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Exponents of sonority in Slavic and Germanic languages

Paula Orzechowska

Adam Mickiewicz University, Poznań, Poland
paulao@wa.amu.edu.pl

Abstract

The study of phonotactics has been largely based on the principle of sonority [19], which orders segments in the syllable according to their articulatory opening. This generalizing principle, however, has been challenged by languages admitting long strings of consonants. Among phonotactically complex systems, Slavic and Germanic families have been mentioned [15]. Therefore, the present contribution aims at decomposing sonority into constituent parameters, which provide more detailed insights into cluster structure. The idea goes in line with previous contribution [16, 17, 18], suggesting that specific parameters of place, manner and voice affect cluster structure to varying degrees, resulting in disproportionate cross-linguistic phonotactic variability. The analysis is based on large sets of word-onset clusters varying in length from CC to CCCC in Polish, Russian, English and German.

Index Terms: sonority, distinctive features, Slavic and Germanic.

1. Introduction

Research on phonotactics has mainly focused on the evaluation of cluster formedness. Sonority (see [19] for an overview) orders segments in affinity to the vocalic peak. It is associated with the degree of articulatory opening, and the resulting loudness of sounds [6, 14], which increase from obstruents (O) through sonorants (S) to vowels (V). All the sonority scales proposed after [28] rely on the manner of articulation features but vary in the degree of detail. For instance, [2, 29] include broad classes of obstruent and sonorant consonants (C), while [26] distinguishes between liquids /r/ and /l/. Additionally, some scales account for voicing or vowel height [10, 23].

The principle which specifies the universal ordering of syllable segments is the *Sonority Sequencing Generalisation* (SSG, [22]). According to the SSG, syllable constituents should exhibit a decreasing sonority profile from the peak outwards, resulting in well-formed onsets, such as /pl kw tr/, and ill-formed codas, such as /tm ps kl/. A body of research has challenged the principle on the basis of initials such as English /sp st str/ in *speak, stand, string*. This untypical behaviour of /s/+stop clusters has been attributed to the extrasyllabic status of the fricative in non-linear approaches [5, 11, 12]. A similar type of clusters is found in German, where /s/ and /ʃ/ are found cluster-initially, e.g. /ʃp ʃtʁ skl/ in *Spiel* 'game', *Strand* 'beach', and *Sklave* 'slave'. Apart from sC(C) clusters, Slavic languages feature other types of SSG-violating sequences (e.g. /rt mʃ bʒd/ in Polish *rtęć* 'mercury', *msza* 'mass', *brzdąc* 'tot'). It must be emphasized that some of the longest clusters are morphologically complex [3] and emerge in prefixation (e.g. Polish /vb skl/ in *w+chodzić* 'walk inside', *skleić* 'glue up'), or in V:Ø alternation (e.g. Russian /mx lv/ in *mxa, lv'a*, genitive forms of *mox* 'moss', *lev* 'lion').

Sonority specifies a priori well-formedness conditions in the evaluation of cluster structure, and in such a way overshadowing the role of individual phonological features in phonotactics. Some markedness models have formulated formedness conditions based on place, manner and voice features [4], providing an extension of and an alternative to the SSG. Therefore, the objective of the present paper is to investigate the distribution and organization of phonological features in two Slavic and two Germanic languages, possibly shedding light on the properties which contribute to cluster structure and its complexity.

2. Phonotactics: state of the art

The most exhaustive typological classification of the syllable in the *World Atlas of Language Structure* [15] labels German and Polish as complex. Indeed, both systems admit at least three segments in the onset position, as in /ʃpʁ/ *Sprache* 'language' and /ʑʥbw/ *źdźbło* 'grass stalk'. However, 50-60 initial clusters attested in German are far from being comparable to over 450 clusters found in Polish. Similar disproportions are attested across the Germanic and Slavic language families, with English and Russian mirroring the pattern. In other words, languages which are considered to exhibit a comparable degree of syllable complexity differ vastly in terms of cluster inventories and their structure.

Table 1 presents the evaluation of large lists of word-initial cluster types in English (EN), German (GE), Polish (PL) and Russian (RU) collected for the purpose of this study (see 3.). The classification is based on the sonority scale in [6] commonly applied in the study of phonotactics; V > glide > liquid > nasal > fricative > affricate > plosive. Well-formed (WF) clusters follow the SSG, ill-formed (IF) clusters violate the SSG, and plateaus are composed of identical segment types (e.g. /bd/ plosive + plosive /bd/, /mn/ nasal + nasal). Note that clusters longer than CC involve several patterns (e.g. /vzgl/: plateau+decrease+increase) are considered IF.

Table 1: *Evaluation of clusters in terms of sonority.*

SSG	EN		GE		PL		RU	
	No	%	No	%	No	%	No	%
WF	43	74	35	65	200	43	140	43
IF	13	23	15	28	220	48	147	45
plateau	2	3	4	7	40	9	40	12

Table 1 illustrates parallels between the Germanic and Slavic systems. English (74%) and German (65%) favour a preferred rising sonority profile from the left-most consonant rightwards. To the contrary, Polish and Russian feature a greater variety ill-formed clusters. Plateau articulation is generally considered to be marked due to insufficient sonority differential [2], resulting in the prevalence (57%) of SSG-violating clusters in both languages.

On the basis of Table 1, the languages can be ordered on a scale of increasing phonotactic complexity. The ranking EN < GE < PL, RU ('<' means 'smaller than') captures the generalization that English follows the SSG to the greatest degree, and constitutes the least complex of the systems under investigation. In contrast, Polish and Russian, rich in marked clusters, are located at the most complex extreme of the scale.

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Given the prevalence of ill-formed clusters in Slavic, this paper investigates the structure of word-initial phonotactics beyond the principle of sonority. The analysis embraces eight parameters. Cluster length, manner of articulation and voicing can be viewed as exponents of sonority, and provide insights into patterns of featural organization of consonant clusters. We upturn the existing analyses, and instead of evaluating cluster markedness, we ask the following questions: How shall the primitive of formedness be defined? Which parameters correspond most adequately with the SSG in a language? Which features are exploited across language families?

The idea of reconstructing the sonority hierarchy into constituent parameters goes back to [17]. The analysis demonstrated that German word-initial phonotactics relies on the manner and voicing features. The results were confirmed in [18], which demonstrated that German favours parameters that conspire to create a preferred sonority profile, while Polish relies on voice and place parameters. The role of sonority was also studied in ERP experiments. Electro-physiological responses to well- and ill-formed final clusters in Polish [27] and German [24] demonstrated the main effect of sonority in German speakers, and lowered sensitivity to sonority violations in Polish speakers. That is, the learning process at the neuro-physiological level is strongly affected by sonority in a phonotactically simpler language. Similar results were obtained for English. In a theoretical statistically-based analysis of initial clusters, [16] suggested that, similarly to German, the manner of articulation and voice features have the greatest statistical weight, i.e. play a crucial role in cluster discrimination. A similar idea was pursued in [1], who demonstrate that some features are universally more favoured in the formation of phonemic systems than others. The objective of this paper is to find such parameters in the formation of clusters in the four languages.

3. Study

The objective of this paper is to propose a statistically-based description of phonotactics in Slavic and Germanic. Cluster lists are described in terms of eight parameters (P) drawn from previous contributions [16, 17, 18]. Here, emphasis is placed only on those parameters that can be viewed as core exponents of sonority, accounting for the manner of articulation and voicing. The dataset was extracted from existing dictionary- and corpus-based cluster lists [18, 25, 29], resulting in 58 English, 54 German, 460 Polish and 327 Russian word-initial clusters. The inventories contain some well-adapted proper nouns and loans. Obsolete items with obviously foreign status were excluded from the analysis. For each languages, clusters were transcribed phonemically and labelled according to the IPA description consonants [8, 9, 13, 21].

3.1. Results

Tables 2-8 summarize the results of the analysis for P1-P8. Each table reports on the number of cluster types (No) representing each parameter pattern. Percentages (%) are calculated for the total of clusters found in each language.

3.1.1. Cluster length

The first criterion of cluster description is related to the number of adjacent consonants. CV violation, which results in a two-member cluster is generally acceptable cross-linguistically. Although sonority makes no predictions as to the number of constituent segments, the longer a cluster becomes, the more challenges it meets in preserving the preferred sonority profile. In other words, sequences of length 3 and 4 are disfavoured in comparison to length 2.

Table 2: *P1: Cluster length.*

	EN		GE		PL		RU	
P1	**No**	**%**	**No**	**%**	**No**	**%**	**No**	**%**
2	49	84	46	85	219	48	213	65
3	9	16	8	15	211	46	98	30
4	-	-	-	-	30	6	16	5

As shown in Table 2, German, English and Russian tend to be composed of two segments (>65%). In Polish, longer sequences prevail; CCC(C) constitute more than one half of the inventory (52%). On this basis, we propose a ranking for P1. GE < EN < RU < PL captures an increasing degree of complexity from simpler German to more complex Polish. German follows the CV universal to the greatest extent by featuring numerous CC types (85%). Polish clusters, in turn, display more severe violation of the universal, leading to CCC(C).

3.1.2. Manner of articulation

Since sonority hierarchies are largely based on the manner features, we posit four parameters P2-5 which inspect the number and distribution of broad manner classes. First, emphasis is placed on the proportion of obstruents (O) to sonorants (S), summarized in Table 3. In order to adequately account for obstruenty, two-, three-, and four-member clusters are kept distinct. Percentages are calculated for each length group separately. Column P2 specifies the number of obstruents in a sequence, ranging from zero to three. Full obstruency defines clusters composed solely of plosives, fricatives and affricates (e.g. /pt fsk vzdv/) labelled '2' in CC, '3' in CCC, '4' in CCCC). A reverse pattern is attested in sequences containing exclusively sonorants (e.g. /ln mj mw/), and labelled '0'.

Table 3: *P2: Obstruency*

	EN		GE		PL		RU	
P2	**No**	**%**	**No**	**%**	**No**	**%**	**No**	**%**
				CC				
2	7	14	18	39	104	47	93	44
1	39	80	28	61	105	48	109	51
0	3	6		-	10	5	11	5
				CCC				
3		-	1	13	52	25	23	24
2	9	100	7	87	122	58	70	71
1		-		-	37	17	5	5
				CCCC				
4					2	7	1	6
3					18	60	15	94
2					10	33	-	-

Generally, all languages display a tendency to maximize the number of obstruents but avoid full obstruency. A preferred pattern is cluster length *n-1*. Sonorant-only strings are rare, and found exclusively in the CC group. A ranking proposed for P2 is based on two-member clusters, whose rising sonority profile is guaranteed by an O+S combination. Recall that sonority makes no specific formedness predictions regarding clusters with combined gestures such as OOS and OSS). The ranking EN < GE < RU < PL again confirms that Russian patterns between Polish and the Germanic languages.

Obstruency illustrates the proportion of obstruents to sonorants but says little about their distribution in a cluster. Therefore, P3 and P4 inspect the presence of broad manner classes at cluster margins. Table 4 summarizes the results for the C1 slot, while Table 5 specifies the consonant in the prevocalic position. Additionally, we provide a distinction into specific articulatory types, including plosives (P), fricatives (F), affricates (A), nasals (N), liquids (L) and glides (G).

Table 4: *P3: Manner features cluster-initially.*

	EN		GE		PL		RU	
P3	No	%	No	%	No	%	No	%
				general				
O	55	95	54	100	414	90	293	90
S	3	5	-	-	46	10	34	10
				specific				
P	21	36	21	39	135	29	77	24
F	34	59	30	56	247	54	216	66
A	-	-	3	6	32	7	-	-
N	2	3	-	-	21	5	17	5
L	1	2	-	-	18	4	17	5
G	-	-	-	-	7	1	-	-

Table 5: *P4: Manner features cluster-finally.*

	EN		GE		PL		RU	
P4	No	%	No	%	No	%	No	%
				general				
O	7	12	19	35	192	42	142	43
S	51	88	35	65	268	58	185	57
				specific				
P	4	7	6	11	58	13	69	21
F	3	5	12	22	99	21	73	22
A	-	-	1	2	35	8	-	-
N	4	7	9	17	78	17	47	14
L	21	36	26	48	81	18	126	39
G	26	45	-	-	109	24	12	4

The vast majority of clusters (≥90%) starts with an obstruent (in particular a fricative). As discussed earlier, clusters are expected to have the O+S structure. The prevocalic position is particularly important as the absence of a sonorant C can easily lead to the SSG violation. The preference for a sonorant cluster finally is pronounced in English (88%) but is much weaker in Polish (≥57%). The following complexity rankings can be proposed; GE < EN < PL, RU for P3, and EN < GE < PL < RU for P4.

Apart from classifying clusters into binary classes, degrees of formedness can be established on the basis of articulatory distances. According to the *Sonority Dispersion Principle* [2], an optimal CCV structure in a demisyllable should display a sharp rise in sonority from the first C rightwards. That is, O+L+V and L+G+V exhibit the largest and smallest distances, respectively. The notion of distance was explored in [4], whose phonotactic model is based on the computation of auditory distances between pairs of segments. In line with [4], P5 inspects distances between adjacent consonants, where a distance of one holds between adjoining manner classes (e.g. fricative+nasal /sn/, liquid+glide /lj/). For clusters longer than CC, an averaging procedure was employed.

Table 6: *P5: Manner distances.*

P5	EN		GE		PL		RU	
	No	%	No	%	No	%	No	%
0	2	3	6	11	40	9	42	13
1	5	9	7	13	98	21	63	19
2	13	22	17	31	152	33	114	35
3	14	24	15	28	99	21	67	20
4	14	24	9	17	54	12	35	11
5	10	17	-	-	17	4	6	2

In determining the ranking, we examine two largest distances admissible in each language. In line with [2, 4], we assume that cluster preferability increases with the increase in distance. Table 6 shows that English features the greatest variety of cluster types with medium and larger distances (two to five). In German, Polish and Russian, clusters with medium distances (two to three) prevail. Clusters displaying a larger distance constitute 45% in German, 41% in English, 16% in Polish and 13% in Russian, leading to the following P5 ranking: GE < EN < PL < RU.

3.1.3. *Voicing*

Apart from the manner of articulation, some sonority scales account voicing. P6 and P7 summarized below define voiced (+) and voiceless (-) consonants at cluster edges. Voiceless consonants are less sonorous, and expected to occur farther away from the vowel than their voiced counterparts [10, 23]. Table 7 shows that this preferred voicing profile is preserved in all the languages. The majority of clusters in English and German starts with a voiceless segment (≥71%). The tendency holds in the Slavic languages but is less pronounced. As regards the right cluster edge, all the systems favour a voiced consonant (≥76%). The complexity rankings are the following: GE < EN < RU < PL for P6, and EN < GE < RU < PL for P7.

Table 7: *P6-7: Voice features at cluster margins.*

	EN		GE		PL		RU	
P6	No	%	No	%	No	%	No	%
				cluster-initial				
+	17	29	9	17	219	48	155	47
-	41	71	45	83	241	52	172	53
P7				cluster-final				
+	53	91	44	81	349	76	263	81
-	5	9	10	19	111	24	63	19

Again, P6 and P7 present data only for cluster margins. In order to adequately capture the voice profile of clusters longer than CC, in terms of voice agreement, P8 is proposed. Words with total agreement are either uniformly voiced or voiceless, disregrading the number of constituent segments (e.g. /st br/ in *stay, bring*). Words with no agreement contain no adjacent segments with the same voice specification (e.g. /pr tw/ in *pray, twist*). Most of CCC(C) sequences exemplify a pattern of partial agreement, where at least one adjacent pair agrees in voicing (e.g. voiceless+voiceless+voiced /spr/).

Table 8 illustrates differences between the language families. In English and German, no pattern defines the majority of clusters. Polish and Russian, in turn, tend to agree in voicing (66% and 61%, respectively). Given that a universally favoured sequence should start with a voiceless segment and end with a voiced one, the pattern of no agreement constitutes the basis for proposing the complexity ranking: GE < EN < RU < PL.

Table 8: *P8: Voice agreement.*

P8	EN		GE		PL		RU	
	No	%	No	%	No	%	No	%
total	22	38	19	35	305	66	201	61
partial	9	16	8	15	92	20	58	18
no	27	47	27	50	63	14	68	21

3.2. Statistical analysis

On the basis of the percentage data in Tables 2-8, a ranking of parameters can be established. The *Principal Component Analysis* (PCA) is a mathematical method, which reduces numerous (possibly correlated) variables to a smaller number of linearly uncorrelated variables, called principal components (Comp). That is, Comp1 explains the largest portion of the observations, while each successive component (Comp2-8) accounts for the remaining variability in the data. The analysis performed with help of the R software [20] shows that Comp1 explains the English data in 50%, German in 41%, Russian in 35% and Polish in 34%.

Additionally, PCA loadings make it possible to establish the statistical weight of parameters in each language. The loadings indicate the degree to which a parameter discriminates between clusters. The loading values range from zero to one. The higher the value, the greater the weight of a parameter, and the greater its discriminatory power. Since the loadings are relatively low, in line with [16] parameters reaching a threshold ≥0.4 in Comp1 are used for data interpretation. 42 28

Table 9: *Ranking of parameters (Comp1).*

W	Parameters	P	%
	English		
1	Number of obstruents	2	42
2	Manner cluster-finally	4	28
3	Voice cluster-finally	7	20
	German		
1	Cluster length	1	36
2	Voice cluster-finally	7	30
3	Number of obstruents	2	18
	Polish		
1	Voice agreement	8	47
2	Voice cluster-finally	7	29
	Russian		
1	Voice cluster-finally	7	26
2	Manner cluster-initially	3	21
3	Number of obstruents	2	20
4	Voice agreement	8	17

Table 9 demonstrates that different sets of parameters surface as relevant predictors of cluster structure depending on a language. Column P lists the relevant parameters, while column W orders P1-P8 according to their decreasing statistical weight (W 1-4). Loading values turned into percentages (%) indicate the degree to which a particular parameter explains the variability of the data.

Overall, out of eight parameters two define most or all cluster sets. The number of obstruents (P2) and voicing cluster-finally (P7) show to be the fundamental properties of phonotactics cross-linguistically. Interestingly, length (P1) has a discriminatory power only in German. That is, the CV universal is freely violated not only in phonotactically elaborate systems but also in English, which was shown to follow the SSG to the greatest extent. As regards the Slavic family, Polish and Russian rely on voice agreement. The fact that P8 has great statistical weight can be attributed to the morphological complexity of initial clusters. Prefixation of consonant-only morphs is determined by voice properties of the stem-initial segment. This parameter serves to distinguish between the Slavic and Germanic families.

It must be emphasized, however, that parameters in Table 9 explain only up to 35% of the Slavic data, but 50% of the English data. That is, although voice agreement and voicing cluster-finally have the greatest statistical weight, their discriminatory power is relatively strong only for a smaller subset of Polish and Russian clusters.

4. Discussion

In this paper, we have decomposed the sonority hierarchy into eight constituent parameters in order to trace the role of specific manner and voice features in phonotactics. The analysis revealed the phonological properties that account for the differences between English, German, Polish and Russian.

First, the P1-P8 complexity hierarchies demonstrate that the manner and voice properties are exploited differently by the Slavic and Germanic systems, but similarly within language families. The extremes of the rankings are never occupied by two languages belonging to the same family. Rather, a Germanic language is always found at the least complex end of the scale, while a Slavic language (esp. Polish) represents the most complex extreme. Within each family, languages display comparable results. Major differences between the families are represented by P8 (voice agreement).

Second, the rankings reveal the complexity relationship between the languages. Recall the hierarchy in Table 1 (EN < GE < PL, RU), suggesting that English, followed by German, feature a wide range of SSG-obeying clusters. No complexity degrees can be established for Polish and Russian, as the proportion of WF and IF/plateau clusters is equal. This overarching hierarchy is taken as a baseline for the analysis of specific parameters. Table 10 presents parameters P1-P8 grouped into five classes (I-V): (I) obstruency (P2), voice cluster-finally (P7); (II) size (P1), voice in C1 (P6), voice agreement (P8); (III) manner cluster-finally (P4); (IV) manner distances (P5); (V) manner in C1 (P3). The sonority-based hierarchy is given at the top of the table.

Table 10: *Classes of complexity.*

SSG	EN	GE	PL/RU	
I	EN	GE	RU	PL
II	GE	EN	RU	PL
III	EN	GE	PL	RU
IV	GE	EN	PL	RU
V	GE	EN	PL/RU	
increasing complexity →				

Rankings representing classes I and III are most comparable to the SSG. That is, obstruency, voicing and manner cluster-finally show to be the most adequate exponents of sonority in the Germanic languages. That is, German and English clusters pattern according to their length (CC), maximization of obstruents in a cluster (but not full obstruency) and the presence of a sonorant (i.e. voiced) C prevocalically. As can be observed, the final segment in a cluster shows to play a particular role in Germanic phonotactics, catering for a smooth transition from C1 towards a vowel. These results are confirmed in PCA loadings, where P1, P2, P4 and P7 show to have the greatest discriminatory power (see Table 9). The interpretation of the results for the Slavic systems is less straightforward. Since Polish and Russian cannot be ranked with respect to each other in terms of sonority (PL/RU, see Table 1), the ranking in class V shows to be most adequate for data interpretation. P3 specifies the manner features cluster-initially. This results is partially supported in the statistical analysis (see Table 9), where the S/O distinction in the C1 slot has a high loading value in Russian.

5. Conclusions

The paper has proposed a method of decomposing sonority into eight parameters, offering a new statistically-based description of phonotactics in Polish, Russian, English and German. We have demonstrated that cluster length, manner of articulation and voicing are exploited differently and to different degrees in the systems under investigation.

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