Tone licensing and categorical alignment in Serbo-Croatian[1]

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1 Introduction

This paper offers an analysis of tone and stress in Neo-Štokavian Serbo-Croatian, with a focus on the ways in which tone is licensed and stress is assigned. The paper revisits the data from Inkelas & Zec (1988) and Zec (1999), with the advantage of recent theoretical advances: Tone-to-TBU constraints (Selkirk 2005), span theory (McCarthy 2004) and categorical alignment (McCarthy 2003).

My account of the Serbo-Croatian data is different from Zec's (1999) OT account in three main ways. First, I understand tones as being pronounced within headed tonal domains, as opposed to the headless auto-segmental representations that Zec (1999) uses. This will turn out to be crucial, because the head and non-head of a tone span turn out to be subject to different Tone-to-TBU constraints. Secondly, I make formal use of categorical alignment constraints , the need for which is acknowledged in Zec (1999). Lastly, I offer an analysis done transparently in one step, unlike Zec's (1999) two-step derivation à la Kiparsky (2000).

The theory of Tone-to-TBU constraints that I will be using is Selkirk's (2005). In this theory, tones are licensed by strong positions, i.e. by coinciding with heads of prosodic domains. I show that in Serbo-Croatian, tones are subject to two levels of licensing: a tone that is the head of its span must be licensed by the head mora of a syllable, while a tone that's not a head of its span must be licensed by the head syllable of the word.

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2 The data

Serbo-Croatian is a system where both tone and stress play a role in the phonology. Roots are either toneless (1) or with tone (2). There is no faithfulness to the position and number of tones in a word: If a word contains a least one High tone in its UR, it will surface with a tone aligned to its right edge. If a word is underlyingly toness, it will surface with an epenthetic tone at its left edge.

Throught this paper, the acute accent marks high tone. The feet marked here are the main feet, i.e. the main stresses of the words.

(1) Toneless roots:

a.	jezero	→	F jé.ze.ro	‘lake’
b.	zaastav+a	→	F zá̰a.sta.va	‘flag’
c.	meseec	→	F mé.seec	‘moon’

(2) Roots that have a high tone:

a.	H harmonik+a	→	F har.mó.ní.ka	‘accordion’
b.	H raazlik+a	→	F ra̰á.zlí.ka	‘difference’
c.	H violiin+a	→	F vi.o.l ḭí.ná	‘violin-Nom/Sg’
d.	H karakteer	→	F ka.rák.téer	‘character’

We see that toneless roots (1) show up with a High tone perfectly aligned to the left edge of the word. The main stress of the word falls on the initial mora as well.

In roots that have an underlying tone (2), the situation is a bit more complicated. When the last syllable of the root is light, as in (2a) and (2b), the High tone is pronounced over two moras, with its right edge aligned with the right edge of the root. The main stress of the word then falls on the syllable that contains the leftmost mora pronounced with High tone.

When the last syllable of the root is heavy, as in (2c) and (2d), the High tone cannot align with the righmost mora of the root. Inkelas & Zec (1988) attributes this to the need for a High tone to be licensed by the strong mora of a syllable. In our terms, the strong mora of a syllable licenses the head of a bi-moraic tone span. When there is inflection following the

root, the tone goes one mora to the right (2c). When there is no overt inflection, as in (2d), the High tone goes one mora to the left. In both cases, the High tone span is bi-moraic, and the syllable that contains the leftmost mora of the span is the head of the word.

In a case like (2c), where the last syllable of the root is heavy, the generalization is that the right edge of the High tone is one mora to the right of the root's right edge; the High tone is right aligned with the inflection suffix just in case it is mono-moraic. The difference can be seen in (3), where two moras are available after the root. The High tone shows up one mora to the right of the root, not all the way to the right.

		H		F	
(3)	a.	violiin+ama	→	vi.o.l i í.ná.ma	'violin-Dat/Pl'

Suffixes in Serbo-Croatian come in three flavors, labeled by Zec (1999) M1, M2 and MW.

M1 suffixes are a subset of the language's derivational suffixes. M1 suffixes behave like a part of the root: when M1 suffixes are present, the right edge of the last M1 suffix is the suffix that High tones align with. In terms of Zec (1999), roots and M1 suffixes define "M1 domains".

M2 suffixes follow any M1 suffixes that might be present, and they include all the derivational suffixes that are not in the M1 set. This paper will not deal with the behavior of M2 suffixes, since there is very little data about these suffixes in Zec (1999).

Finally, words of Serbo-Croatian end in one inflectional suffix, or MW suffix, which can be Ø. The MW suffixes are all toneless in the UR. The tonelessness of MW suffixes could be accidental, or it could be simply derived from a ranking of FAITH-Root over general faithfulness.

The example in (4) shows a root and two M1 suffixes, for a total of three M1 domains, and an MW suffix. Only one of the underlying High tones surfaces, and it right-alignes with the last mora of the biggest M1 domain.

		H H		F		
(4)	a.	lan]$_{M1}$ en]$_{M1}$ ij]$_{M1}$ a]$_{MW}$	→	la.né.ní.ja		'more flaxen'

The last piece of data I'd like to consider is vowel shortening, which happens to the left of the main stress. The example in (5) shows a root with a long vowel that surfaces with a short vowel when stress is farther to the right.

		H		F		
(5)	a.	dooboš]$_{M1}$ aar]$_{M1}$ a]$_{MW}$	→	do.bó.šáa.ra		'drummer'

3 Constraints on tones and feet

This paper uses two kinds of constraints on tone and feet: categorical alignment constraints, in the spirit of McCarthy (2003) and Tone-to-TBU (Selkirk 2005).

3.1 Categorical Alignment

Categorical Alignment constraints replace the older gradient alignment constraints, in keeping with McCarthy's (2003) arguments against gradience. They are of the form in (6).

(6) AlignX_{π}(Cat1,Cat2) =
There is no π between the X edge of every Cat1 and the X edge of some Cat2

Where π is a prosodic unit (μ, σ, F, ...)
Where X is an edge (left or right)
And where Cat1, Cat2 are phonological or morphological units.

For instance, AlignR_{μ}(H,PWd) is satisfied if there is no mora intervening between the right edge of tone spans and the right edge of the PWd. If at least one mora intervenes, one violation mark is assessed, no matter how many intervening moras there are.

3.2 Tone-to-TBU constraints

These licensing constraints are of the form in (7).

(7) X:Y =
If there is a mora *m* such that *m* is dominated by an X, then *m* is dominated by a Y

In this paper, I will use Tone-to-TBU licensing constraints to relate tone spans to metrical positions. I will refer to metrical positions using the format $\Delta_{\pi}\rho$, which should read "the head π of ρ". For instance, $\Delta_{\mu}\sigma$ is the head mora of a syllable, and Δ_{μ}F is the head mora of a foot.

Tone spans are also headed. In this paper, I will use constraints that refer to tone spans in three ways:

(a) H refers to the whole tone span
(b) ΔH refers to the head mora of the tone span
(c) $-\Delta$H refers to any mora that is in a tone span but it is not the head of the span.

Since in Serbo-Croatian tone spans are maximally bi-moraic, $-\Delta$H picks out at most one mora in each tone span.

4 Prosodic Word mapping

When a root and one or more M1 suffixes are present, tones align with the largest M1 domain available. The question is, how do tones avoid alignment with smaller M1 domains?

Zec (1999) circumvents the problem by simply disregarding the smaller domains. I propose that the right domain can be derived.

I propose that through constraint interaction, the largest M1 domain is mapped onto a Prosodic Word. Then, tones can align with the edge of the prosodic word. MW suffixes will be outside the Prosodic Word, dominated directly by the Minor Phrase. Universally, the Minor Phrase is the level at which many languages require that exactly one High tone be present.

The constraint in (8) demands that the right edge of every M1 domain be aligned with the right edge of a Prosodic Word.

(8) ALIGNR_{μ}(M1,PWd)
There must not be a mora between the right edge of every M1 domain and the right edge of some Prosodic Word.

The constraint in (8) would prefer a nested structure, in which a Prosodic Word is created for each M1 domain available. Such a nested structure is penalized by REC (Selkirk 1995), a constraint against recursion of the prosodic word (9). The constraint WRAP (Truckenbrodt 1995) in (10) makes sure that the Prosodic Word created in the output is big enough to include all the material in the largest M1 domain.

(9) *REC
No PWd dominated by PWd

(10) WRAP
The phonological exponent of every M1 domain must be fully contained in some Prosodic Word

The interaction of these constraints gets us a PWd that includes all and only the material in the largest M1 domain. An example is shown in the tableau in (11).

(11)

H H lan]$_{M1}$ en]$_{M1}$ ij]$_{M1}$ a]$_{MW}$		*REC	WRAP	ALIGNR_{μ}(M1,PWd)
a.	[[[[lan]$_{PWd}$ en]$_{PWd}$ ij]$_{PWd}$ a]$_{MiP}$	*!*		
b.	[[lan]$_{PWd}$ en ij a]$_{MiP}$		*!*	**
c.	[[lan en]$_{PWd}$ ij a]$_{MiP}$		*!	**
☞ d.	[lan en ij]$_{PWd}$ a]$_{MiP}$			**
e.	[lan en ij a]$_{PWd}$]$_{MiP}$			***!

In the tableau above, candidate (a) has a PWd nicely aligned with each of the M1 domains, but that violates the constraint against nested Prosodic Words. Candidate (b) wraps a PWd around the M1 domain defined by the root “lan”, but the two M1 domains defined by the suffixes —en and —ij are not inside any PWd, so that gets (b) two violations of WRAP. Candidate (c) has a PWd that includes the root and one of the M1 suffixes, but the last M1 suffix is not inside a PWd. In both (b) and (c), two of the M1 domains don’t have a PWd at their right edge.

The winner (d) has one PWd that nicely wraps all the M1 domains, so it wins even without a PWd aligned to to the right edge of two M1 domains. Candidate (e) shows that including the inflection suffix in the PWd makes alignment worse.

The alignment contraint that I propose in (8) penalizes misalignment by at least one mora. Coda or onset consonants, which are not moraic in Serbo-Croatian, will not be effected by this constraint. Therefore, it's impossible to tell whether the winner is [lan en ij]$_{PWd}$ a]$_{MiP}$ or [lan en i]$_{PWd}$ ja]$_{MiP}$, and it does not matter.

5 Alignment of tone and stress - all light syllables

Now that we have the right edge to align to, we can see how an underlying tone is realized on the surface. I will use span theory (McCarthy 2004), in which a High tone needs to be pronounced inside a High tone span. A span is a headed unit that organizes phonological features. For Serbo-Croatian, right-headed tone spans are needed, and this is achieved by the undominated constraint in (12).

Tone spans will need to right align with the Prosodic Word in order to satisfy the constrain in (13). Coupled with a binarity constraint on spans (14), this will extend High tones one mora to the left. This phenomenon is known as tone spreading or tone doubling in the autosegmental parlance.

(12) ALIGR$_\mu$(ΔH,H)
There must not be a mora between the right edge of the head of every High tone span and the right edge of some High tone span.

(13) ALIGNR$_\mu$(H,PWd)
There must not be a mora between the right edge of every High tone span and the right edge of some Prosodic Word.

(14) SPANBIN
A High tone span must not be mono-moraic.

A example with all light syllables is in (15).

(15)

	H harmonik]$_{M1}$ a]$_{MW}$	ALIGNR$_\mu$(H,PWd)	SPANBIN
a.	[[harmo(ní)k]$_{PWd}$ a]$_{MiP}$		*!
☞ b.	[[har(móní)k]$_{PWd}$ a]$_{MiP}$		
c.	[[(hármó)nik]$_{PWd}$ a]$_{MiP}$	*!	

Candidate (a) fails to have a tone span spread over two moras. Candidate (c) has a mis-aligned tone span. The winner has a perfectly aligned binary tone span.

When the Prosodic Word is mono-moraic, the High tone is still aligned with the right edge of the prosodic word, forcing a violation of SPANBIN:

(16)

H lan]$_{M1}$ a		ALIGNR$_{\mu}$(H,PWd)	SPANBIN
a.	[[(lán]$_{PWd}$ á)]$_{MiP}$	*!	
☞ b.	[[(lán)]$_{PWd}$ a]$_{MiP}$		*

Turning to stress, we see that the word stress shows up on the leftmost syllable that has a High tone pronounced on it, i.e. the word stress must include the non-head of the tone span. I propose that this needs to be understood in terms of tone licensing. The weak position of the tone span receives compensation for its tonal weakness by being in a strong metrical position. This licensing requirement is formalized in (17).

(17) –ΔH:Δ$_{\sigma}$PWd
If there is a mora *m* such that *m* is the non-head of a High tone span, then *m* is dominated by the head syllable of a Prosodic Word.

The tableau in (18) shows the derivation of "harmonika" with its tone domain and foot. The feet in (18) should be understood as the head feet of their words. The Prosodic Word and Minor Phrase structure is omitted for ease of reading; it was explicitly derived in (11).

(18)

H harmonik]$_{M1}$ a		–ΔH:Δ$_{\sigma}$PWd
a.	F har.(mó.n í).ka	*!
☞ b.	F har.(mó.ní).ka	
c.	F har.(mó.ní)ka	*!

This concludes the initial stage of the analysis. I have proposed that a PWd is constructed such that it is right aligned with the biggest M1 domain. Tones are organized in binary tone spans that are right aligned with the Prosodic Word. Stress feet are placed such that the non-head of a High tone span is pronounced inside the strong syllable of the PWd's head foot.

6 M1-final long vowels

We have seen that non-heads of tone spans are licensed by a strong syllable. In this section, we see that heads of tone spans also need to be licensed. Tone span heads must be licensed by a strong mora, i.e. the first mora of a syllable, which is universally the strong mora. This is enforced by the constraint in (19).

(19) $\Delta H{:}\Delta_\mu\sigma$
If there is a mora *m* such that *m* is the head of a High tone span, then *m* is the head mora of a syllable.

The effect of $\Delta H{:}\Delta_\mu\sigma$ can be seen in an example like (20), where the High tone is forced away from the right edge of the PWd.

(20)
	H		F F	
	karakteer	→	ka.rák.téer	'character'

This situation is derived in (21). The last mora of the prosodic word is weak, and it cannot license the head of the tone domain. This prevents perfect alignment of the tone span with the prosodic word.

(21)

H karakteer		$\Delta H{:}\Delta_\mu\sigma$	ALIGNR_μ (H,PWd)
☺ a.	F (ká.rák).teer]$_{PWd}$		*
☺ b.	F ka.(rák.té)er]$_{PWd}$		*
c.	F ka.rak.(téér)]$_{PWd}$	*!	

As for the shape of feet in Serbo-Croatian, I will assume that they must be trochaic. Following Hayes (1995), I will assume that universally, an optimal trochee is a sequence of two light syllables or one heavy syllable. In Serbo-Croatian, undominated constraints make sure that only these kinds of trochees will be available as possible feet in the language.

Recall that High tone spans are right-headed in Serbo-Croatian. In candidate (c), the head of the tone span is a weak mora. Candidates (a) and (b) both satisfy $\Delta H{:}\Delta_\mu\sigma$, and they incur the same violation of ALIGNR_μ(H,PWd). So what prefers the actual outcome, candidate (b)?

I propose that the actual outcome is not (b), but rather a candidate that has a foot dominating its last syllable. This foot is required by the constraint in (22). Coupled with a constraint against mis-alignment of the tone span by a foot, in (23), we will get the right result.

(22) ALIGNR_μ(PWd,F)
There must not be a mora between the right edge of every PWd and the right edge of some Foot.

(23) ALIGNR$_F$(H,PWd)
There must not be a foot between the right edge of every High tone span and the right edge of some Prosodic Word.

(24)

H karakteer		ΔH:Δ$_\mu$σ	ALIGNR$_\mu$ (H,PWd)	ALIGNR$_\mu$ (PWd,F)	ALIGNR$_F$ (H,PWd)
a.	F (ká.rák).teer]$_{PWd}$		*	*!	
b.	F ka.(rák.té)er]$_{PWd}$		*	*!	
c.	F F (ká.rák).teer]$_{PWd}$		*		*!
☞ d.	F F ka.(rák.té)er]$_{PWd}$		*		
e.	F ka.rak.(téér)]$_{PWd}$	*!			

Candidates (a) and (b) are repeated from (21), and this time they are ruled out because they don't have a foot aligned with the right edge of their PWd. Between candidates (c) and (d), candidate (d) wins because its High tone span is close enough to be one mora, but not one foot away from the right edge of the word.

Candidate (e), which has perfect alignment of the High tone span to the word was eliminated by ΔH:Δ$_\mu$σ. But we could imagine that alignment would force the shortening of the last vowel of the root. Since this doesn't happen, and because vowels do shorten in Serbo-Croatian when they precede the main stress, I conjecture that vowels are protected from shortening in footed syllables.

I formalize this in terms of positional faithfulness. Long vowels inside feet are protected by a constraint that does not protect them outside a foot. For this case, we will only need the constraint in (25c) — the other two will be crucial later.

(25) a. IDENT(μ)
If there is a segment *x* in the output, and there exists some *x'* in the input such that *x* and *x'* correspond, then *x* and *x'* are linked to the same number of moras.

b. *VV
No long vowels

c. IDENT(μ)$_F$
If a segment *x* is parsed into a foot in the output, and there exists some *x'* in the input such that *x* and *x'* correspond, then *x* and *x'* are linked to the same number of moras.

(26)

H karakteer		IDENT(μ)$_F$	ΔH:Δ$_μ$σ	ALIGNR$_μ$ (H,PWd)
a.	F ka.(rák.tér)]$_{PWd}$	*!		
☞ b.	F F ka.(rák.té)er]$_{PWd}$			*

In summary, we have seen that when the final vowel of the biggest M1 domain is long, the High tone span cannot perfectly align with the right edge of the PWd. The right edge of the tone domain shows up one mora to the left of the PWd's right edge.

7 M1-final long vowels + overt inflection

In the previous section, we have seen that M1-final long vowels disrupt perfect alignment of tone spans and Prosodic Words. Since there was no material available to the right of the PWd edge, the tone span had to go to the left. In this section, we see that when inflection suffixes are present, the High tone span will go one mora to the right of the Prosodic word, as in (27).

(27) a. H violiin]$_{M1}$ a]$_{MW}$ → F vi.o.l i í.ná 'violin-Nom/Sg'

b. H violiin]$_{M1}$ ama]$_{MW}$ → F vi.o.l i í.ná.ma 'violin-Dat/Pl'

What does our grammar predict for (27a) so far? We know that wherever the tone span will be, its weak mora will be dominated by the head syllable of a foot. We also know that candidates with a foot right-aligned with the PWd are preferred. So let's consider candidates where these things hold:

(28)

	H violiin]$_{M1}$ a]$_{MW}$	ΔH:$\Delta_{\mu}\sigma$	ALIGNR$_{\mu}$ (H,PWd)	ALIGNR$_{\mu}$ (PWd,F)	ALIGNR$_{F}$ (H,PWd)
☺ a.	F vi.o.l i (í.n]$_{PWd}$ á)]$_{MiP}$		*		
b.	F vi.o.(l í í).n]$_{PWd}$ a]$_{MiP}$	*!			
☺ c.	F F vi.(ó.l í)i.n]$_{PWd}$ a]$_{MiP}$		*		
d.	F F (v í .ó).l i i.n]$_{PWd}$ a]$_{MiP}$		*		!*

Candidate (b) is the only one that has a tone span perfectly aligned with the right edge of the Prosodic Word, but it is ruled out because the head of the tone span is not licensed by a strong mora. All the other candidate are misaligned with the PWd to the same extent — in each case, it is at least one mora away from the right edge of the PWd. The decision is passed down to ALIGNR$_{F}$(H,PWd), which rules out candidate (d), whose tone span is a whole foot away from the right edge. We are left with two equally harmonic candidates, (a) and (c). The constraint that prefers (a) over (c) is FOOTBIN.

(29)

	H violiin]$_{M1}$ a]$_{MW}$	FOOTBIN
☞ a.	F vi.o.l i (í.n]$_{PWd}$ á)]$_{MiP}$	
b.	F F vi.(ó.l í)i.n]$_{PWd}$ a]$_{MiP}$	*!

This is the point where the analysis proposed here diverges significantly from the proposal in Zec (1999). Zec (1999) proposes is that the tone is preferably aligned with the largest M1 domain, and if that's impossible, it aligns with the MW domain. For me, the alignment of the tone span with MW is accidental: What's forcing the tone span to the right is the combination of ALIGNR$_{F}$(H,PWd) and FOOTBIN.

The difference between the two proposals shows up in a case like (27a), repeated as (30) below. If indeed the tone span wants to align with the right edge of MW, we would expect the output to be *violi(námá).

(30) a. H violiin]$_{M1}$ ama]$_{MW}$ → F vi.o.l i í.ná.ma 'violin-Dat/Pl'

A derivation of (30) with the grammar we have so far is attempted in (31). I haven't considered a candidate with a tone span perfectly aligned with the right edge of the PWd, since we know that it's sure to lose.

(31)

H violiin]$_{M1}$ ama]$_{MW}$		ALIGNR$_{\mu}$ (H,PWd)	ALIGNR$_{\mu}$ (PWd,F)	ALIGNR$_{F}$ (H,PWd)	FOOTBIN
☺ a.	F F vi.o.l i i(n]$_{PWd}$ á.má)]$_{MiP}$	*			
☺ b.	F vi.o.l i (ín]$_{PWd}$ á).ma]$_{MiP}$	*			
c.	F F vi.(ó.l í)in]$_{PWd}$ a.ma]$_{MiP}$	*			*!
d.	F F (v í .ó).l i in]$_{PWd}$ a.ma]$_{MiP}$	*		*!	

Candidates (c) and (d) in (31) are eliminated for the reasons that we have seen before: a mono-moraic foot in (c), and a tone-span that is a whole foot away from the right edge of the PWd in (d). In (31), candidates (a) and (b) are equally harmonic. What prefers candidate (b), the actual output?

We already have the answer in the analysis. The constraint –ΔH:Δ_{σ}PWd, in (17), breaks the tie. Candidate (a) incurs a violation of –ΔH:Δ_{σ}PWd since it has a non-head of a tone span that's not dominated by the head syllable of the PWd.

(32)

H violiin]$_{M1}$ ama]$_{MW}$		–ΔH:Δ_{σ}PWd
a.	F F vi.o.l i i(n]$_{PWd}$ á.má)]$_{MiP}$	*!
☞ b.	F vi.o.l i (ín]$_{PWd}$ á).ma]$_{MiP}$	

This completes the analysis of M1 domains with underlying tones. We have seen that tones are organized in optimally right-headed binary tone spans. The head of the tone span must be licensed by the strong mora of a syllable, and the non-head of the tone span must be licensed by the strong syllable of the PWd.

In cases were the last syllable of the largest M1 domain is heavy, the tone span cannot perfectly align with the word. In these cases, the right edge of the tone span shows up one mora to the right of the PWd when such a mora is available, and one mora to the left otherwise.

The location of tone spans is determined by constrains on tone spans and by constraints on the shape and location of stress feet.

8 Toneless roots

Recall that toneless roots surface with initial stress and with a High tone on their initial mora, as in (33), repeated from (1).

(33) Toneless roots:

a.	jezero	→	F jé.ze.ro	‘lake’
b.	zaastav+a	→	F zá.a.sta.va	‘flag’
c.	meseec	→	F mé.seec	‘moon’

Our system so far would put a tone span close to the right edge of these words, contrary to what we need. A distinction needs to be made between underlying tones, which align with the right edge of the word, and epenthetic tones, whose spans’ heads align with the left edge. This derived environment effect can be achieved by conjoining markedness and faithfulness (Łubowicz 2002): A markedness constraint that demands left alignment of a tone span’s head, and the faithfulness constraint DEP-H, which militates against epenthetic High tones. The conjoined constraint is in (34).

(34) ALIGNL$_{\mu}$(ΔH,PWd) &$_{\text{Pwd}}$ DEP-H
In the domain of the Prosodic Word, there must not be a mora between the left edge of the head of every High tone span and the left edge of some Prosodic Word, and there must not be an epenthetic High tone.

The result is that if there is one or more epenthetic High tones in a word, the head of all spans will have to align with the left edge of the word, as in (35).

(35)

jezero		ALIGNL$_{\mu}$(ΔH,PWd)&DEP-H	ALIGNR$_{\mu}$(H,PWd)
a.	je(zéró)	*!	
b.	(jé)(zéró)	*!	
c.	(jézé)ro	*!	*
☞ d.	(jé)zero		*

All candidates in (35) have an epenthetic tone, so all heads of tone spans in the word must be perfectly left aligned. Candidates (a), (b) and (c) have a tone span whose head is a mora or more away from the edge, so they are ruled out. The candidates’ performance on ALIGNR$_{\mu}$(H,PWd) does not change their fate.

Candidate (d) is still harmonically bounded, however, by a candidate that doesn’t have an epenthetic tone at all, as in (36).

(36)

jezero		ALIGNL$_\mu$(ΔH,PWd) &DEP-H	ALIGNR$_\mu$ (H,PWd)	ALIGNR$_\mu$ (PWd,F)
☹ a.	F (jé)zero		*!	*
☞ b.	F jezero			

Candidate (a) satisfies ALIGNL$_\mu$(ΔH,PWd)&DEP-H because it only violates its DEP-H part, but its tone is not right aligned. Candidate (b) vacuously satisfies all alignment constraints on tone, since it doesn't have any tones.

We need to make sure that some constraint forces the epenthesis of a tone. The needed constraint is in (37).

(37) Δ_σPWd:H
If there is a mora *m* such that *m* is dominated by the head syllable of a Prosodic Word, then *m* is a part of a High tone span.

As can be seen in (38), this will fix the problem:

(38)

jezero		ALIGNL$_\mu$(ΔH,PWd) &DEP-H	Δ_σPWd:H	ALIGNR$_\mu$ (H,PWd)	ALIGNR$_\mu$ (PWd,F)
☞ a.	F (jé)zero			*	*
b.	F je(zé)ro	*!		*	
c.	F (jé)zero		*!	*	
d.	F jezero		*!		

Candidates (a) and (b), with an epenthetic tone in the strong syllable of the word, satisfy Δ_σPWd:H. Only candidate (a) does so with perfect left-alignment of its span's head, so it is the winner.

This completes the analysis of tone epenthesis in toneless words.

9 Vowel Shortening

In Serbo-Croatian, long vowels surfaces faithfully only in two positions: the stressed syllable and the PWd's final syllable. Since we know that these two positions are also footed

positions (recall that a foot is required at the left edge of every PWd), we can say that long vowels surface inside feet.

Vowels are shortened in other positions. We see vowel length alternations when stress moves to the right, leaving a long vowel to the left of the stressed syllable. The example in (39) shows the initial long syllable of the root surfacing faithfully when stressed, and shortened when a suffix that has a tone makes the stress appear farther to the right.

(39) a. dooboš]$_{M1}$ → F (dó)o.boš 'drum'

H F
b. dooboš]$_{M1}$ aar]$_{M1}$ a]$_{MW}$ → do.(bó.šá)a.ra 'drummer'

This pattern can be derived from constraint interaction: Long vowels will only be licensed in feet, and feet are needed only in two locations — dominating a tone span, and right aligned with the PWd.

Positional faithfulness can be used to license long vowels only inside feet. The constraints needed are in (40), repeated from (25) above.

(40) a. IDENT(μ)
If there is a segment *x* in the output, and there exists some *x'* in the input such that *x* and *x'* correspond, then *x* and *x'* are linked to the same number of moras.

b. *VV
No long vowels

c. IDENT(μ)$_F$
If a segment *x* is parsed into a foot in the output, and there exists some *x'* in the input such that *x* and *x'* correspond, then *x* and *x'* are linked to the same number of moras.

Let's see how these constraints protect long vowels were they are allowed:

(41)

dooboš	IDENT(μ)$_F$	ALIGNR$_μ$ (PWd,F)	*VV	IDENT(μ)
☞ a. F (dó)oboš		*	*	
b. F (dó)boš	*!			*

The feet in (41) dominate tone spans, and this in turn licenses the long vowel.

(42)

meseec	IDENT(μ)$_F$	ALIGNR$_μ$ (PWd,F)	*VV	IDENT(μ)
☞ a. F F (mé).seec			*	
b. F (mé).seec		*!	*	
c. F (mé).sec	*!			*

In (42), ALIGNR$_μ$(PWd,F) protects the root-final vowel from shortening. What happens when no active constraint demands the presence of a foot, as in (43)?

(43)

H dooboš]$_{M1}$ aar]$_{M1}$ a]$_{MW}$	IDENT(μ)$_F$	*VV	IDENT(μ)
☞ a. F F do.(bó.šá)a.ra		*	*
b. F F doo.(bó.šá)a.ra		**!	
c. F F F do.(bó.šá)a.ra	*!	*	*
d. F F F doo.(bó.šá)a.ra		**!	

In (43), two feet are needed: one to dominate the non-head of the tone span, and one to right-align with the PWd. The initial foot in candidate (d) doesn't help to license the long vowel, since nothing disfavors the unfaithful (a).

10 Conclusion

This paper revisits the Serbo-Croatian data in Inkelas & Zec (1988) and Zec (1999). I offer an analysis in terms of headed tonal domains which are licensed by metrical strong positions. The analysis goes transparently from input to output, with no intermediate steps.

The positioning of tone spans and feet are subject to alignment constraints on tones spans and on feet and to licensing constraints that relate tone spans to feet and vice versa. In the rule based analysis of Inkelas & Zec (1988), tones were assigned first, and feet were assigned later. The only reflex of this in the OT analysis is the fact that there is faithfulness to the presence of tone(s) in the input, but no faithfulness to foot structure; foot structure is determined solely by markedness constraints.

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