Local well-formedness constraints for non-linear phonology

Adam Jardine & Jeffrey Heinz

Dept. of Linguistics & Cognitive Science
University of Delaware

University of Pennsylvania
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Introduction

- This talk presents a theory of variation in tone patterns based on language-specific, inviolable constraints which forbid substructures
- These constraints are fundamentally **local**, in a computational sense
- Previous approaches:
  - Directional association and rules in derivational frameworks (e.g., Goldsmith, 1976; Archangeli and Pulleyblank, 1994)
  - Optimal satisfaction of violable constraints (Zoll, 2003)
- Both invoke a globally evaluated notion of directionality; misses the local nature of tonal patterns and thus makes bad predictions
- Forbidden substructure constraints are restrictive, empirically adequate, and learnable

What is the nature of sound patterns in language?

- Two central issues in phonology:
  - **Well-formedness**
    blick vs. **bnick* (Chomsky and Halle, 1965)
  - Systematic changes in pronunciation of sounds (**transformations**)
    write [raɪtˀ] vs. *writer* [raɪɾər]
- How do we best characterize variation in language-specific well-formedness patterns and transformations?
- That is,
  - What is a possible well-formedness pattern/transformation?
  - How might they be learned?

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Tonal well-formedness patterns

Mende word tone (Leben, 1973; Goldsmith, 1976)

a. kɔ́	H	‘war’	b. pɛ́lɛ́	HH	‘house’	c. háwámá	HHH	‘waist’
d. kpà	L	‘debt’	e. bɛ̀lɛ̀	LL	‘pants’	f. kpàkàlì	LLL	‘stool’
g. mbû	F	‘owl’	h. ngílà	HL	‘dog’	i. félàmà	HLL	‘junction’
j. mbǎ	R	‘rice’	k. nìká	LH	‘cow’	l. ndàvúlá	LHH	‘sling’
m. mbâ	R-F	‘comp.’	n. nyàhâ	LF	‘woman’	o. nìkílì	LHL	‘nut’

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- Words choose between 5 melodies (*HLH)
- Stretches of tone appear at the right edge of the word
  HHH, HLL
  *LLH, *HHL
- Contours appear at the right edge of the word
  R, LF, *RL

Tonal well-formedness patterns

Hausa tone-integrating suffixes (Newman, 1986, 2000)

a. jáa	H	‘pull’	b. jíráa	HH	‘wait for’	c. béebíyáa	HHH	‘deaf mute’
c. wàa	L	‘who?’	d. màcè	LL	‘woman’	e. zàmfàrà	LLL	‘Zamfara’
f. jàakíi	LH	‘donkey’	g. jìmìnúu	HHL	‘ostriches’	h. bàbbàbbàkú	LLLH	‘roasted’
i. fáadì	HL	‘fall’	j. hántúnàa	LLH	‘noses’	k. búhúnhúnàa	HHHL	‘sacks’
l. mântá	FH	‘forget’	m. káràntá	HLH	‘read’	n. kákkáràntá	HHLH	‘reread’

- HLH allowed (LHL not depicted)
- Stretches of tone appear at the *left* edge of the word
  LLH, HHL
  *LHH, *HLL
- Contours appear at the *left* edge of the word
  FH, *HR

Tonal well-formedness patterns

Kukuya word tone (Hyman, 1987; Zoll, 2003)

a. kâ ‘to pick’	F	b. sámà ‘conversation’	HL	c. káràgà ‘entangled’	HLL
d. sǎ ‘knot’	R	e. kàrá ‘paralytic’	LH	f. m^{w}àrə̀gí ‘brother’	LLH
g. bá ‘palms’	H	h. bágá ‘show knives’	HH	i. bálágá ‘fence’	HHH
j. bvîfalls’	R-F	k. pàlî ‘goes out’	LF	l. kàlə́gì ‘turns’	LHL

- Contours on right edge of word
- No stretches of H in the presence of L

Tonal well-formedness patterns

N. Karanga Shona non-assertive tense
(Odden, 1986; Hewitt and Prince, 1989)

hàndákà-p-á	‘I didn’t give’	H
hàndákà-tór-à	‘I didn’t take’	HL
hàndákà-tór-ès-á	‘I didn’t make take’	HLH
hàndákà-tór-és-èr-á	‘I didn’t make take for’	HHLH
hàndákà-tór-és-ér-àn-á	‘I didn’t make take for e.o.’	HHHLH
hàndákà-tór-és-ér-ès-àn-á	‘I didn’t make take a lot for e.o.’	HHHLLH
hàndákà-tór-és-ér-ès-ès-àn-á	〃 〃	HHHLLLH

- Two Hs on either end, first spreads to three syllables maximally

Tonal well-formedness patterns

Unattested generalizatons

- The number of Hs in the word must be in the Fibonacci sequence
- The number of Hs and Ls must be equal
- A single H appears as close to the center of the word as possible

Summary: Tonal well-formedness patterns

- Attested
  - Fixed melodies realized over words of different lengths (all)
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Justifying autosegmental representations

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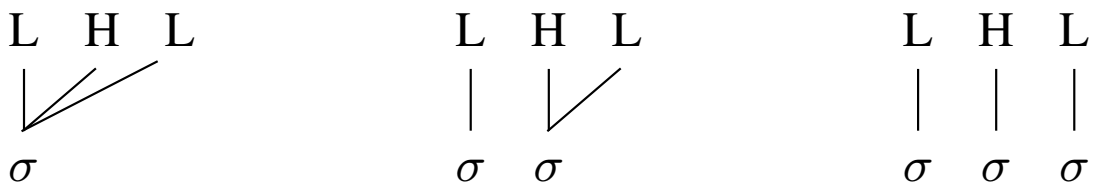


Justifying autosegmental representations

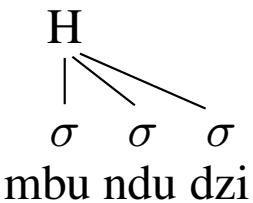
- Tones behave independently of syllables
  Tiv (Pulleyblank, 1986)

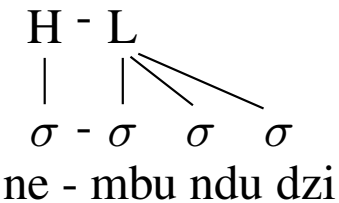
sə́ŋ è sə́ŋ	HLH	‘bird of bird’	[¯ _ ¯]	H L H | | | σ σ σ
sə́ŋ ꜜsə́ŋ	HꜜH	(same)	[¯ ¯]	H L H | | σ σ

Justifying autosegmental representations

- Stretches of tone behave as single units
  Shona (Odden, 1980)

mbwá	H	‘dog’	né-mbwà	H-L	‘with dog’
hóvé	HH	‘fish’	né-hòvè	H-LL	‘with fish’
mbúndúdzí	HHH	‘worm’	né-mbùndùdzì	H-LLL	‘with worm’





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Computational locality

- *blick* vs. **bnick*
- Constraint: **#bn*
- This is a **forbidden substructure constraint**

* | # | b | n |

| # | b | l | ɪ | k | # |

| **#** | **b** | **n** | ɪ | k | # |

Computational locality

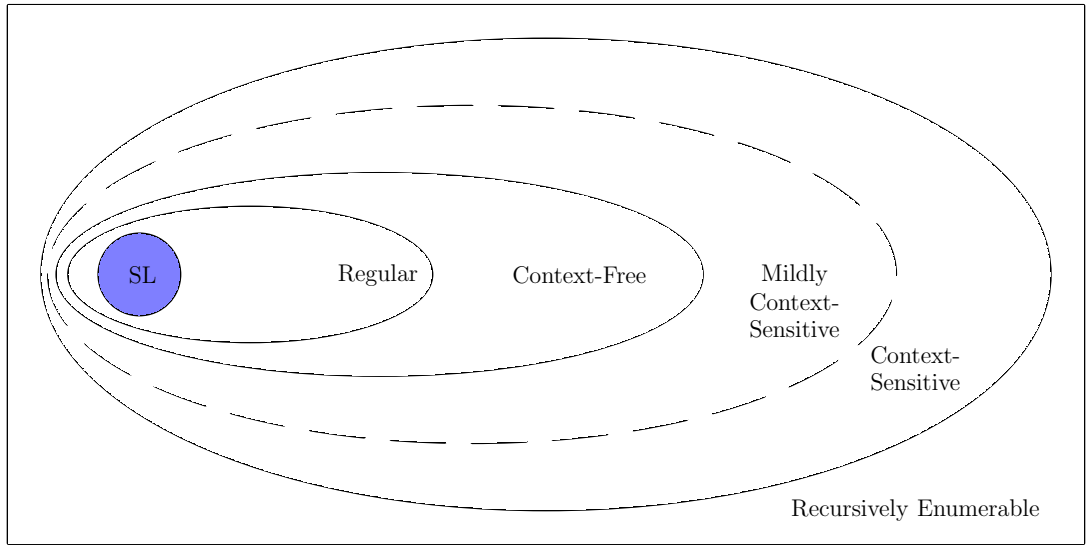


Fig: Strictly Local string sets in the Chomsky Hierarchy

- **Strictly Local string sets**: sets of strings described by list of forbidden substrings (McNaughton and Papert, 1971; Rogers et al., 2013)
- SL computations are among the *simplest* possible
- Many segmental well-formedness constraints are SL (Heinz, 2009, 2010; Rogers et al., 2013)

Computational locality

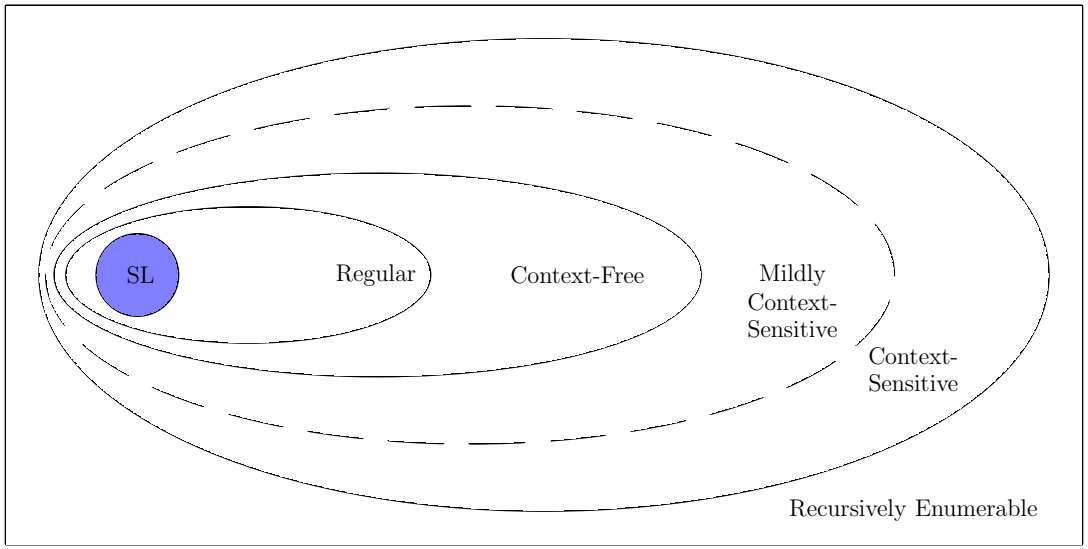
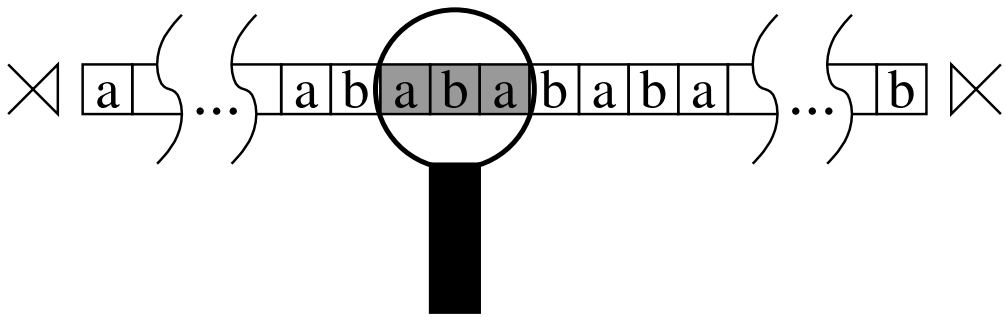


Fig: Strictly Local string sets in the Chomsky Hierarchy

- Forbidden substring constraints are learnable (García et al., 1990; Heinz, 2010; Jardine and Heinz, accepted)
- Locality has been extended to learnable classes of transformations (Chandlee, 2014; Chandlee et al., 2015)

Computational locality

- Well-formedness determined solely by well-formedness of local substructures



Rogers and Pullum (2011); Rogers et al. (2013)

Computational locality

- As such, forbidden substructure constraints cannot specify patterns in which:
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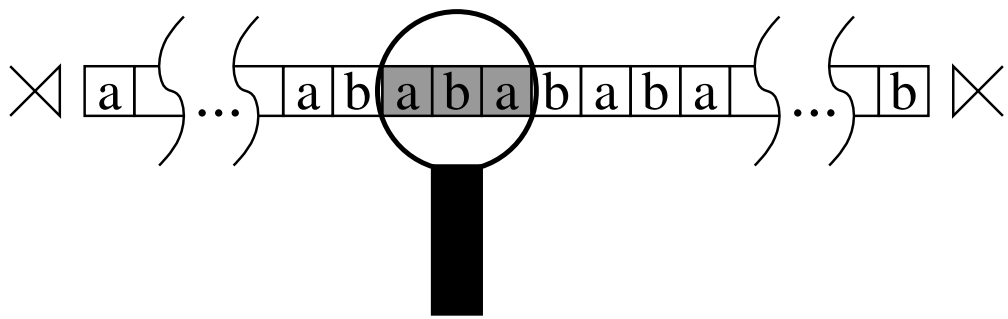
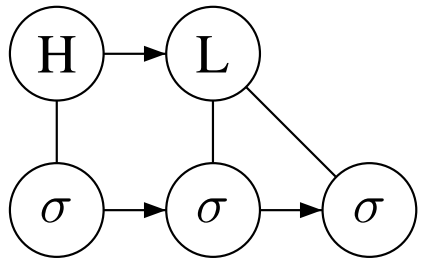


Rogers and Pullum (2011); Rogers et al. (2013)

Computational locality

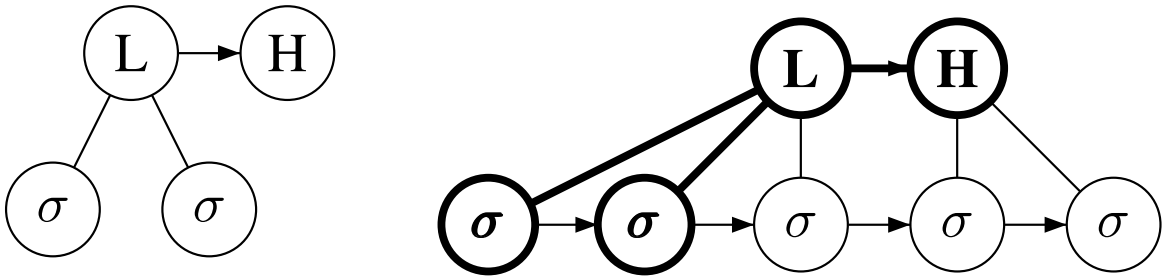
- What is a substructure in an autosegmental representation?

- Autosegmental representations are **graphs** (Goldsmith, 1976; Coleman and Local, 1991)

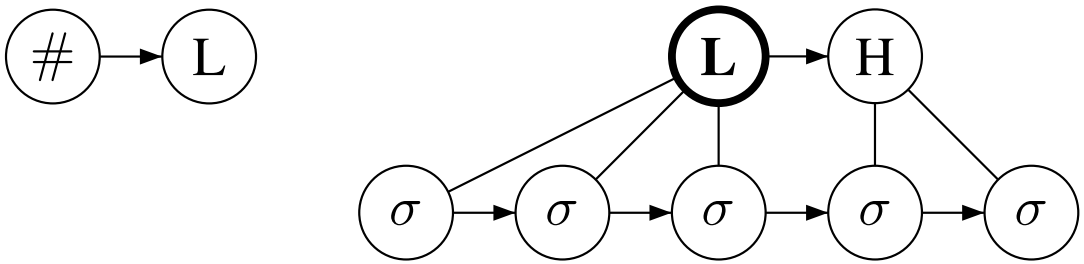


Computational locality

- Let a **subgraph** be some finite, connected piece of a graph



- Subgraphs may refer to boundaries on each tier (not depicted in full graphs)



Language-specific well-formedness

- We specify lists of **forbidden subgraph constraints** as in the following, where each ϕ_i is a subgraph:

$$\neg\phi_1 \wedge \neg\phi_2 \wedge \neg\phi_3 \wedge \ldots \wedge \neg\phi_n$$

- $\neg\phi$ means "ϕ is a forbidden substructure"
- These constraints are **inviolable** and **language-specific**

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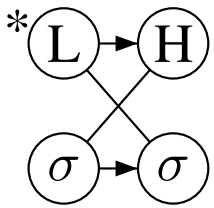
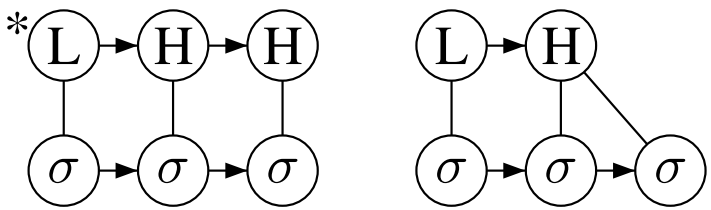
Some assumptions

- Association preserves precedence relations **(the No-Crossing Constraint (NCC))**

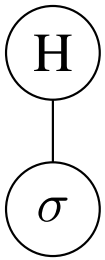


- Adjacent nodes on tonal tier cannot be identical **(the Obligatory Contour Principle (OCP)**

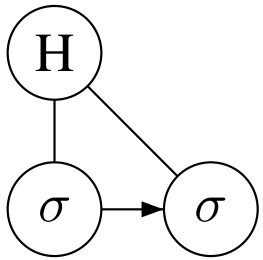


Case study: Mende

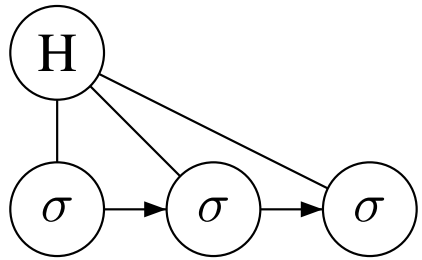
- Autosegmental representations in Mende:



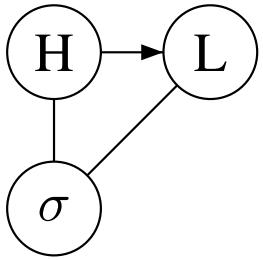
(H)



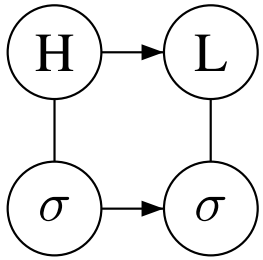
(HH)



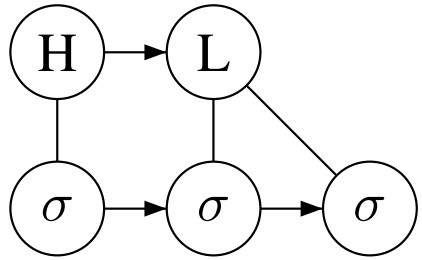
(HHH)



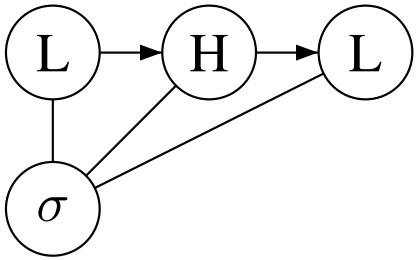
(F)



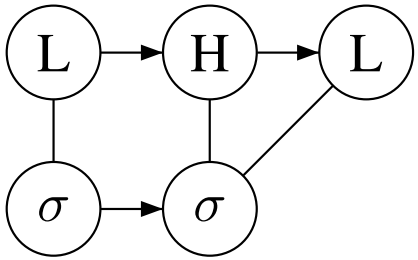
(HL)



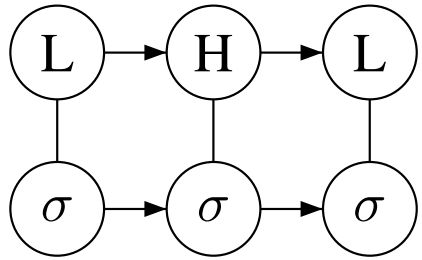
(HLL)



(R-F)



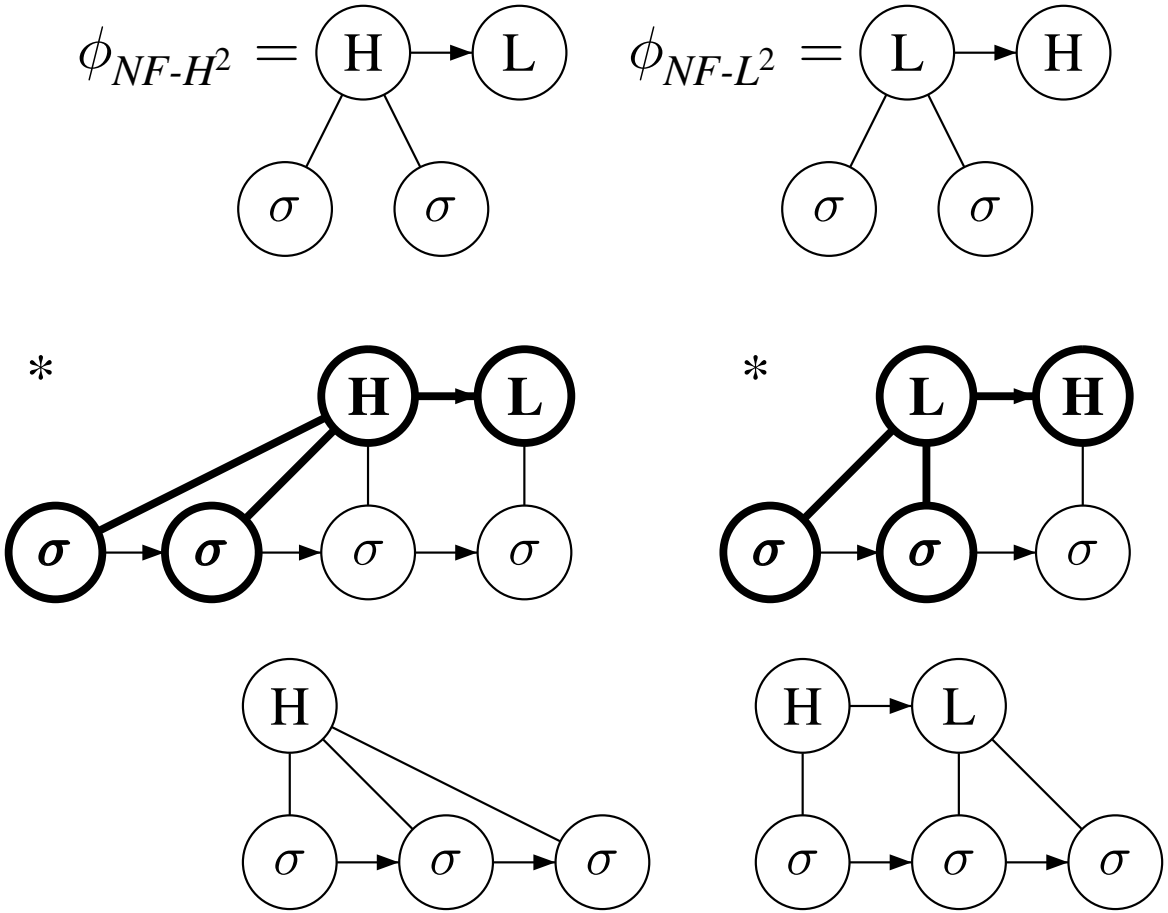
(LF)



(LHL) . . .

Case study: Mende

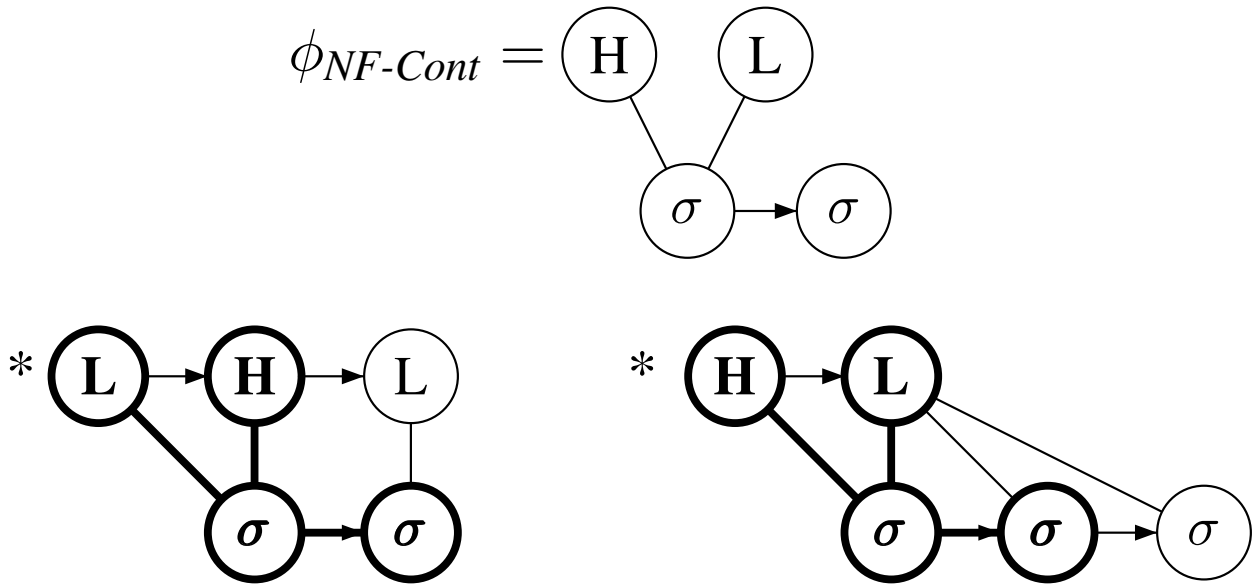
Stretches of tone in Mende



- Kukuya will use $\phi_{NF\text{-}H^2}$ but not $\phi_{NF\text{-}L^2}$

Case study: Mende

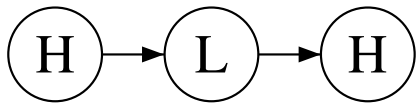
Contours in Mende

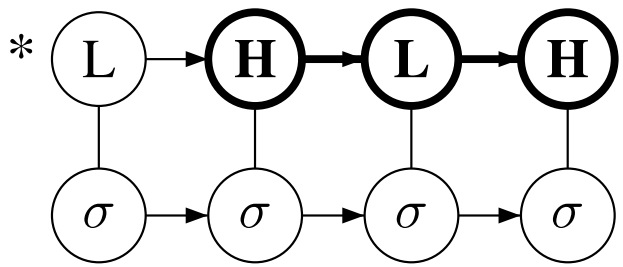


- c.f. Zhang (2000)

Case study: Mende

Melody constraint in Mende

$\phi_{HLH} =$ 



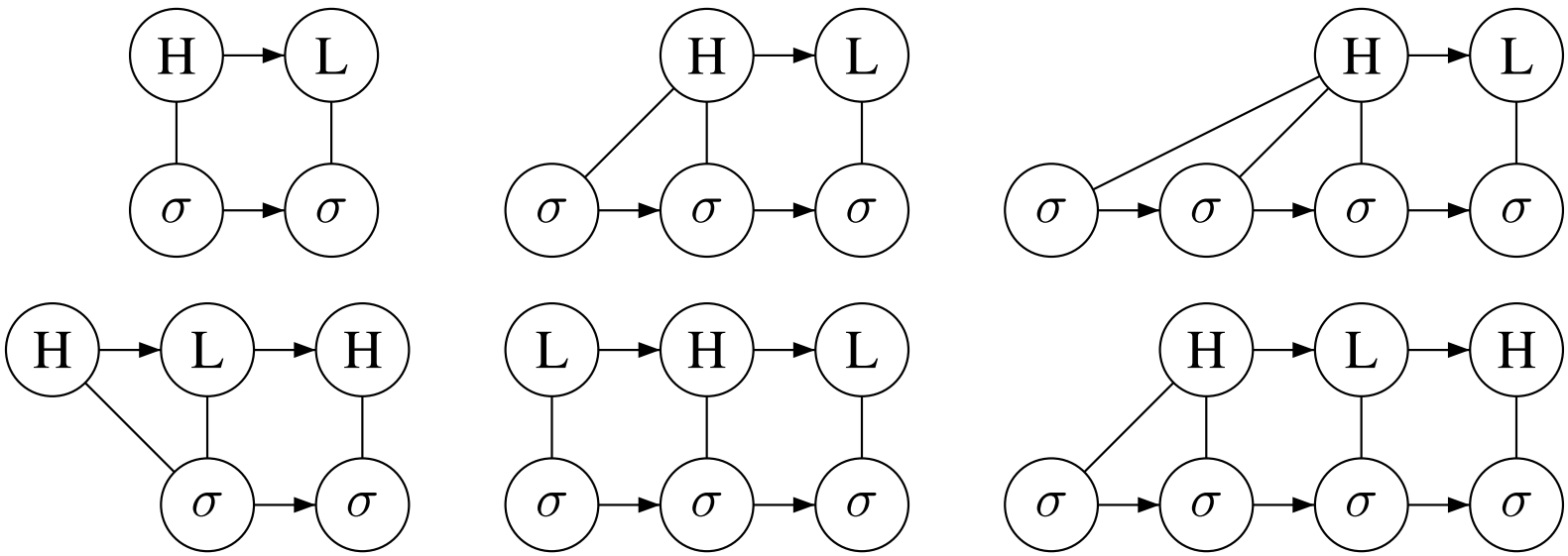
Case study: Mende

- Mende summary:

$$\neg\phi_{HLH} \wedge \neg\phi_{NF\text{-}Cont} \wedge \neg\phi_{NF\text{-}H^2} \wedge \neg\phi_{NF\text{-}L^2}$$

Case study: Hausa

- Autosegmental representations in Hausa:



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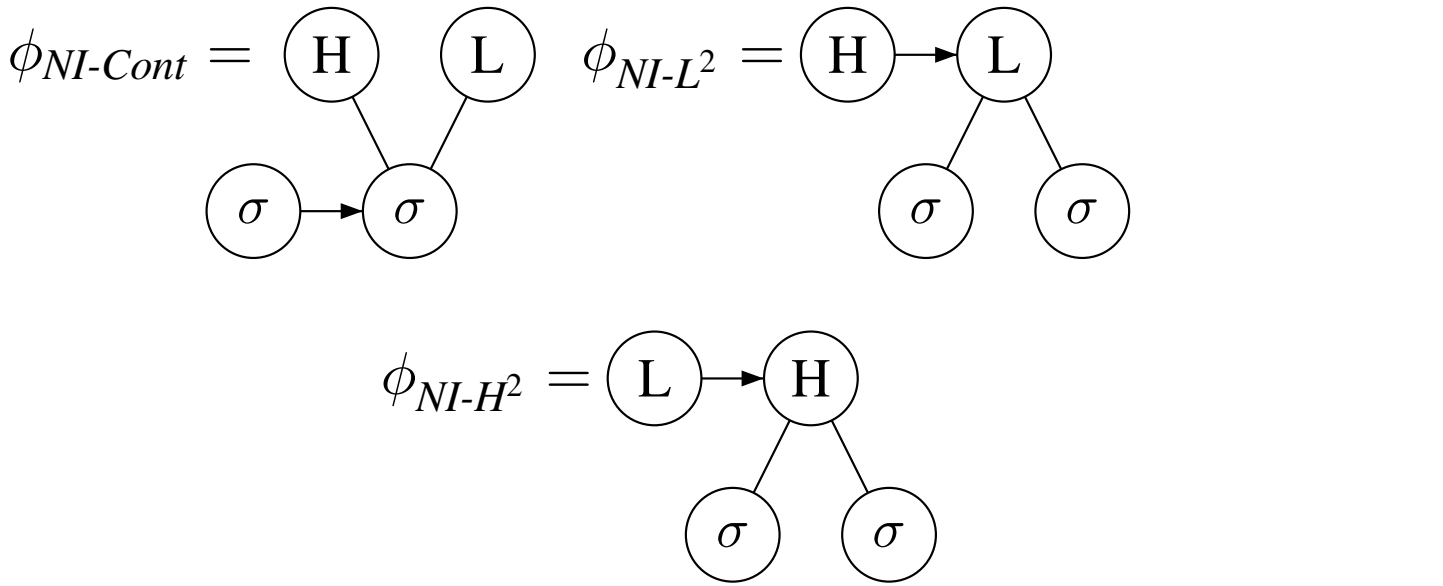
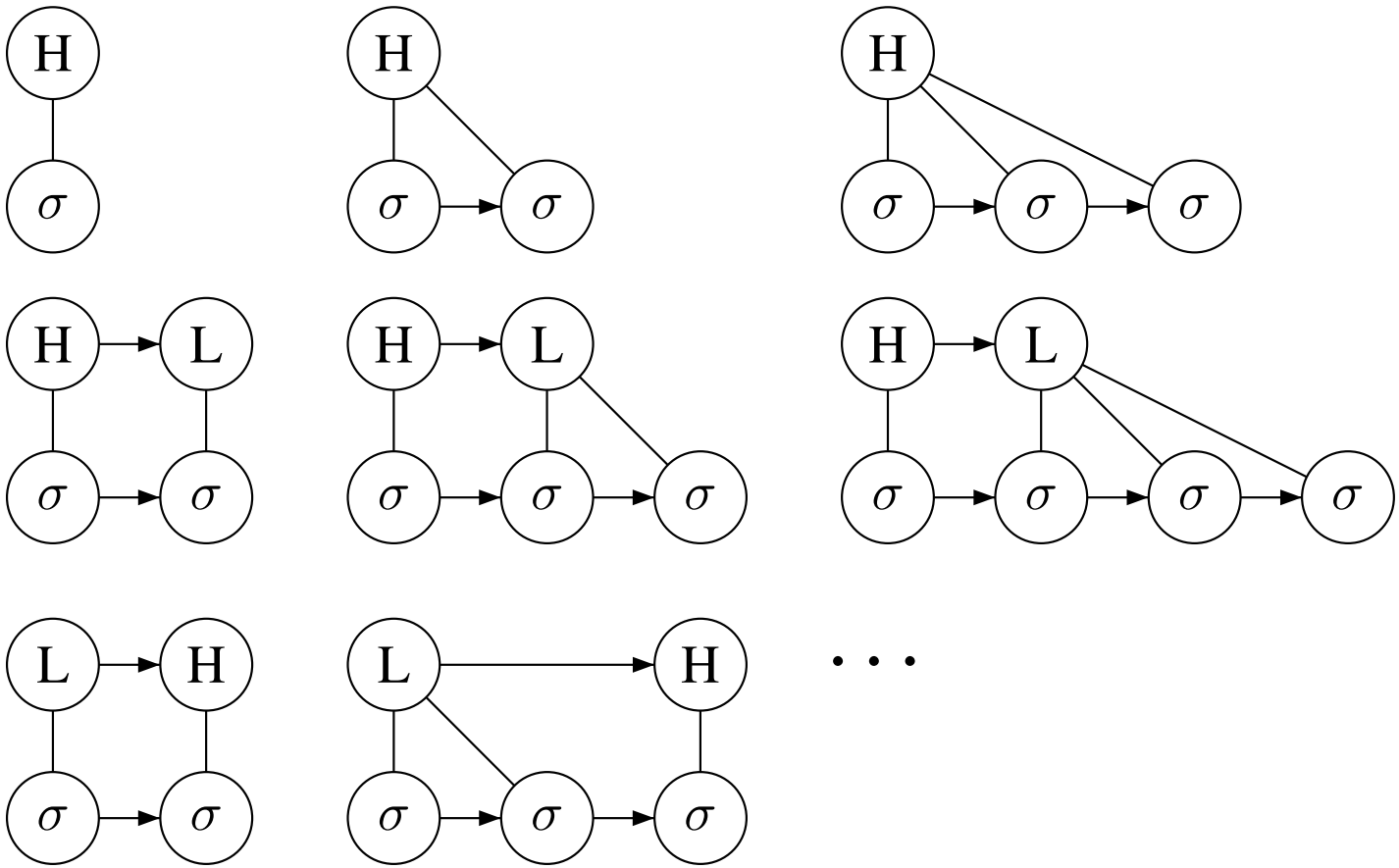
Case study: Hausa

Forbidden sub-structures in Hausa



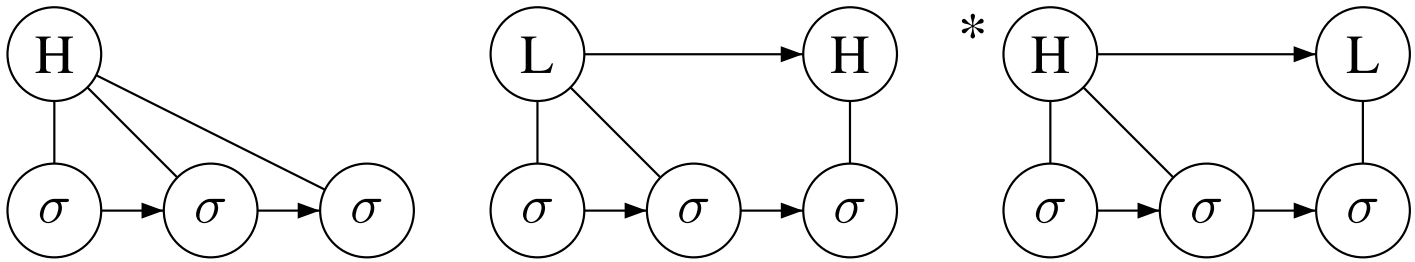
Case study: Kukuya

- Autosegmental representations in Kukuya

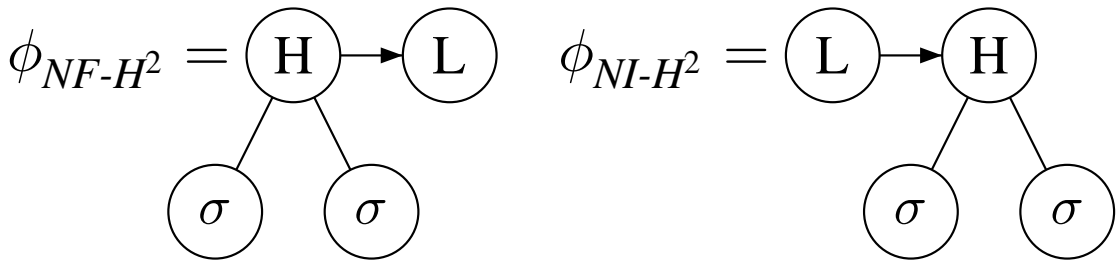


Case study: Kukuya

- H cannot spread in the presence of another tone

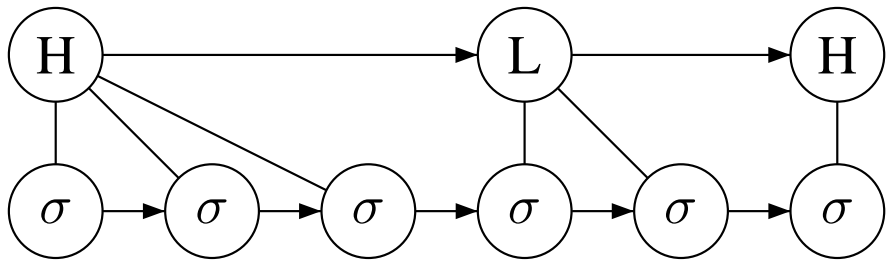


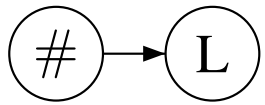
- In terms of forbidden subgraphs, this is just conjunction of $\neg\phi_{NF\text{-}H^2}$ (Mende) and $\neg\phi_{NI\text{-}H^2}$ (Hausa)

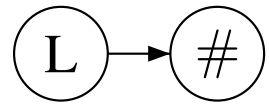


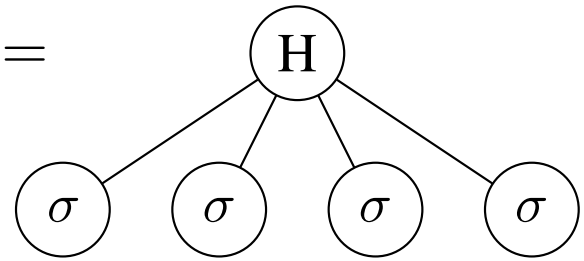
Case study: N. Karanga

- H on both edges; first spreads maximally to three syllables



$\phi_{IL} =$ 

$\phi_{FL} =$ 

$\phi_{H^4} =$ 

Discussion

- We have characterized the following variation in tone patterns with **local** constraints:
  - Fixed melodies realized over words of different lengths (all)
  - Contours and stretches of tone may be restricted to left or right (Mende vs. Hausa)
  - Stretches of a particular tone may be banned (Kukuya)
  - Tones may appear on both edges (N. Karanga)

Discussion: theory comparison

- Rule-based frameworks parameterized directionality (e.g., Archangeli and Pulleyblank, 1994) and employed language specific rules for tone-dependent spreading (Hyman, 1987)
- It is unclear how rules can be constrained or learned

Discussion: theory comparison

- Zoll (2003) captures these with violable constraints in OT; *CLASH for Kukuya, ALIGN for directionality
- ALIGN constraints can generate ‘H closest to center’ pattern (Eisner, 1997)
- ALIGN constraints cannot capture N. Karanga Shona

Discussion: theory comparison

- *Both* derivational and optimization-based approaches miss generalization that well-formedness is local, which is a central feature of the current proposal

Conclusions/future work

- How can we characterize variation in tone well-formedness?
  - Through **forbidden substructure constraints** over autosegmental representations
- These constraints are inviolable, language-specific, and fundamentally **local**

Conclusions/future work

- This notion of locality can form the basis for autosegmental **transformations** (Jardine, dissertation), just as it has been shown for string transformations (Chandlee, 2014)
- For **learning autosegmental patterns,** we can take lessons from learning forbidden substructure constraints in strings (Jardine and Heinz, LSA 2016), which can be done by paying attention to substructures of a certain size (García et al., 1990; Heinz, 2010; Jardine and Heinz, accepted; Chandlee, 2014; Chandlee et al., 2015)

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