal state. Consonants that are VOICED are produced with vocal cord vibration, while those that are VOICELESS are produced without vocal cord vibration. The TENSE/LAX opposition refers primarily to temporal properties of consonants, but in the case of stops also to the amplitude of the burst. Consonants described as TENSE have longer durations than those described as LAX. In addition, stops that are TENSE have louder bursts than their LAX counterparts. The features VOICED and LAX generally occur concomitantly, and similarly the features VOICELESS and TENSE. In a language like English, which has aspiration, timing is more important, and Jakobson, Fant and Halle state that the TENSE/LAX opposition is distinctive. On the other hand, it is the VOICED/VOICELESS opposition that is distinctive for Slavic languages. This claim is supported, for instance, by Keating's (1980) finding that the invariant cue for voiced stops in Polish is pre-voicing, which appears as periodicity of the wave form during closure, rather than a duration measure. However, other studies, for example, Andersen's (1969a) work on Slavic lenition and Bethin's (1985) on Ukrainian voicing assimilation, suggest that there may be Slavic dialects for which the TENSE/LAX opposition is distinctive. Regardless of which opposition is distinctive in a language, there is usually more than one phonetic cue to phonological voicing (Lisker 1978). The phoneme /d/, in contrast to /t/, is usually produced with some vocal cord vibration during closure, resulting in greater low frequency amplitude than is found in /t/, and is typically of shorter duration with a quieter burst than /t/. We therefore examined two types of properties in order to determine whether the final obstruent in an OBSTRUENT + LIQUID + OBSTRUENT cluster has a direct effect on the voicing of the initial obstruent. Since rules of voicing assimilation do not apply to obstruents preceding a sequence of LIQUID + VOWEL, we first examined the phonetic properties of stops before LIQUID + VOWEL in order to have a basis for comparing the phonetic properties of stops before LIQUID + OBSTRUENT.

### *2.1. Fricatives*

In order to determine how Russian voiced and voiceless fricatives are distinct from each other in the environment before LIQUID + VOWEL and in the environment before LIQUID + OBSTRUENT, we put each of the words listed in (18) and (19) into two sentences, one in which the word was preceded by either the preposition *s* 'with' or the homophonic *s* 'from', and another in which it was preceded by either the preposition *iz* or *bez*. The prepositional phrases in these pairs of sentences constituted minimal pairs. Note that each of the words in (18) begins with liquid plus stressed vowel, while each of those in (19) begins with liquid plus obstruent plus stressed vowel. Also note that the stressed vowels are the same in both sets of words.

| | | | | |
|---|---|---|---|---|
| (18) | rublenyj | 'minced' | lišnij | 'extra' |
| | risk | 'risk' | ličnyj | 'personal' |
| | rezkij | 'sharp' | | |
| (19) | rtut' | 'mercury' | l'stivyj | 'flattering' |
| | rtišče | 'mouth [aug.]' | l'dina | 'ice-floe' |
| | rdejuščij | 'glowing' | | |

All our targets were preceded by reduced vowel and followed by stressed vowel; however, in tokens with nonsyllabic prepositions consisting of /s/, there was also a boundary before the fricative. For example, in (20a) and (20b) the vowel preceding /s/ is the final syllable of the preceding word. Since Russian has no syllabic preposition ending in /s/ we had no control over this factor.

(20a) Stjuardessa vse ob"jasnila ***s l***išnim predupreždeniem dlja passažirov s malen'kimi det'mi.
'The flight attendant explained everything with an extra warning for passengers with small children.'

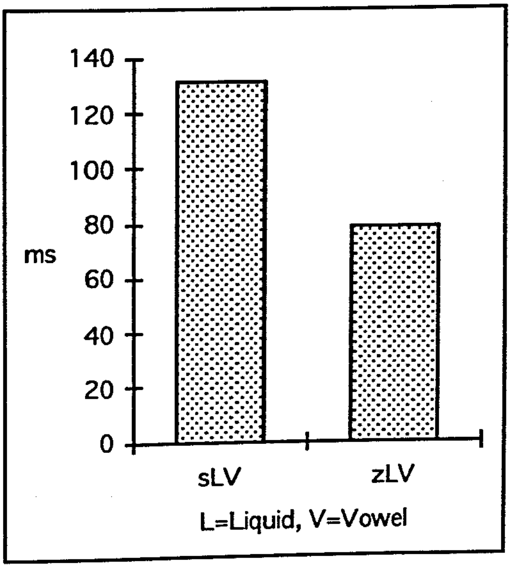
(20b) Pereprygaja ***s l'd***iny na l'dinu, Nikolaj dobralsja do berega.
'Jumping from ice-floe to ice-floe, Nikolaj reached the shore.'

All sentences were checked for grammaticality and naturalness by a native speaker. Four native speakers were recorded reading the group of sentences three times, each time with a different randomization.[6] As a result there were three repetitions of each minimal pair based on the lexemes in (18) and (19). We examined closure duration and the amplitude of low frequency energy for each token.[7]

The overall shape of the spectrum reflects the properties of the glottal source and the filter function of the supralaryngeal vocal tract. Vowels are characterized by several peaks throughout the spectrum. In contrast, fricatives are produced with aperiodic energy peaks at frequencies in the range of approximately 2.5 kHz to 5 kHz, depending on place of articulation (Ladefoged 1975; Lieberman and Blumstein 1988). We marked the beginning of the fricative at the point where there was an indication of such frication noise as determined by a discrete Fourier transform (DFT). The end of the fricative was set visually where there was a change in the pattern of the waveform.

*2.1.1 Fricatives before* LIQUID + VOWEL. Voiced fricatives are typically of shorter duration than their voiceless counterparts. According to Barry (1988), in Russian intervocalic /z/ is 42% shorter than intervocalic /s/. Similarly, we found a significant difference between the duration of voiced and voiceless fricatives followed by LIQUID + VOWEL (*Figure 1*). The mean duration of /z/ before LIQUID + VOWEL was 51.8ms shorter than that for /s/ ($p<.005$).[8]

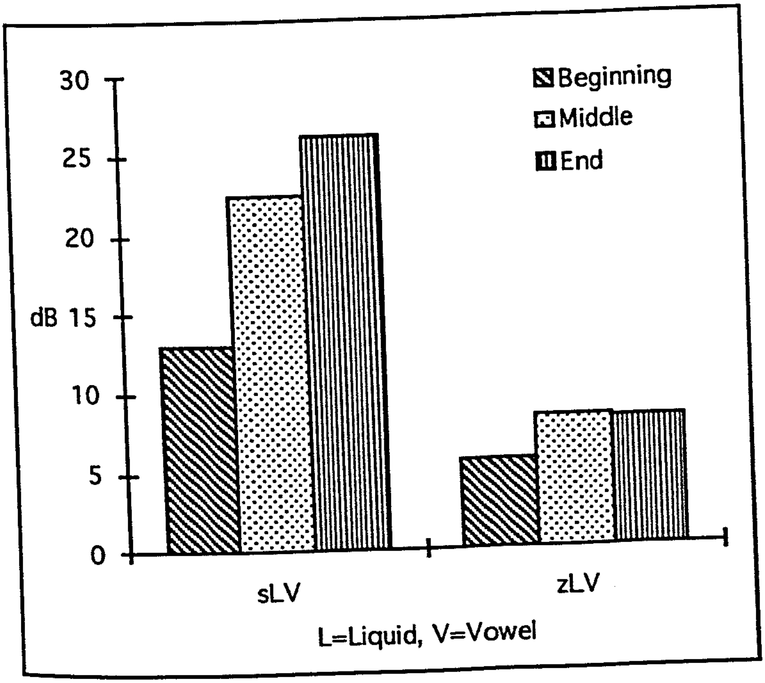
**Figure 1: Mean Closure Durations of Fricatives before LIQUID + VOWEL**




Vocal cord vibration produces low frequency energy. In order to determine whether /z/ was produced with significantly greater vocal cord vibration than /s/ we examined the amplitude of low frequency energy during closure. Voicing of a particular sound segment may be partial in that vocal cord vibration may not occur throughout the entire interval.[9] For this reason, we examined low frequency energy at three different points: the beginning of the fricative, the middle of the fricative, and the end of the fricative. Since it is possible that the overall amplitude of tokens in our sample varied, we did not examine the absolute amplitude of low frequency energy. Rather, we examined the amplitude of low frequency energy in the fricative relative to that in the following stressed vowel. We used a 25.6ms Hamming window to determine the difference between the amplitude of the vowel and fricative.

*Figure 2* shows the mean relative amplitude at each of the three different intervals. At the beginning of the fricative the relative amplitude is 7.5dB smaller for /z/ than for /s/; in the middle it is 14.1dB smaller, and at the end it is 18.1dB. At all three locations, the relative amplitude of /z/ is significantly smaller than that of /s/ (at the beginning of the fricative $p<.05$, in the middle $p=.001$, and at the end $p<.005$).

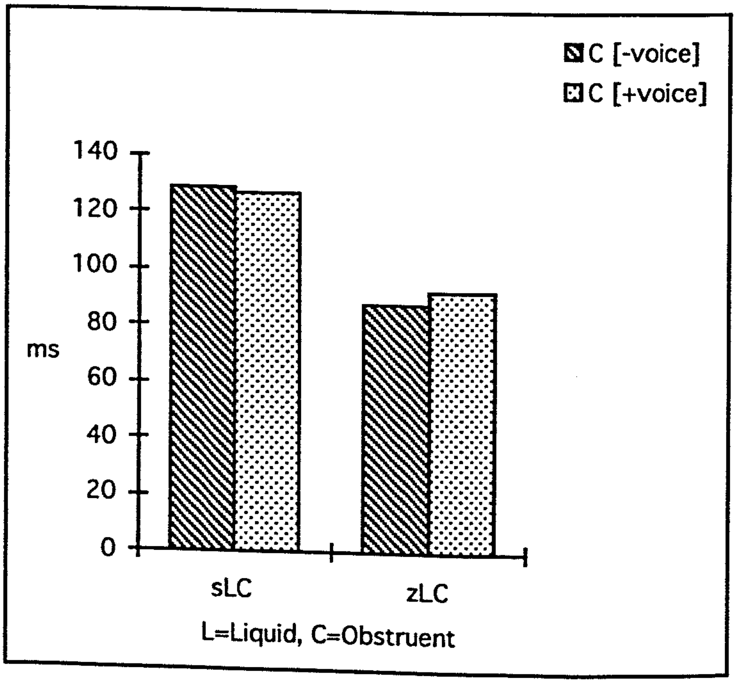
**Figure 2: Difference between the Amplitude of the Vowel and Fricative (before LIQUID + VOWEL)**




Our analyses show that duration and relative amplitude are indicators of voicing in fricatives before LIQUID + VOWEL. Now let us turn to the fricatives before LIQUID + OBSTRUENT.

*2.1.2 Fricatives before LIQUID + OBSTRUENT* If an initial fricative assimilates to a cluster-final obstruent, the duration of the initial fricative should depend on the voicing of the final obstruent. Our results indicate, however, that the voicing of the cluster-final obstruent has no effect on the initial fricative ($p>.1$). This is shown in *Figure 3*. *Figure 3* also shows that the duration of the initial fricatives in these clusters is consistent with underlying voicing ($p$<.0005).

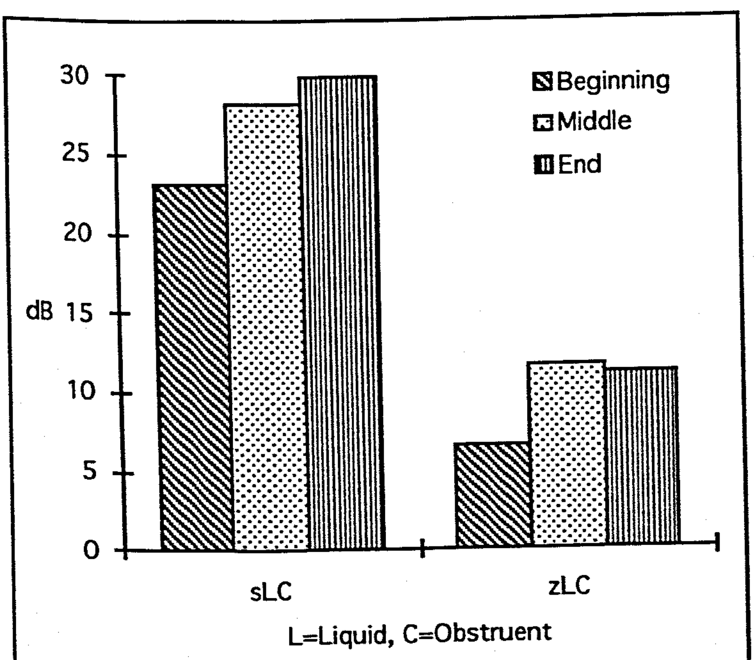
**Figure 3: Mean Closure Durations of Fricatives before LIQUID + OBSTRUENT**




Relative amplitude is affected by vowel height. Since our clusters ending in voiced obstruents have different vowels than those ending in voiceless obstruents, we are unable to compare these different environments to each other.[10] We can nevertheless examine the effect that underlying voice has on our minimal pairs.

If assimilation occurs, underlying /s/ and /z/ in the minimal pairs should have similar spectral properties. But *Figure 4* shows that they are significantly different. In the environment before a LIQUID + OBSTRUENT the relative amplitude of /z/ is smaller than that of /s/ at the beginning of the fricative ($p<.001$), in the middle ($p=.005$), and at the end ($p<.005$). The spectral properties of these fricatives are consistent with underlying voice, and not with descriptions of assimilation.

**Figure 4: Difference between the Amplitude of the Vowel and Fricative (before LIQUID + OBSTRUENT)**



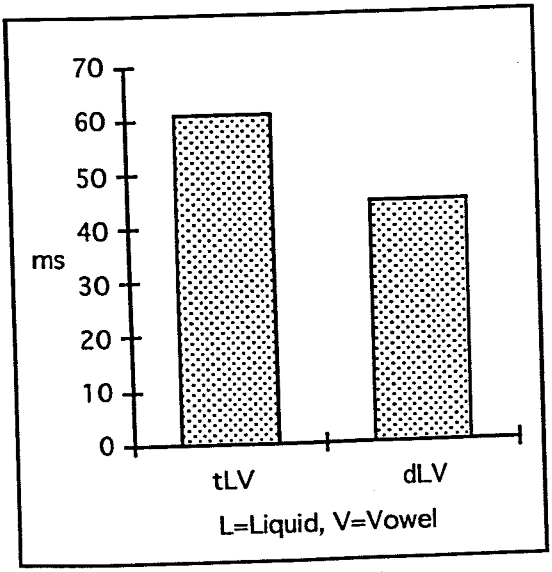
## 2.2. *Stops*

Our study of stops was conducted in much the same way as our study of fricatives. We examined the voicing properties of sequences of STOP + LIQUID + VOWEL and of STOP + LIQUID + OBSTRUENT. We used the same lexical items as above, but this time they were embedded in sentences with different prepositions. In one sentence they were preceded by the preposition *ot* 'from', and in the other by either the preposition *pod* 'under' or *nad* 'over'.[11]

Recall that vowels are characterized by several peaks throughout the spectrum. The closure interval of voiced stops typically has one large spectral peak in the low frequency range, and the closure interval of voiceless stops has no large spectral peak (Lieberman and Blumstein 1988). The beginning of closure was therefore marked at the point where a change in the DFT indicated that energy peaks were no longer present throughout the spectrum. The end of closure was set visually based on the appearance of rapid random fluctuations in the waveform indicating release.

*2.2.1 Stops before* LIQUID + VOWEL Barry (1988:89) reports that the closure duration of intervocalic /d/ in Russian is 18% shorter than that of /t/. In our sample the mean closure duration of /d/ was 16.1ms shorter than the mean closure duration of /t/ when followed by LIQUID + VOWEL (*Figure 5*). This difference was marginally signficant ($p<.1$).

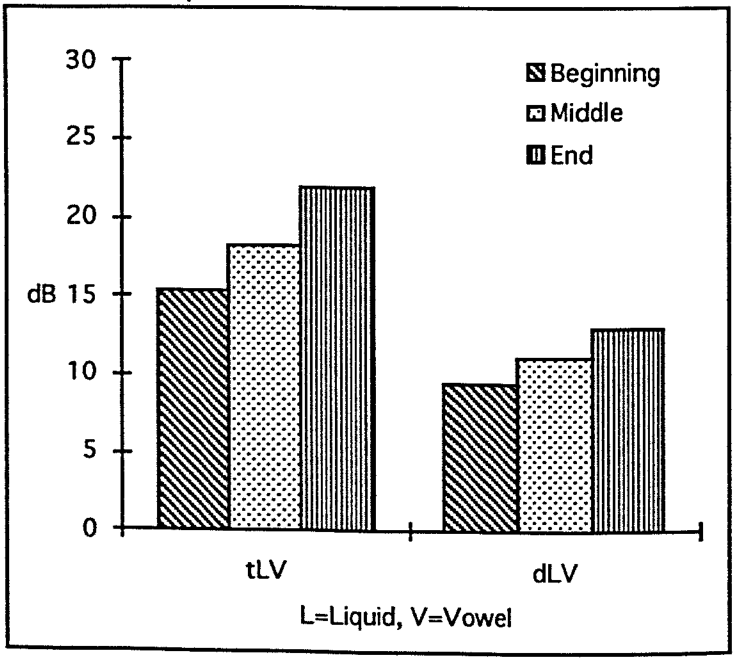
**Figure 5: Mean Closure Durations of Stops before LIQUID + VOWEL**




The mean closure durations of stops are much shorter than the durations of fricatives. We therefore used a smaller 15ms full Hamming window to compare the amplitude of the first spectral peak of the closure interval to the amplitude of the first harmonic in an interval of the same size in the vowel. Since voiced consonants, like vowels, are produced with vocal cord vibration, we expected the relative amplitude of /d/ to be smaller than that of /t/.

*Figure 6* depicts the relative amplitude of the three intervals that we examined. At all three intervals the mean relative amplitude of /d/ before LIQUID + VOWEL was significantly less than that of /t/ (at the beginning of closure $p<.05$, at the middle $p<.005$, and end of closure $p<.005$). We conclude from these differences that the closure of /d/ followed by LIQUID + VOWEL has greater vocal cord vibration than the closure of /t/ at all three intervals.

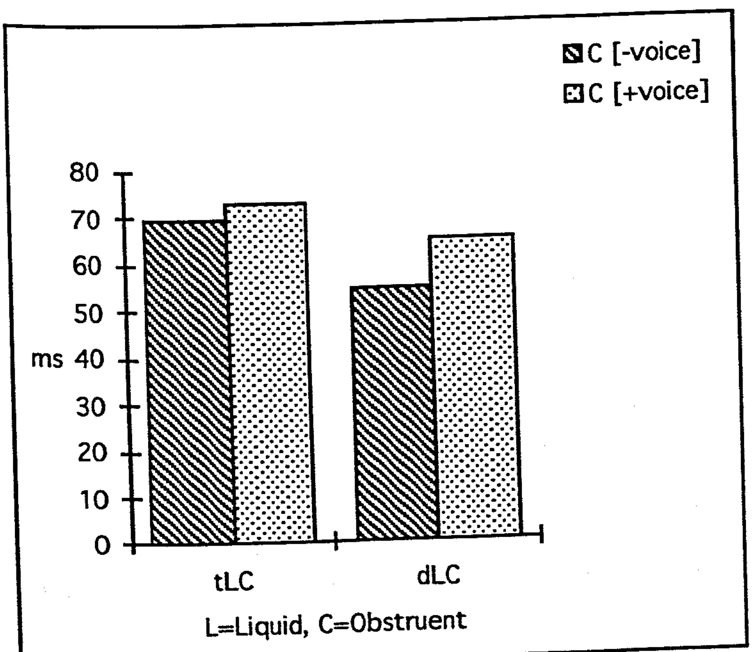
**Figure 6: Difference between the Amplitude of the Vowel and Stop (before LIQUID + VOWEL)**




It appears then that at least one and possibly two properties distinguish Russian voiced stops followed by LIQUID + VOWEL from voiceless stops in the same environment. One is the the relative amplitude of low frequency energy, and the other is closure duration. Let us now consider whether an analysis of these voicing properties shows an effect of the final obstruent on the voicing of the initial obstruent in clusters of STOP + LIQUID + OBSTRUENT.

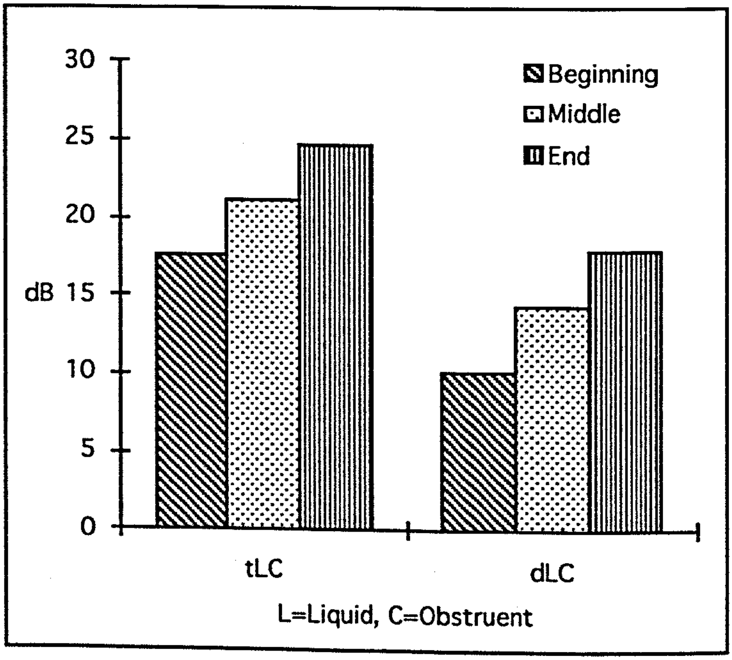
*2.2.1 Stops before LIQUID + OBSTRUENT* *Figure 7* depicts the mean closure durations of stops before LIQUID + OBSTRUENT. If the initial stop assimilates to the final obstruent, durations would be shorter in clusters ending in voiced obstruents and longer in those ending in voiceless consonants. Note, however, that the stop durations are shorter before clusters ending in *voiceless* obstruents. Although stop durations in this sample correlate with environment ($p<.5$) rather than underlying voicing ($p>.1$), they do not provide evidence of assimilation.

**Figure 7: Mean Closure Durations of Stops before LIQUID + OBSTRUENT**




Let us now consider the difference between the amplitude of the vowel and stop. Recall that voiced stops have relatively greater low frequency energy than voiceless stops. In *Figure 8* a bigger difference between the amplitude of the stop and vowel represents less low frequency energy. If there is assimilation, low frequency energy in the initial obstruent of our minimal pairs should be the same.

**Figure 8: Difference between the Amplitude of the Vowel and Stop (before LIQUID + OBSTRUENT)**




An analysis of relative amplitude, however, reveals significant differences in the relative amplitude of underlying /d/ vs. /t/ at all three points (in the beginning $p<.05$, the middle $p<.05$, and the end $p<.05$).

## 3. Discussion

Current phonological theory uses two different approaches to describe Russian voicing assimilation. Metrical accounts have been proposed by Halle and Vergnaud (1981), Berendsen (1983), and Hayes (1984) which posit a single voicing feature that spreads to other segments within the rule's projection. They are all based on Jakobson's description. In Halle and Vergnaud, as well as Berendsen, sonorants are viewed as transparent, failing to function as either targets or triggers of voicing assimilation; while in Hayes' analysis, sonorants are viewed as targets that later undergo a sonorant revoicing rule. These nonlinear analyses all treat the phonetic properties of the sonorant as irrelevant to the voicing characteristics of the cluster-inital obstruent. In contrast, Kiparsky's (1985) description treats Russian voicing assimilation as an iterative process, arguing that sonorants are unspecified for voicing at the derivational level, but potential triggers of voicing assimilation at the inflectional level. Their ability to function as triggers is determined by their phonetic properties.

The results of this study provide no evidence that the voicing of the final obstruent in sequences of OBSTRUENT + LIQUID + OBSTRUENT has a direct effect on the voicing of the initial obstruent, revealing no asymmetry between clusters ending in voiced vs. voiceless obstruents.[12] This suggests either that assimilation does not occur, or that it is variable and affected by something other than the final consonant, probably the intervening sonorant. If there is no assimilation in these clusters, then Russian provides no important evidence in support of the various phonological theories. However, if assimilation is variable and affected by the phonetic properties of the sonorant, it is better described by a theory such as Lexical Phonology, which treats the sonorant as a potential trigger of assimilation.

Our results indicate a difference between cluster-inital stops and fricatives. In sequences of LIQUID + OBSTRUENT the durations of fricatives correspond to underlying voice, while the durations of stops do not. Burton and Robblee (in press) observes a similar effect on stop durations in intervocalic clusters of FRICATIVE + STOP and those of STOP + FRICATIVE; and Barry (1988) reports that closure duration is not distinctive in word-final position. It may be that closure duration of stops is significant only for those occurring between two segments that are [+sonorant].

It appears that stops undergo partial neutralization—without assimilation—which fricatives do not. This may be due to their different manners of articulation, as well as the different syllabic structures of our targets. In Russian, manner of articulation and syllabic structure both play a role in assimilation of palatalization. Stops are less likely than fricatives to become palatalized. For example, the initial stop in (21) is produced without palatalization, while the initial fricative in (22) may be palatalized.

| | | | | | |
|---|---|---|---|---|---|
| (21) | ot piva | 'from beer' | /t p'/ | → | [t p'] |
| (22) | bez piva | 'without beer' | /zp'/ | → | [sp' ] ~ [s'p'] |
| (23) | s pivom | 'with beer' | /sp'/ | → | [s'p'] |

In addition, a fricative that is the final sound of a syllabic preposition is less likely to assimilate to a following palatalized consonant than a fricative that constitutes a nonsyllabic preposition. Avanesov (1972:112) reports that assimilation of palatalization is optional in (22), but that it is the norm in (23). Note, however, that neither the syllabic prepositions *iz* and *bez* nor the nonsyllabic *s* show an effect of the cluster-final obstruent with regard to voicing, e.g., the /z/ in the expression *bez rtišča* is not significantly longer than the /z/ in the expression *bez rdejuščix šček*, and the /s/ in the expression *s rtiščem* is not significantly longer than the /s/ in the expression *s rdejuščimi ščekami.*

We believe that the manner of articulation of the sonorant and of the final obstruent plays some role in the phonetic implementation of sequences of OBSTRUENT + LIQUID + OBSTRUENT. In a pilot study to this work we observed that clusters with intermediate nasal sonorants seemed to be quite unstable. Speakers tended to insert an epenthetic vowel into the clusters or to simplify them. In expressions such as example (24), where the initial obstruent is a fricative, speakers frequently simplified the cluster by deleting the initial obstruent altogether. In expressions like example (25), which has a cluster-initial stop, they would delete the stop or fail to release it.

| | | |
|---|---|---|
| (24) | iz mstitelja | 'from [an] avenger' |
| (25) | ot mšistyx | 'from mossy' |

Speakers similarly tended to simplify those clusters in which the final obstruent was a palatal fricative, for example, the clusters in (26) and (27).

| | | |
|---|---|---|
| (26) | iz lživyx | 'from false' |
| (27) | s ržavčinoj | 'with rust' |

In these cases it was the sonorant that was often deleted or assimilated to the following obstruent. However, we have not quantified these tendencies, so the question of what effect the manner of articulation of the sonorant and of the final obstruent has on the initial obstruent requires further study.

## 4. Conclusions

Voicing assimilation of contiguous segments is a common cross-linguistic phonemenon. However, the type of voicing assimilation described for Russian is quite rare, if not nonexistent in other languages. There is evidence of consonantal disharmony involving the voicing of noncontiguous segments in a few languages (McCarthy 1988), but we are unfamiliar with any such processes of assimilation. Jakobson and Ševoroškin nevertheless agree that the initial obstruent in (13) may be devoiced. This suggests that it may be useful to examine Russian voicing assimilation as a perceptual process. Since we observed a great deal of variation in the wave forms of CLC clusters, and since Jakobson and Ševoroškin agree that in at least some instances initial obstruents in CLC clusters assimilate the voicing of final obstruents, we cannot rule out the possibility of at least variable assimilation. It may be that in these types of clusters even a nonsyllabic sonorant can be realized in a variety of ways with varying degrees of frication noise, and that the voicing properties of the cluster-initial obstruent depend on the phonetic implementation of that sonorant. This suggests that the nonsyllabic sonorant is not transparent, but is an active participant in voicing assimilation.

**Notes**

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1 Barry (1989:53) reports that word-final sonorants following voiceless obstruents are more likely to be voiceless than those following voiced obstruents. For instance, speakers are more likely to devoice word-final liquids in words like *smotr*

'review' than in words like *kedr* 'cedar'. In such instances, voicing assimilation is progressive since the voicing of the segment on the left affects voicing of the segment on the right.

2 There is, however, evidence of at least limited participation of sonorants in voicing assimilation. Coats and Harshenin (1971:471) reports that sonorants may assimilate to word-final obstruents that have been devoiced (for example, the word *stolb* 'post' may be produced with a voiceless /l/ assimilating to the following [p] < /b/); and Barry (1989) provides other evidence that sonorants are targets of progressive voicing assimilation (see note 1).

3 Reformatskij (1975) describes another peculiarity of the phonemes /v, v'/ with respect to voicing assimilation. He claims that they are targets of word final devoicing, but fail to trigger voicing assimilation of a preceding obstruent. (For instance, *trezv* 'sober' is produced as [tr'ezf] with the word-final /v/ produced as [f], but the preceding /z/ as [z].) While Jakobson (1978) supports Reformatskij's claim, it is contradicted by Coats and Harshenin (1971), who report that *trezv* is produced with word-final [sf]. Barry (1989) reports acoustic evidence that supports the description of Coats and Harshenin, rather than that of Reformatskij. (See also Zaliznjak (1975) which suggests possible variation.)

4 This was pointed out to us by Alan Timberlake.

5 See Shapiro (1993) for a review of additional evidence conflicting with Jakobson's description.

6 Speaker #1 was a 41 year old female, from the Moscow region, who had been in the United States part-time for two and a half years, and spoke little English. Speaker #2 was an 18 year old male from Moscow, who had been in the United States part-time for almost 2 years, and who spoke English with some fluency. Speaker #3 was a 49 year old female born and raised in Latvia speaking Russian; she moved to Volgograd when she was 23 years old, and had been in the US for 10 months, speaking virtually no English. Speaker #4 was a 20 year old male from Moscow, who had been in the United States part-time for almost 2 years; he was an undergraduate at Penn State and spoke English fluently.

7 One of the CLV tokens and six of the CLC tokens were eliminated from the analysis. In one CLC token, the liquid was syllabic. In other instances the speaker misspoke or simplified the cluster through some kind of deletion.

8 Statistical significance for obstruents followed by a sequence of LIQUID + VOWEL was determined by a two-way analysis of variance of speaker means with underlying phoneme (voiced vs. voiceless nature of the initial obstruent) and sonorant (/l, l'/ vs. /r, r'/) as factors. For obstruents followed by a sequence of LIQUID + OBSTRUENT statistical significance of durations was determined by a three-way analysis of variance with underlying phoneme, sonorant and environment (voiced vs. voiceless

nature of the cluster-final obstruent) as factors; the statistical significance of spectral analyses was determined by a two-way analysis of variance with underlying phoneme and sonorant as factors.

9 Wells (1987) describes instances of partial voicing assimilation in Russian, and Stevens et al. (1992) reports that in fricatives, speakers of English may implement phonological voicing distinctions of intervocalic fricatives only at certain locations. (Voicing may occur throughout the consonant, or only near the transitions between fricatives and vowels.)

10 Lexical limitations make it impossible to control the following stressed vowel.

11 Seven of the CLV tokens and 3 of the CLC tokens were eliminated from the analysis of stops. In seven instances the speaker deleted the stop, in one instance the speaker paused between the inital obstruent and sonorant, and in one instances we were unable to find the relevant landmarks.

12 Note, however, that seven of the nine defective CLC clusters had a cluster-final obstruent that was voiceless. This may support a weaker version of Ševoroškin's claim that clusters ending in voiceless obstruents pattern differently than those ending in voiced obstruents.

## APPENDIX

Values for Figure 1:

| | sLV | zLV |
|---|---|---|
| | 130.9ms | 79.1ms |

Values for Figure 2:

| | sLV | zLV |
|---|---|---|
| Beginning | 13.1dB | 5.6dB |
| Middle | 22.4dB | 8.3dB |
| End | 26.2dB | 8.1dB |

Values for Figure 3:

| | sLC | zLC |
|---|---|---|
| C [-voice] | 128.6ms | 88.1ms |
| C [+voice] | 126.9ms | 92.4ms |

Values for Figure 4:

| | sLC | zLC |
|---|---|---|
| Beginning | 23.2dB | 6.6dB |
| Middle | 28.2dB | 11.6dB |
| End | 29.8dB | 11.2dB |

Values for Figure 5:

| tLV | dLV |
|---|---|
| 60.8ms | 44.7ms |

Values for Figure 6:

| | tLV | dLV |
|---|---|---|
| Beginning | 15.4dB | 9.5dB |
| Middle | 18.3dB | 11.1dB |
| End | 21.9dB | 13.1dB |

Values for Figure 7:

| | tLC | dLC |
|---|---|---|
| C [-voice] | 69.5ms | 54.4ms |
| C [+voice] | 72.9ms | 64.7ms |

Values for Figure 8:

| | tLC | dLC |
|---|---|---|
| Beginning | 17.5dB | 10.2dB |
| Middle | 21.1dB | 14.3dB |
| End | 24.6dB | 17.9dB |

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Slavic Languages and Literatures
211 Sparks Building
The Pennsylvania State University
University Park, PA 16802
ker4@psu.edu