Sonority profile and temporal organization of clusters: evidence from Russian

Stefania Marin[1], Marianne Pouplier[2], Alexei Kochetov[3]
[1, 2] Institute of Phonetics and Speech Processing, LMU Munich; [3]Department of Linguistics, University of Toronto
marin|pouplier@phonetik.uni-muenchen.de

It is well-known that consonant clusters obeying the sonority sequencing principle are universally preferred over clusters violating it; what is less clear is the status of sonority violating clusters in languages that have them. These clusters could betray their typological "markedness" by differing from sonority-obeying clusters in the same language. However, it may actually be the case that once they are part of a language's grammar, sonority-violating clusters are indistinguishable from sonority-obeying ones. In the current research, we address this issue by comparing onset clusters with different sonority profiles in Russian – sonority-raising /bl-/, /gl-/, sonority falling /lb-/, /lg-/, and sonority-flat /kt-/, /tk-/. Because the articulatory timing of onsets has been previously shown to be sensitive to various factors affecting syllable and cluster composition (as we describe below), we compare the different sonority profile clusters in terms of their temporal organization.

Research on several languages and cluster types has shown that as onset complexity increases, the timing lag between the vowel-adjacent consonant and a fixed anchor point decreases, indicative of an increased overlap with the vowel (cf. Marin & Pouplier, 2014 for a review). This effect is assumed to be the manifestation at the production level of a so-called c-center organization of onsets (Browman & Goldstein, 2000). Exceptions to a c-center organization have also been reported on stop-sibilant or stop-stop clusters, with patterns reflecting additional constraints (Pastätter & Pouplier, 2015). The timing between the consonants themselves in the cluster (henceforth intra-cluster timing) has also been shown to be affected by cluster composition (cf. Marin & Pouplier, 2014 for a review).

On the basis of articulatory (EMA) data from 6 Russian native speakers, we investigate the extent to which the sonority profile of an onset cluster affects the expected onset (c-center) organization, as well as its intra-cluster timing. We recorded four repetitions of clusters and matching singletons (e.g. set BL: *blag* – *lag*). The target words were preceded by a similar context in the singleton and cluster condition (see Table 1), and they were embedded in a carrier sentence. To assess the c-center organization of these sets, the timing lags between the vowel-adjacent consonant (e.g. /l/ in set BL) and the constant consonantal anchor (e.g. /g/ in set BL) were computed and compared across singleton and cluster words (the peak velocity of the constriction formation was used as temporal landmark for both adjacent consonant and anchor). Ratios between cluster lags and corresponding singleton lag means were also computed such that ratios smaller than 1 indicate shorter cluster lags. Shorter temporal lags in clusters compared to singletons indicate a shift of the cluster vowel-adjacent consonant towards the vowel, and hence more overlap with the vowel, as predicted for onset clusters. We predict that this pattern should be observed for sonority-raising Russian clusters (similar to other clusters in other languages so far examined), but possibly not for sonority-reversal clusters if they have a distinct status in the language. To determine intra-cluster timing, we computed the timing lag from the articulatory release of the first consonant in the cluster to the articulatory achievement of target of the second consonant, normalized by the entire constriction interval of the cluster (from articulatory achievement of target of the first consonant to articulatory release of the second consonant).

To assess whether cluster sonority profile may be confounded by language internal cluster frequency, cluster frequency was calculated on the basis of the Russian word internet corpus (Sharoff, 2006). The normalized frequency (instances per million) was summed across words where the cluster of interest appeared in word-initial position and then the natural logarithm was determined. This analysis shows that indeed sonority is partly confounded by frequency: sonority-raising clusters are highly frequent (/bl-/: 11.527, /gl-/: 12.711), sonority-falling are infrequent (/lb-/: 8.393, /lg-/: 7.063), while sonority-flat are mixed (/kt/: 12.135, /tk-/: 8.891). We therefore also use frequency as a factor in the analyses (high: /bl-/, /gl-/, /kt-/; low: /lb-/, /lg-/, /tk-/). For statistical analyses, linear mixed models were computed using the *lme4* package for R, with *p*-values being obtained by a $\chi2$ log-likelihood ratio test in which the full model was compared to a model without the factor(s) in question. All models included random intercepts for factors Speaker and Set/Cluster.

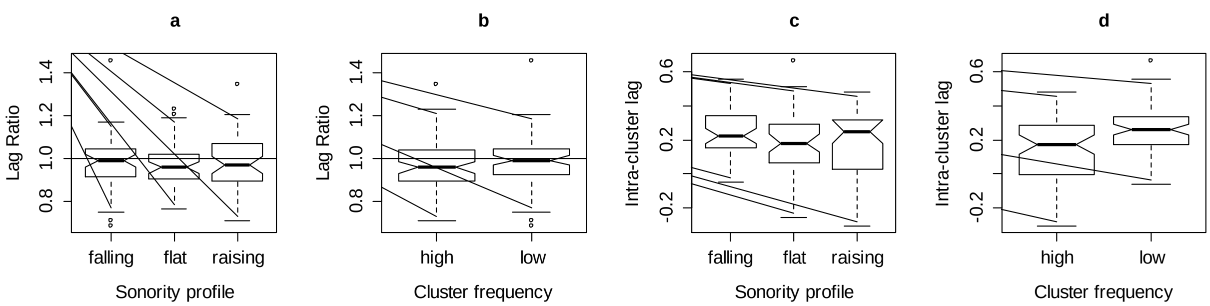
The results comparing cluster and singleton lags showed a main effect for factor Complexity ($\chi2(1) = 6.239$, $p = .012$), with cluster lags being significantly shorter than singleton lags, indicating an increasing overlap of the vowel-adjacent consonant with the vowel as a function of onset complexity increase (cf. Figure 1 showing ratio values under 1). The interaction between Complexity and Sonority was however not significant ($p = .22$). The interaction with Frequency was at a trend level ($\chi2(3) = 6.638$, $p = .08$). A further comparison of ratio values showed that the magnitude in change from singleton to cluster lag was not significantly different as a function of either sonority profile ($p = .73$) or frequency of the cluster ($p = .68$). The results on intra-cluster timing showed no effect of sonority ($p = .66$), but showed an effect of frequency ($\chi2(1) = 4.17$, $p = .04$), with high frequency clusters having shorter intra-cluster lags (for this analysis only cluster words were used).

Our results show that, at least on the measures used, the sonority profile of a cluster does not affect its temporal organization. Russian sonority-violating clusters exhibit the same timing patterns as sonority-obeying clusters and they all exhibit the timing predicted for complex onsets, and generally observed for onsets in other languages (a c-center organization). This indicates that grammar has a stabilizing function: once sonority-violating onset clusters are part of a language's grammar, they behave as such and they exhibit the temporal organization expected of clusters. If anything, language internal cluster frequency may be a factor influencing cluster timing.

Table 1. Stimulus list. Vowel-adjacent consonants are shown in bold face, anchors are underlined.

Sonority-raising			Sonority-falling			Sonority-flat		
SET	Cluster	Singleton	SET	Cluster	Singleton	SET	Cluster	Singleton
BL	ga b**l**ag	gab **l**ag	LB	ga l**b**ag	gal **b**ag	KT	ba k**t**ap	bak **t**ap
GL	ba g**l**ab	bag **l**ab	LG	ba l**g**ab	bal **g**ab	TK	ba t**k**ap	bat **k**ap

Figure 1. Cluster/Singleton lag ratios by sonority (a) and frequency (b). Intra-cluster timing by sonority (c) and frequency (d).



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