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Phonology A

Sonority Sequencing, Phonological Scales, and Russian Word Edges

This paper is an examination of sonority sequencing in syllables. By formulating the Pairwise Sonority Sequencing Principle, we reject analyses formulated using strict prosodic hierarchy. Instead, we emphasize the role of segment adjacency in syllable composition. We then apply this constraint to the case of Russian, a language which follows the Sonority Sequencing Principle in most cases, but violates it at word edges—we take a positional faithfulness approach to this particular problem.

Sonority Sequencing

In general, syllables across languages tend to follow a particular pattern—syllables form a curve of sonority. The sonority of the segments of a syllable start low, rise as you approach the peak, and then fall toward the end of the syllable. This can be formalized as the Sonority Sequencing Principle.

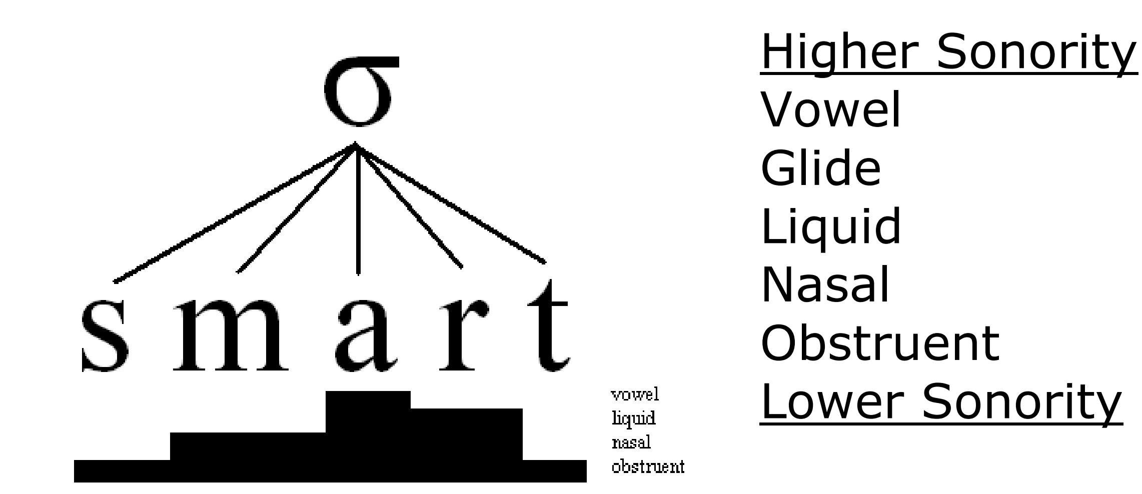
(1) **Sonority Sequencing Principle, SSP (Clements 1990, Dost 2004)**
Between any member x of a syllable and the syllable peak p, only sounds of higher sonority rank than x are permitted.

Throughout this paper, we will be using a rough scale of sonority, with broad categories of segments. Hopefully this makes our analysis as widely applicable as possible, but a more involved analysis would necessarily explore this issue.

(2) **Sonority Scale (Clements 1990)**
| Obstruent > Nasal > Liquid > Glide/Vowel |

By combining the SSP and the sonority scale, we can evaluate a syllable for markedness. Such an example for the English syllable *smart* is given in graphical form below.

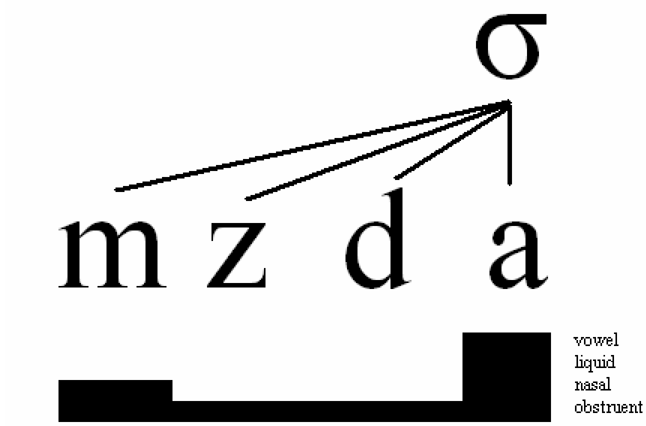
(3)



As shown in (3), the syllable *smart* is well-formed in terms of the SSP and the scale in (2). It starts with an obstruent, increases in sonority to a nasal, and peaks with a vowel. After the peak, it descends with a liquid, ending in an obstruent. The sonority curve is well formed—roughly the shape of an upside-down U, or like the symbol for set-intersection ∩. That is to say, there is only one peak (in the sense of local maxima) and no inner troughs (local minima within the syllable).

On the other hand, a Russian syllable like *mzda* 'recompense' violates the SSP. As shown in (4), this syllable has two peaks (local maxima) on the sonority curve, and a single trough (local minima). Between the segment [m] and the syllable nucleus [a], there are sounds of lower sonority, namely [z] and [d].

(4)



The Sonority Sequencing Principle maps a phonological scale to some type of constraint system, ultimately allowing us to evaluate the markedness of syllables. This is very much in the vein of Paul de Lacy's (2002) dissertation, which also deals with scales in grammar and how they map to constraint systems.

De Lacy (2002), mapping scales to positional constraints, DTEs

In de Lacy's dissertation (2002), various scales map to markedness and faithfulness constraints to form a subset/superset relation. Due to this relation, adjacent points on the scale can be conflated in a language, but they can never be reversed.

A given scale | A > B > C | corresponds to three markedness constraints, each containing the most marked element, and each containing a contiguous part of the scale. In this case, the constraints would be *{A}, *{A,B}, and *{A,B,C}. De Lacy's example of place of articulation is given below.

(5) a Major Place of Articulation Scale:
| dorsal > labial > coronal > glottal |

b Place of Articulation Markedness Constraints:
*{dor} *{dor,lab} *{dor,lab,cor} *{dor,lab,cor,glot}

One particular example de Lacy gives appears to be relevant because it deals with sonority. His example concerns the sonority of the nucleus of an accented syllable. He uses the terminology of 'Designated Terminal Element', or DTE. For this particular scale, he refers to the DTE of feet—the DTE of a foot would be the segment that corresponds to the head mora of the head syllable of that foot. You go down the hierarchy, looking for the head of each lower position. The DTE of the prosodic word would also be the DTE of the head foot of that word, and so on.

In reference to DTEs of head feet, he makes an argument using positional markedness. A scale can reflect what is best for a particular position. For the DTEs of feet—accented syllables—schwa is the worst vowel, and [a] is the best.

(6) a Vowel Sonority Scale: | ə > i,u > e,o > a |

b Vowel Sonority Scale in DTEs of feet:

$*DTE_{ft}$ {ə} $*DTE_{ft}$ {ə, i/u}

$*DTE_{ft}$ {ə, i/u, e/o} $*DTE_{ft}$ {ə, i/u, e/o, a}

De Lacy also refers to non-DTEs. The reversal of the constraints in (6b) would be positional markedness constraints for non-accented syllables. As expected, this set of constraints encodes sonority in the exact opposite way—schwa is the best possible vowel for an unaccented syllable, and [a] is the worst.

(7) Vowel Sonority Scale in non-DTEs of feet:

$*–DTE_{ft}$ {a} $*–DTE_{ft}$ {a, e/o}

$*–DTE_{ft}$ {a, e/o, i/u} $*–DTE_{ft}$ {a, e/o, i/u, ə}

The idea of Designated Terminal Elements works well for de Lacy's analysis—it places a theoretical limitation on the kind of structures markedness and faithfulness hierarchies can correspond to. For instance, a constraint cannot talk about the non-head mora of the head-syllable of a non-head foot. Either you're talking about a DTE, in which case you follow the hierarchy of heads, or you're talking about non-DTEs, in which case you take the complement of the set of DTEs.

Can we extend de Lacy's analysis to sonority sequencing?

The scale in (6a) is a scale of sonority, but it is limited to vowels. We could try to use our own general sonority scale from (2) in the same manner.

Syllable nuclei, in terms of Designated Terminal Elements, correspond to +DTEσ, and onsets and codas correspond to –DTEσ. So, like the vowel sonority scale and stress, we would have two sets of opposing constraints.

(8) Sonority Scale in Syllables:

a.	b.
*DTEσ{O}	*–DTEσ{V}
*DTEσ{O,N}	*–DTEσ{V,L}
*DTEσ{O,N,L}	*–DTEσ{V,L,N}
*DTEσ{O,N,L,V}	*–DTEσ{V,L,N,O}

This analysis might have merit. We predict that certain adjacent levels of the scale could conflate—for instance, obstruents and nasals might act the same in terms of onset or nucleus restrictions. We also predict that the scale can never be reversed—there will be no languages where obstruents are preferred as nuclei but vowels are avoided.

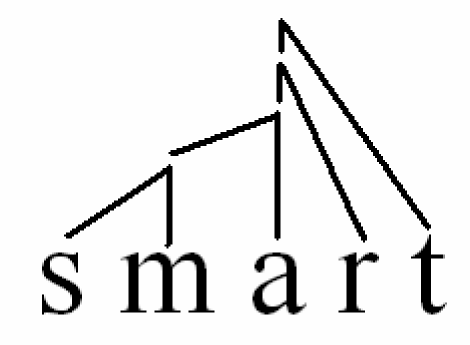
However, this is only a preliminary understanding of sonority in syllables. This analysis makes no mention of onsets or codas, nor does it propose how to deal with consonant clusters.

Because of the use of DTEs, and the prosodic hierarchy proposed by de Lacy, there is no good way to refer to onset or coda consonants. They tend to look a lot alike, in that they are –DTEσ. Onset consonants are –DTEμ. If a coda consonant has weight, then it would be +DTEμ, but if it does not have weight, then it would have no value for DTEμ (it would be neither + or - DTEμ, because it would have non-strict layering, the coda directly under the syllable without a mora layer).

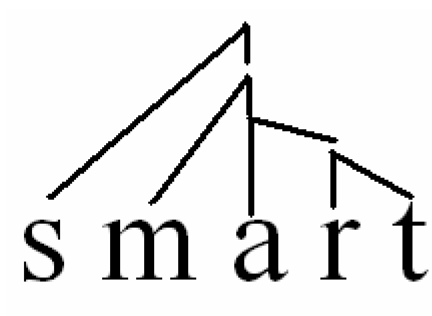
We also want a way to talk about consonant clusters. The ordering of the consonants has a strong effect on their distribution and markedness—according to the SSP, the cluster [pl] is a good onset, but [lp] is rather marked. Using our representations of DTEs, all the onset segments look alike—they are all –DTEσ, –DTEμ. A theory that captures the generalizations of sonority sequencing has to place a premium on adjacency, and Designated Terminal Elements are not the correct way to express these relations.

Of course, we could try to force the theory of DTEs into working for us. We could imagine a baroque structure of onsets and codas, where each segment is in a binary system with some adjacent structure, headed by the structure closer to the syllable peak, as in (9).

(9) a.
$[\,[\,s_{-}\ m_{+}]_{-}\ a_{+}\,]_{+}\ r_{-}\,]_{+}\ t_{-}$



b.
$[s_{-}\ [\,m_{-}\,[\,a_{+}\,[r_{+}\ t_{-}]_{-}\,]_{+}\,]_{+}$

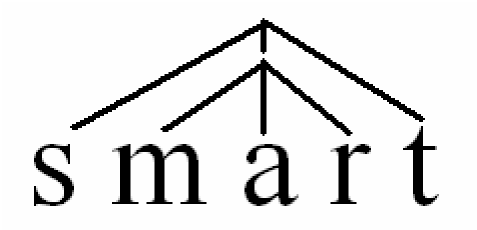


In one branch of (9a), *m* is the head and *s* is its complement. Then, *a* is another head with the [*sm*] structure as its complement. Such a structural description is not only unwieldy, it is also not at all independently motivated. And it is not even descriptively adequate—

what does it mean to compare the sonority of *r* to the sonority of [[*sm*]*a*]? In our analysis, *r* does not care about the sonority of *s* or *m*, only that of *a*.

A trinary structure would not account for the data either.

(9) c.



The inner trinary structure makes some sense—the sonority of the head *a* must be greater than either of its complements *m* or *r*. But the outer structure is less useful. We want to compare the sonority of *s* with that of *m*, but given its complements, the structure looks like we should compare *s* with [*m a r*] and *t*.

In essence, either formulation is forcing a tree structure to account for surface adjacency. It becomes increasingly apparent that structural effects and adjacency effects are two distinct forces.

Adjacency and Scale Constraints

What does de Lacy have to say about adjacency? In section 4.2.3.1 of de Lacy (2002), he makes reference to adjacency and sonority, but only as an alternative to systems of stress. In this part of the paper, he is arguing for an analysis that treats stressed and unstressed vowels differently—namely, in Kiriwina, feet of the type (CíCi) are desirable, while those like (CáCa) are avoided. The reason for this, according to de Lacy, is because there is a constraint against [a] in unstressed position—all of the constraints in (7) make reference to [a], because a high-sonority vowel makes a bad unstressed vowel.

In terms of sonority **difference**, there is no difference between the stressed and unstressed vowels in (CíCi) and (CáCa)—[i] and [i] have a sonority distance of 0, as do [a] and [a]. De Lacy's use of DTEs and non-DTEs allow for the two types of feet to be distinguished, while a statement of their relative sonority would not. In other words, a theory of adjacency cannot supplant de Lacy's analysis using DTEs.

According to de Lacy, the success of using DTEs in his account of Kiriwina is "that its constraints focus solely on the sonority of a single element; they do not take into account the sonority of adjacent elements." (p. 129) But, in order to capture the nature of sonority sequencing in the syllable, we need to take into account the sonority of adjacent elements—the very thing that de Lacy ignores to make his analysis work is the very thing we need.

It appears that, in a grand unified theory of all things sonority, we will need both adjacency-oriented constraints and DTE/hierarchically-oriented constraints.

Pairwise SSP and Edge Faithfulness

Now that we have motivated the use of adjacency-oriented constraints, we should modify the Sonority Sequencing Principle to work in an Optimality Theoretic framework. This reworked SSP is pairwise in its assignment of violations—its domain is a pair of adjacent segments, and it assigns a violation when the sonority contrast between the two elements of the pair is in the wrong direction.

(10) **Pairwise Sonority Sequencing Principle (PSSP)**
If x and y are adjacent segments of a syllable, and y is closer to the syllable peak than x, then assign a violation if the sonority of x is greater than the sonority of y (i.e. $|x| > |y|$).

Our English example syllable *smart* does not violate the PSSP for any of the four adjacent segment pairs:

(11) **PSSP and *smart***

Before the nucleus, so x comes before y

s m	x = *s*	y = *m*	$|s| \leq |m|$, therefore no violation
m a	x = *m*	y = *a*	$|m| \leq |a|$, therefore no violation

Past the nucleus, so now y comes before x

a r	x = *r*	y = *a*	$|r| \leq |a|$, therefore no violation
r t	x = *t*	y = *r*	$|t| \leq |r|$, therefore no violation

The Russian example syllable *mzda*, on the other hand, has one violation of the PSSP.

(12) **PSSP and *mzda***

Before the nucleus, so x comes before y

m z	x = *m*	y = *z*	$|m| > |z|$, therefore **one** violation
z d	x = *z*	y = *d*	$|z| \leq |d|$, therefore no violation
d a	x = *d*	y = *a*	$|d| \leq |a|$, therefore no violation

Russian syllables only violate the PSSP in particular positions. Namely, the PSSP can be violated in the onset of the first syllable and coda of the final syllable. In order to be clearer, we will refer to the onset and nucleus of the initial syllable as the **initial edge** of the word, and the rime of the final syllable as the **final edge** of the word. Together, these two positions are the **word edges**, and they are the positions that remain faithful to the input despite violating the PSSP. (The inclusion of the nucleus in both edges is to make constraint formulation more precise.)

Some examples of violations of the PSSP in Russian are given in (13). (13a) shows violations in the initial edge of the word, and (b) shows violations in the final edge. Ito (1982) is the source for these examples.

(13) a. b.

[**mz**da]	recompense	Nasal-Obstruent			
[**mx**i]	mosses	Nasal-Obstruent			
[**rv**at]	to tear	Liquid-Obstruent	[mons**tr**]	monster	Obstruent-Liquid
[**lg**at]	to tell lies	Liquid-Obstruent	[zat**xl**]	musty	Obstruent-Liquid
[**ln**ut]	to cling	Liquid-Nasal			

Below are the Word Edge Faithfulness constraints—EDGE-DEP, EDGE-MAX, and EDGE-IDENT.

(14) Edge of Word Faithfulness (informal):

EDGE-DEP: Do not add segments in the edge.
EDGE-MAX: Do not delete segments that might have appeared in the edge.
EDGE-IDENT: Do not change the features of segments in the edge.

(15) Edge of Word Faithfulness (formal):

EDGE-DEP: Every output segment in the word edge must have a corresponding input segment.

EDGE-MAX: Segment y_o is an output segment in the edge. If y_o has an input correspondent y_i, then y_o's immediately adjacent preceding/following segment x_o must correspond to the immediately adjacent preceding/following segment of y_i. The segment x should precede y in the initial edge and should follow y in the final edge.

In other words, given x_oy_o in the initial edge, assign one violation if x_i does not immediately precede y_i. Given y_ox_o in the final edge, assign one violation if x_i does not immediately follow y_i.

EDGE-IDENT: Every output segment in the word edge must bear all the same features as its corresponding input segment.

Importantly, these EDGE faithfulness constraints make reference to the **output** syllable structure—we do not assume syllabification of the input. Such an assumption would be unjustified, and would place undue importance on the lexicon. Richness of the Base tells us to capture these kinds of generalizations in the grammar, and the constraints above are part of this intent.

Notice that EDGE-DEP and EDGE-IDENT have brief formal descriptions in comparison to EDGE-MAX. This has to do with the nature of Correspondence Theory and positional faithfulness. The position we want to be faithful to is an output position, but MAX in general refers to the **absence** of output segments given the presence of input segments. The formal wording of EDGE-MAX is an attempt to reconcile these two contrasting ideas. In order to do so, I have utilized some of the ideas of CONTIGUITY. It might be best to think of this constraint as a combination MAX/CONTIGUITY constraint.

Regardless of the theoretical implications, this constraint is sufficient for our analysis of Russian word edges.

The tableau in (16) demonstrates how these EDGE faithfulness constraints allow the PSSP to be violated. Word edges are in bold.

(16)

/mzda/	EDGE-IDENT	EDGE-DEP	EDGE-MAX	PSSP
a)☞.**mzda**.				mz
b) .**pzda**.	m→p!			
c) .**ma**z.d**a**.		a!		
d) .**zda**.			z not prec. by m!	

Focusing just on how Edge-Max works, we see that it cannot be side-stepped by simply deleting more and more segments. Regardless of how many segments you delete, there will still be a syllable edge, and that edge will want the segments that you have deleted. The only way to satisfy it would be to have all of the edge material, or to not pronounce anything at all (the null output).

(17)

/monstr/	*NULLOUTPUT	EDGE-MAX	PSSP
a)☞.monstr.			tr
b) .monst.		t not followed by r!	
c) .mons.		s not followed by t!	
d) .mon.		n not followed by s!	
e) .mo.		o not followed by n!	
f) (silence)	*!		

There is still one piece of the puzzle missing. We want to prevent syllabifications like [.m.zda.]. Such a syllabification would be fine by our EDGE faithfulness constraints, and the resulting syllables would be fine by the SSP. What is needed is a structural-oriented positional markedness constraint, like something from de Lacy's dissertation. Looking back to the syllable nucleus constraints in (8), we find that this constraint family is precisely what we need.

(18) Repeated from (8)
- a. *DTEσ{O}
- b. *DTEσ{O,N}
- c. *DTEσ{O,N,L}
- d. *DTEσ{O,N,L,V}

The constraint (18a) is not much use to us, but constraints (b) and (c) help mitigate against nasals as syllable nuclei. According to these constraints, a structure like [.m.zda.] is marked. (18d) seems to work against all syllable nuclei, so it's uncertain how useful it is for our purposes.

This gives us the tableau in (19). Our final ranking is shown in (20).

(19)

/mzda/	*DTEσ{O,N}	EDGE-IDENT	EDGE-DEP	EDGE-MAX	PSSP
a)☞.mzda.					mz
b) .m.zda.	m!				
c) .pzda.		m→p!			
d) .maz.da.			a!		
e) .zda.				z w/o m!	

(20) **Ranking Summary for Russian Word Edges**
*DTEσ{O,N}, *NULLOUTPUT, EDGE-FAITH >> PSSP >> Word-internal Faith

A word about word-internal faithfulness and loanwords

The ranking summary in (20) places the PSSP above word-internal faithfulness. We have no absolute direct evidence for such a ranking. Technically speaking, it might be an accident of the lexicon that, among the millions of words in Russian, some words violate the PSSP at word edges, but none violate the PSSP word-internally. Such a view, while technically possible, does not at all recognize the generalization of Russian grammar.

A true test would be to have an input form that cannot be syllabified in any other way than by violating the PSSP. The output of such a form would then tell us about word-internal faithfulness. Unfortunately, we cannot place an input form in a speaker's head and look for the result—our methods must be more indirect and nuanced.

Sometimes we look to morphology to provide us with such an opportunity. If we could find the right permutation of consonant-heavy morphemes, then we might create such a situation. Often, though, this type of situation just isn't available.

Another way to get at this problem is through the use of loanwords. But this also runs into difficulties concerning underlying representations—when people hear foreign words, their perception of the sounds is affected by their native grammar. However, it is not necessarily the case that their perception is precisely what they would produce. Broadly speaking, language users can sometimes hear contrasts that don't exist in their native language, and sometimes they cannot. Moreover, the acoustic and articulatory aspects of syllabification are not obvious. As such, it is impossible to tell **precisely** what the underlying representation is that they are internalizing, but it is still a worthwhile and productive avenue of research.

Problems and future research possibilities

The present analysis of sonority sequencing and Russian word edges is not without its problems. One issue is the motivation for positions that merit positional faithfulness constraints. Beckman (1998) emphasizes the phonological and psycholinguistic evidence for why the first syllable of a word is prominent. While these arguments might carry over to the word-initial edge, they have little to say why the word-final edge is also faithful. Further research is necessary to tell if this is a well-grounded point of view.

A second problem has to do with long clusters. EDGE faithfulness would want a cluster of two or three segments to be faithful just as much as an initial edge like CCCCCCCV. There must be some limit as to the number of segments allowed in a cluster, and it is unclear if EDGE faithfulness must make this choice, or if some more general markedness constraint should rule out such a syllable onset.

Future research might be able to integrate these ideas of the Sonority Sequencing Principle with the more stringent requirements of Sonority Distance (see Dost 2004). Such an analysis would take into account the **difference** in sonority between two adjacent segments, and assign markedness violations in accordance with an ideal syllable form. This would also make clearer the difference between onsets and codas, which I have ignored in this paper.

Another aspect that needs illumination is how sonority scales relate to one another. We have used a very general scale in this analysis, but as we saw with vowels and de Lacy's work, sometimes more specific, higher-resolution sonority scales are necessary. Is it possible to integrate all these scales together to create one, near-universal sonority scale? Would it follow the same principles that de Lacy (2002) establishes, namely the idea that parts of the scale can be conflated but never reversed? Or do some languages treat the sonority of segments in different ways, even ways that are reverse from other languages? It seems obvious that no languages would say a stop is more sonorous than a vowel, but the question becomes less obvious when dealing with segments within a smaller group.

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