

Computational representation of unbounded stress: tiers with structural features

Hyunah Baek

Stony Brook University
`hyunah.baek@stonybrook.edu`

Computational Phonology Workshop
Dec 12, 2016

Take Home Message

- ▶ Most phonological patterns fit into the class of *tier-based strictly local* dependencies (TSL) (Heinz 2016).
- ▶ However, there still remain patterns that ostensibly display higher complexity than TSL, e.g., unbounded stress.

Tiers with structural features

Once grammar has access to structural information of syllables, unbounded stress patterns are TSL after all.

Take Home Message

- ▶ Most phonological patterns fit into the class of *tier-based strictly local* dependencies (TSL) (Heinz 2016).
- ▶ However, there still remain patterns that ostensibly display higher complexity than TSL, e.g., unbounded stress.

Tiers with structural features

Once grammar has access to structural information of syllables, unbounded stress patterns are TSL after all.

Outline

- 1 Unbounded stress: RHOL as TSL
- 2 Non-final RHOL as TSL?
- 3 TSL with Structural Features
 - Tiers with Structural Features
 - Non-final RHOL as TSL-SF
- 4 Alternative accounts

Unbounded stress: RHOL

Chuvash word stress (Hayes 1995)

One primary stress per word

on the rightmost heavy syllable,
otherwise on the leftmost syllable

well-formed	ill-formed
LH́H	*ĹHH
LH́L	*ĹHH
ĹLL	*LĹL

Unbounded stress: RHOL

Chuvash word stress (Hayes 1995)

One primary stress per word



Culminativity

on the rightmost heavy syllable,
otherwise on the leftmost syllable



RHOL

well-formed	ill-formed
LH́	*ĹHH
LH́L	*ĹHH
ĹLL	*LĹ

Culminativity

Culminativity: Every word has exactly one primary stress

Culminativity is Tier-based Strictly Local (TSL)

$$G = \langle T = \{\acute{H}, \acute{L}, \bowtie, \bowtie\}, \quad S = \{*\acute{H}\acute{H}, *\acute{L}\acute{L}, *\acute{H}\acute{L}, *\acute{L}\acute{H}, *\bowtie\bowtie\} \rangle$$

a.

$\bowtie \quad L \quad H \quad \acute{H} \quad \bowtie$

b.

$* \quad \bowtie \quad \acute{L} \quad H \quad \acute{H} \quad \bowtie$

c.

$* \quad \bowtie \quad L \quad H \quad H \quad \bowtie$

Culminativity

Culminativity: Every word has exactly one primary stress

Culminativity is Tier-based Strictly Local (TSL)

$$G = \langle T = \{\acute{H}, \acute{L}, \times, \times\}, \quad S = \{*\acute{H}\acute{H}, *\acute{L}\acute{L}, *\acute{H}\acute{L}, *\acute{L}\acute{H}, *\times\times\} \rangle$$

a.

.....
 × L H \acute{H} ×

b.

.....
 * × \acute{L} H \acute{H} ×

c.

.....
 * × L H H ×

Culminativity

Culminativity: Every word has exactly one primary stress

Culminativity is Tier-based Strictly Local (TSL)

$$G = \langle T = \{\acute{H}, \acute{L}, \times, \times\}, \quad S = \{*\acute{H}\acute{H}, *\acute{L}\acute{L}, *\acute{H}\acute{L}, *\acute{L}\acute{H}, *\times\times\} \rangle$$

a.

$\times \quad \quad \acute{H} \quad \times$

.....

$\times \quad L \quad H \quad \acute{H} \quad \times$

b.

$\times \quad \acute{L} \quad \quad \acute{H} \quad \times$

.....

$* \quad \times \quad \acute{L} \quad H \quad \acute{H} \quad \times$

c.

$\times \quad \quad \quad \quad \quad \times$

.....

$* \quad \times \quad L \quad H \quad H \quad \times$

Culminativity

Culminativity: Every word has exactly one primary stress

Culminativity is Tier-based Strictly Local (TSL)

$$G = \langle T = \{\acute{H}, \acute{L}, \bowtie, \bowtie\}, \quad S = \{*\acute{H}\acute{H}, *\acute{L}\acute{L}, *\acute{H}\acute{L}, *\acute{L}\acute{H}, *\bowtie\bowtie\} \rangle$$

a.

$\bowtie \quad \acute{H} \quad \bowtie$

 $\bowtie \quad L \quad H \quad \acute{H} \quad \bowtie$

b.

$\bowtie \quad \boxed{\acute{L} \quad \acute{H}} \quad \bowtie$

 $* \quad \bowtie \quad \acute{L} \quad H \quad \acute{H} \quad \bowtie$

c.

$\boxed{\bowtie \quad \quad \quad \bowtie}$

 $* \quad \bowtie \quad L \quad H \quad H \quad \bowtie$

RHOL

RHOL: Rightmost heavy, otherwise leftmost

RHOL is TSL

$$G = \langle T = \{\acute{H}, H, \acute{L}, L\}, \quad S = \{*\acute{H}H, *\acute{L}H, *H\acute{L}, *L\acute{L}\} \rangle$$

a.

b.

c.

* × L \acute{H} H ×

* × \acute{L} H H ×

* × L L \acute{L} ×

RHOL

RHOL: Rightmost heavy, otherwise leftmost

RHOL is TSL

$$G = \langle T = \{\acute{H}, H, \acute{L}, L\}, \quad S = \{*\acute{H}H, *\acute{L}H, *H\acute{L}, *L\acute{L}\} \rangle$$

a.

L \acute{H} H

* × L \acute{H} H ×

b.

\acute{L} H H

* × \acute{L} H H ×

c.

L L \acute{L}

* × L L \acute{L} ×

Unbounded stress: Non-final RHOL

Classical Arabic word stress (McCarthy 1979)

One primary stress

on the rightmost non-final H,
otherwise on the leftmost L

well-formed	ill-formed
LLH́H	*LLH́H
LH́HH	*ĹHHH
́LLLL	*LLĹL

Unbounded stress: Non-final RHOL

Classical Arabic word stress (McCarthy 1979)

One primary stress

on the rightmost non-final H,
otherwise on the leftmost L

Culminativity

non-final RHOL

well-formed	ill-formed
LLH́H	*LLH́H
LH́HH	*LH́HH
́LLLL	*LLĹL

Non-final RHOL as TSL?

Non-final RHOL: Non-final rightmost H, otherwise leftmost

Is Non-final RHOL TSL?

$$G = \langle T = \{\acute{H}, H, \acute{L}, \times\}, S = \{*\acute{H}\times, *\acute{H}H, *\acute{L}H, *\acute{H}\acute{L}, *\acute{L}\acute{L}\} \rangle$$

a.

H H \acute{H} \times

* \times L H H \acute{H} \times

b.

\acute{H} H H \times

* \times L \acute{H} H H \times

c.

\acute{H} H \times

\times L L \acute{H} H \times

Without a distinction between **final** and **non-final** H, TSL approaches over-/under-generate.

Non-final RHOL as TSL?

Non-final RHOL: Non-final rightmost H, otherwise leftmost

Is Non-final RHOL TSL?

$$G = \langle T = \{\acute{H}, H, \acute{L}, \times\}, S = \{*\acute{H}\times, *\acute{H}H, *\acute{L}H, *H\acute{L}, *L\acute{L}\} \rangle$$

a.

H H \acute{H} \times

* \times L H H \acute{H} \times

b.

\acute{H} H H \times

* \times L \acute{H} H H \times

c.

\acute{H} H \times

\times L L \acute{H} H \times

Without a distinction between final and non-final H, TSL approaches over-/under-generate.

Non-final RHOL as TSL?

Non-final RHOL: Non-final rightmost H, otherwise leftmost

Is Non-final RHOL TSL?

$$G = \langle T = \{\acute{H}, H, \acute{L}, \times\}, \quad S = \{*\acute{H}\times, *\acute{H}H, *\acute{L}H, *H\acute{L}, *L\acute{L}\} \rangle$$

a.

H H \acute{H} \times

* \times L H H \acute{H} \times

b.

\acute{H} H H \times

* \times L \acute{H} H H \times

c.

\acute{H} H \times

\times L L \acute{H} H \times

Without a distinction between final and non-final H, TSL approaches over-/under-generate.

Non-final RHOL as TSL?

Non-final RHOL: Non-final rightmost H, otherwise leftmost

Is Non-final RHOL TSL?

$$G = \langle T = \{\acute{H}, H, \acute{L}, \times\}, \quad S = \{*\acute{H}\times, *\acute{H}H, *\acute{L}H, *\acute{H}\acute{L}, *\acute{L}\acute{L}\} \rangle$$

a.

H H $\acute{H} \times$

* \times L H H $\acute{H} \times$

b.

$\acute{H} H$ H \times

* \times L $\acute{H} H H \times$

c.

$\acute{H} H$ \times

\times L L $\acute{H} H \times$

Without a distinction between **final** and **non-final** H, TSL approaches over-/under-generate.

Structural Features

Prosodic elements are composed of structural features.
(e.g., syllable weight, stress, syllable location, word boundary)

×	L	L	Ĥ	H	×
+boundary	+light	+light	+heavy	+heavy	+boundary
	-stress	-stress	+stress	-stress	
	+initial	-initial	-initial	-initial	
	-final	-final	-final	+final	

Structural Features

Prosodic elements are composed of structural features.
(e.g., syllable weight, stress, syllable location, word boundary)

×	L	L	Ĥ	H	×
+boundary	+light	+light	+heavy	+heavy	+boundary
	-stress	-stress	+stress	-stress	
	+initial	-initial	-initial	-initial	
	-final	-final	-final	+final	

Tier-based Strictly Local with Structural Features (TSL-SF)

Non-final RHOL is TSL-SF

$$G = \left\langle T = \begin{Bmatrix} [+stress], \\ [+heavy], \\ [+initial], \\ [+final] \end{Bmatrix}, S = \begin{Bmatrix} * [+heavy, +stress, -initial, +final], \\ * [+light, +stress, -initial], \\ * [+heavy, +stress][+heavy, -stress, -final], \\ * [+light, +stress][+heavy, -stress, -final] \end{Bmatrix} \right\rangle$$

- ▶ T specifies feature matrices such that a symbol is projected onto the tier iff it is compatible with one of the matrices.
- ▶ S specifies forbidden substrings that must not be present in strings projected on the tier.

Tier-based Strictly Local with Structural Features (TSL-SF)

Non-final RHOL is TSL-SF

$$G = \left\langle T = \begin{Bmatrix} [+stress], \\ [+heavy], \\ [+initial], \\ [+final] \end{Bmatrix}, S = \begin{Bmatrix} * [+heavy, +stress, -initial, +final], \\ * [+light, +stress, -initial], \\ * [+heavy, +stress] [+heavy, -stress, -final], \\ * [+light, +stress] [+heavy, -stress, -final] \end{Bmatrix} \right\rangle$$

a.

* ✕ L H́ H H ✕

b.

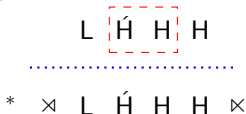
✕ L L H́ H ✕

Tier-based Strictly Local with Structural Features (TSL-SF)

Non-final RHOL is TSL-SF

$$G = \left\langle T = \begin{Bmatrix} [+stress], \\ [+heavy], \\ [+initial], \\ [+final] \end{Bmatrix}, S = \begin{Bmatrix} * [+heavy, +stress, -initial, +final], \\ * [+light, +stress, -initial], \\ * [+heavy, +stress][+heavy, -stress, -final], \\ * [+light, +stress][+heavy, -stress, -final] \end{Bmatrix} \right\rangle$$

a.



b.

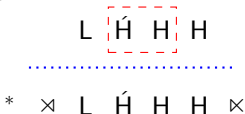


Tier-based Strictly Local with Structural Features (TSL-SF)

Non-final RHOL is TSL-SF

$$G = \left\langle T = \begin{Bmatrix} [+stress], \\ [+heavy], \\ [+initial], \\ [+final] \end{Bmatrix}, S = \begin{Bmatrix} * [+heavy, +stress, -initial, +final], \\ * [+light, +stress, -initial], \\ * [+heavy, +stress] [+heavy, -stress, -final], \\ * [+light, +stress] [+heavy, -stress, -final] \end{Bmatrix} \right\rangle$$

a.



b.

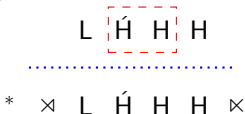


Tier-based Strictly Local with Structural Features (TSL-SF)

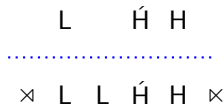
Non-final RHOL is TSL-SF

$$G = \left\langle T = \begin{Bmatrix} [+stress], \\ [+heavy], \\ [+initial], \\ [+final] \end{Bmatrix}, S = \begin{Bmatrix} * [+heavy, +stress, -initial, +final], \\ * [+light, +stress, -initial], \\ * [+heavy, +stress][+heavy, -stress, -final], \\ * [+light, +stress][+heavy, -stress, -final] \end{Bmatrix} \right\rangle$$

a.



b.



Tier-based Strictly Local with Structural Features (TSL-SF)

Non-final RHOL is TSL-SF

$$G = \left\langle T = \begin{Bmatrix} [+stress], \\ [+heavy], \\ [+initial], \\ [+final] \end{Bmatrix}, S = \begin{Bmatrix} * [+heavy, +stress, -initial, +final], \\ * [+light, +stress, -initial], \\ * [+heavy, +stress][+heavy, -stress, -final], \\ * [+light, +stress][+heavy, -stress, -final] \end{Bmatrix} \right\rangle$$

a. * **LH**[́]H

b. ***L**[́]LH

c. ***L**[́]HH

Tier-based Strictly Local with Structural Features (TSL-SF)

Non-final RHOL is TSL-SF

$$G = \left\langle T = \begin{Bmatrix} [+stress], \\ [+heavy], \\ [+initial], \\ [+final] \end{Bmatrix}, S = \begin{Bmatrix} * [+heavy, +stress, -initial, +final], \\ * [+light, +stress, -initial], \\ * [+heavy, +stress][+heavy, -stress, -final], \\ * [+light, +stress][+heavy, -stress, -final] \end{Bmatrix} \right\rangle$$

a. * LHH́

b. ***L**L**H**

c. ***L**HH

Tier-based Strictly Local with Structural Features (TSL-SF)

Non-final RHOL is TSL-SF

$$G = \left\langle T = \begin{Bmatrix} [+stress], \\ [+heavy], \\ [+initial], \\ [+final] \end{Bmatrix}, S = \begin{Bmatrix} * [+heavy, +stress, -initial, +final], \\ * [+light, +stress, -initial], \\ * [+heavy, +stress][+heavy, -stress, -final], \\ * [+light, +stress][+heavy, -stress, -final] \end{Bmatrix} \right\rangle$$

a. * LHH́

b. *ĹLH

c. *ĹHH

Tier-based Strictly Local with Structural Features (TSL-SF)

Non-final RHOL is TSL-SF

$$G = \left\langle T = \left\{ \begin{array}{l} [+stress], \\ [+heavy], \\ [+initial], \\ [+final] \end{array} \right\}, S = \left\{ \begin{array}{l} * [+heavy, +stress, -initial, +final], \\ * [+light, +stress, -initial], \\ * [+heavy, +stress][+heavy, -stress, -final], \\ * [+light, +stress][+heavy, -stress, -final] \end{array} \right\} \right\rangle$$

a. * LHH́

b. *ĹLH

c. *ĹHH

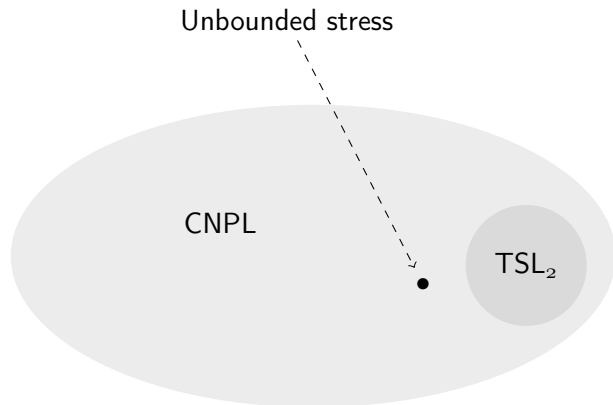
Unbounded stress such as non-final RHOL is TSL-SF.

An alternative account

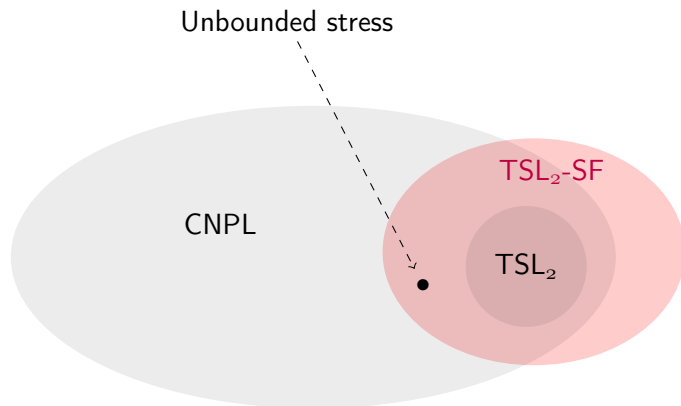
Strother-Garcia et al. (2016): Unbounded stress as Conjunction of Negative and Positive Literals (CNPL) with enriched strings

$$G_{RHOL} = \sigma \wedge \acute{\sigma} \wedge \neg \acute{L}\sigma \wedge \neg H\acute{\sigma}$$

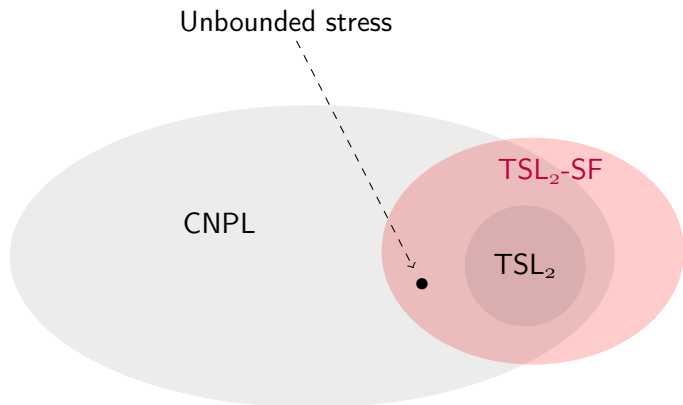
CNPL, TSL, TSL-SF, and other accounts



CNPL, TSL, TSL-SF, and other accounts

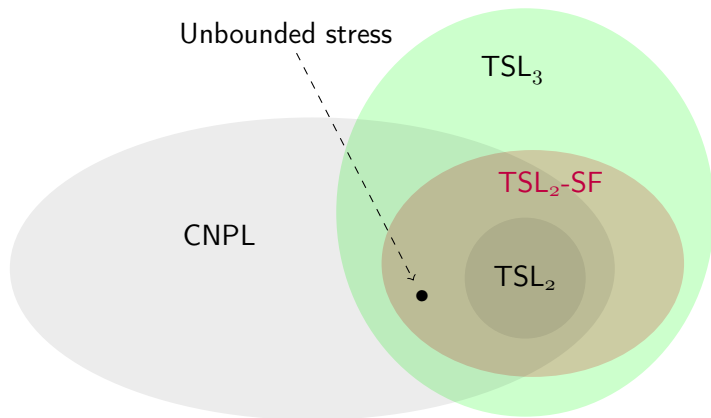


CNPL, TSL, TSL-SF, and other accounts



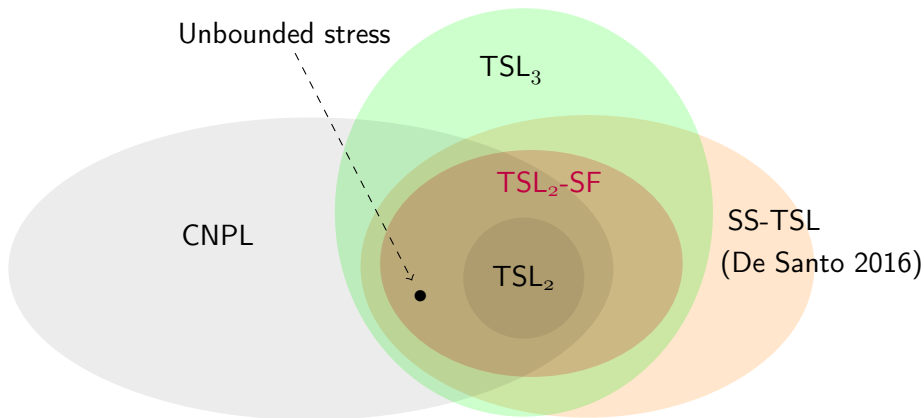
- ▶ CNPL and TSL(-SF) are two incomparable formal classes.
- ▶ However, TSL-SF has the advantage of staying closer to the hypothesis that phonological patterns are TSL.

CNPL, TSL, TSL-SF, and other accounts



- ▶ CNPL and TSL(-SF) are two incomparable formal classes.
- ▶ However, TSL-SF has the advantage of staying closer to the hypothesis that phonological patterns are TSL.

CNPL, TSL, TSL-SF, and other accounts



- ▶ CNPL and TSL(-SF) are two incomparable formal classes.
- ▶ However, TSL-SF has the advantage of staying closer to the hypothesis that phonological patterns are TSL.

Conclusion: Unbounded Stress is TSL-SF

- ▶ TSL-SF makes structural features of syllables available in tier projection and substring evaluation.
- ▶ This expands the expressivity of TSL and accommodates unbounded stress patterns like non-final RHOL.

References

- De Santo, A.** 2016. *A Game of Tiers: Exploring the Formal Properties of TSL Languages*. Ms., Stony Brook University.
- Hayes, B.** 1976. *A Metrical Theory of Stress Rules*. Doctoral Dissertation, MIT.
- Heinz, J.** 2014. Culminativity times harmony equals unbounded stress. In *Word Stress: Theoretical and Typological Issues*, 255-275.
- Heinz, J.** 2016. *The computational nature of phonological generalizations*. Ms., University of Delaware.
- Jardine, A.** 2014. Computationally, tones are different. *Under review with Phonology*.
- McCarthy, J.**, 1979. On stress and syllabification. *LI* 10(3), 443-465.
- Strother-Garcia, K., Hwangbo, H. J., & Heinz, J.** 2016. *Characterizing and learning unbounded stress patterns with a restricted logic and enriched strings*. AMP 2016 abstract.

Appendix 1: suprasegment vs. segment

- ▶ Jardine (2014): Suprasegmental phonology is more powerful than segmental phonology.
- ▶ e.g., **First-Last Harmony**(unattested) (Heinz 2016): Word-initial and word-final sibilants agree in anteriority, but word-medial sibilants may disagree.

well-formed	ill-formed
simasas	ʃimasas
sokefus	sokefuʃ
ʃakemiʃ	sakemiʃ
ʃusomeʃ	ʃusomes

Appendix 1: suprasegment vs. segment

- ▶ In the current analysis, the computational gap is derived from the limited availability of structure features.
- ▶ That is, in prosodic phonology the grammar can refer to structural features of syllables, but not in segmental phonology.
- ▶ This mirrors existing phonological theories where prosodic features such as *stress* play roles only at a later stage of derivation (Hayes 1976).

Appendix 2: Culminativity as TSL-SF

Non-final RHOL is TSL-SF

$$G = \left\langle T = \begin{Bmatrix} [+stress], \\ [+heavy], \\ [+initial], \\ [+final] \end{Bmatrix}, S = \begin{Bmatrix} * [+heavy, +stress, -initial, +final], \\ * [+light, +stress, -initial], \\ * [+heavy, +stress][+heavy, -stress, -final], \\ * [+light, +stress][+heavy, -stress, -final] \end{Bmatrix} \right\rangle$$

Culminativity is TSL-SF

$$G = \left\langle T = \begin{Bmatrix} [+boundary], \\ [+stress] \end{Bmatrix}, S = \begin{Bmatrix} * [+boundary][+boundary], \\ * [+stress][+stress] \end{Bmatrix} \right\rangle$$