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Phonological Learning with Output-Driven Maps

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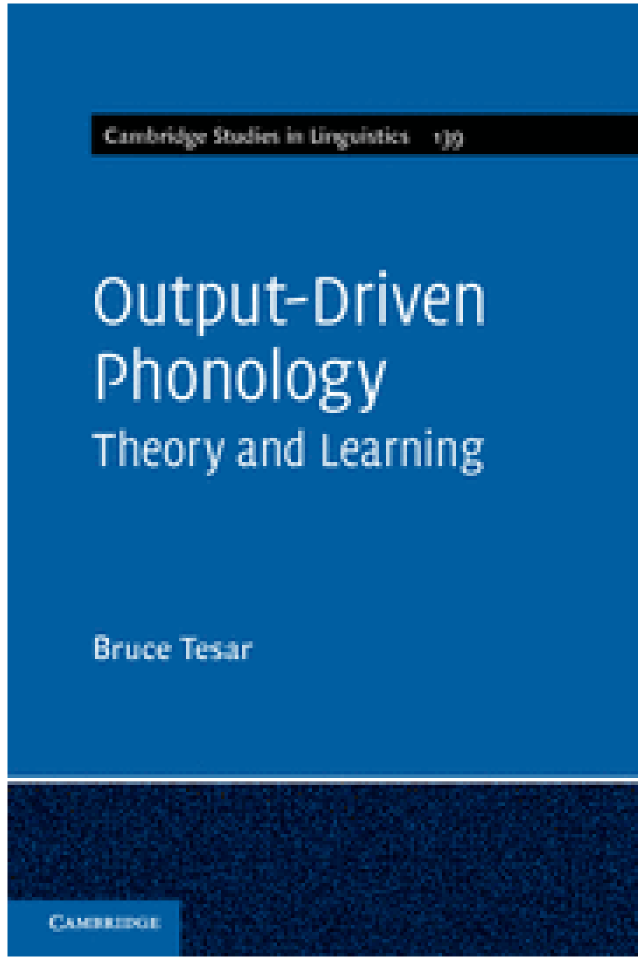
Outline

- Simultaneous learning of:
  - constraint rankings
  - underlying forms
- Output-Driven Maps
  - Phono-LOGICAL Reasoning: logical entailment over algebraic lattices
- Exploiting ODM structure in learning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Output-Driven Phonology
Theory and Learning
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Need Additional Structure

- Joint learning of constraint rankings and underlying forms.
  - Jarosz 2006, Apoussidou 2007, Merchant 2008
- These techniques are still implausibly slow.
- Faster learning requires additional posited structure:
  - relating the space of possible UFs to rankings.
- Proposal: Output-Driven Maps

A System for Illustration

- Words: root + suffix
  - Both roots and suffixes are monosyllabic.
- Each vowel has two features:
  - Vowel length: long (+) or short (–)
  - Main stress: stressed (+) or unstressed (–)
- Example surface words:
  - *páka pá:ka paká páka: pa:ká: pa:ká*
  - Each word has exactly one main stress in the output.

The Constraints

- Six Constraints

MAINLEFT	main stress on the initial syllable
MAINRIGHT	main stress on the final syllable
*V:	no long vowels
WSP	long vowels are stressed
ID[stress]	correspondents have equal stress value
ID[length]	correspondents have equal length value

(McCarthy & Prince 1993, 1995; Prince 1990; Rosenthall 1994)

Language L20

r1=/pa/	r2=/pa:/	r3=/pá/	r4=/pá:/	
páka	*pá:ka*	*páka*	*pá:ka*	s1=/-ka/
páka	*pá:ka*	*páka*	*pá:ka*	s2=/-ka:/
paká	*paká*	*páka*	*pá:ka*	s3=/-ká/
paká:	*paká:*	*páka*	*pá:ka*	s4=/-ká:/

Ranking: WSP $\gg$ ID[s] $\gg$ ML $\gg$ MR $\gg$ ID[l] $\gg$ *V:

Output-Driven Maps

(Tesar 2008; Tesar 2014)

- A map is output-driven if:
  - for every grammatical candidate A→X of the map:
  - if candidate B →X (same output) has greater similarity than A→X,
  - then B→X is also grammatical.

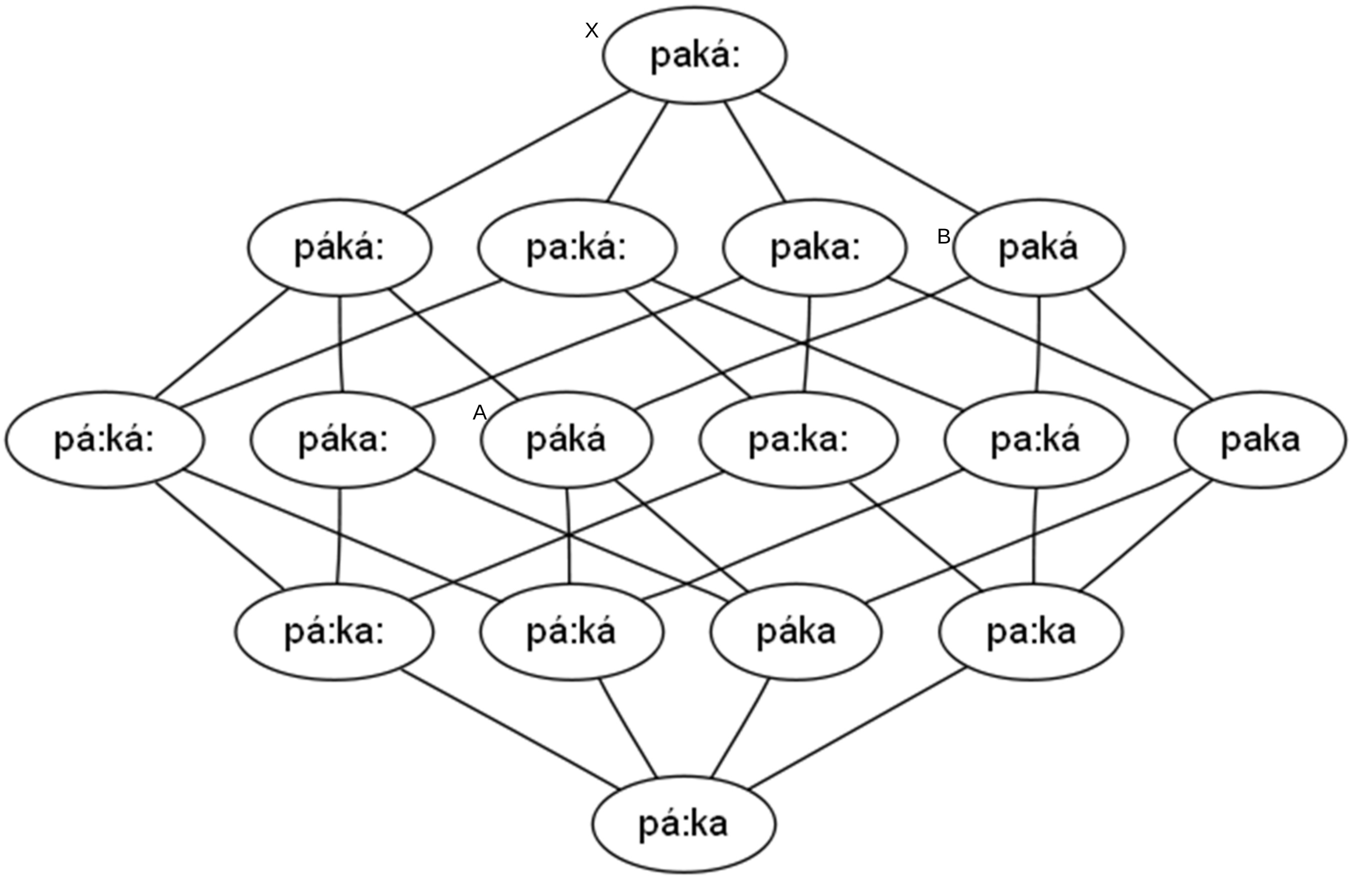
- Simplified:
  - for every grammatical candidate A→X of the map:
  - if input B is more similar to X than A is,
  - then B also maps to X.

Greater Similarity

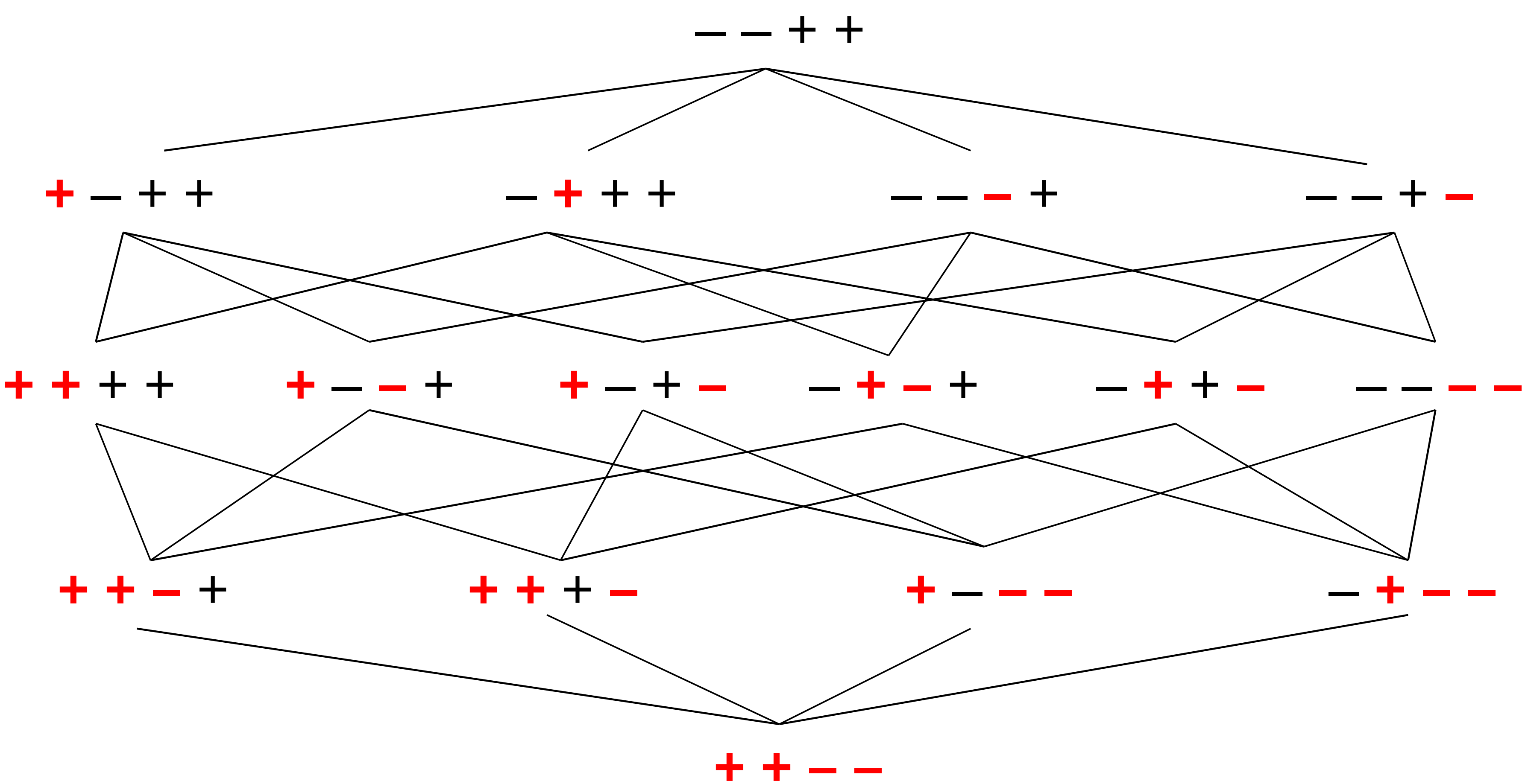
- Candidate B→X has **greater similarity** than candidate A→X if every disparity in B→X has an identical corresponding disparity in A→X.
  - The relation is only defined for pairs of candidates sharing the same output.

		(+/–stress +/–length)
A→X	*páká → paká:*	[+ – + –] → [– – + +]
B→X	*paká → paká:*	[– – + –] → [– – + +]

Relative Similarity (up = greater similarity)



Relative Similarity (+/–stress +/–length)



Exploiting ODM Structure in Learning

- ODM structure can be exploited in the learning of both:
  - underlying feature values
  - ranking information

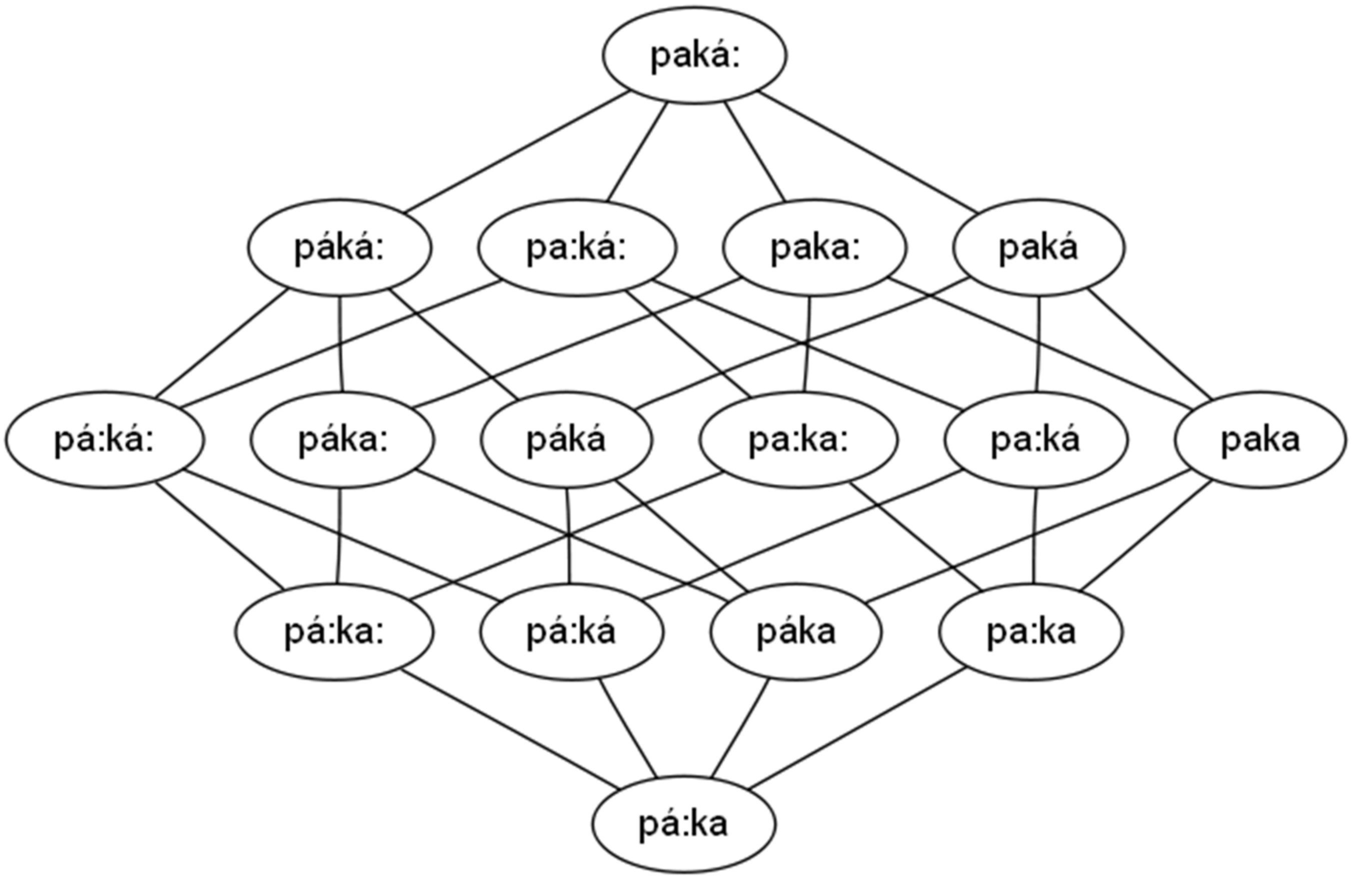
- Major benefit: computational efficiency

Phonotactic Learning

- Identity Map Property
  - underlying forms identical to the observed output.
  - Prince & Tesar (2004), Hayes (2004)

- The Identity Map property follows from ODM structure.
  - Phonotactic learning can be done as before.

ODM entails the Identity Map Property



Ranking Information Content of *paká:*

/paká:/	WSP	ML	MR	*V:	ID[s]	ID[l]
paká: winner		*		*		
paká loser		*				*
ERC *paká: ~ paká*				L		W

Word r1s4 has surface form *paká:*

Mapping that form to itself yields ID[l] $\gg$ *V:

Learning Underlying Feature Values

- ODM: A→X entails B→X
- Contrapositive: NOT (B→X) entails NOT (A→X)
  - If a given input cannot map to the output, then all inputs with lesser similarity (additional disparities) cannot map to that output.

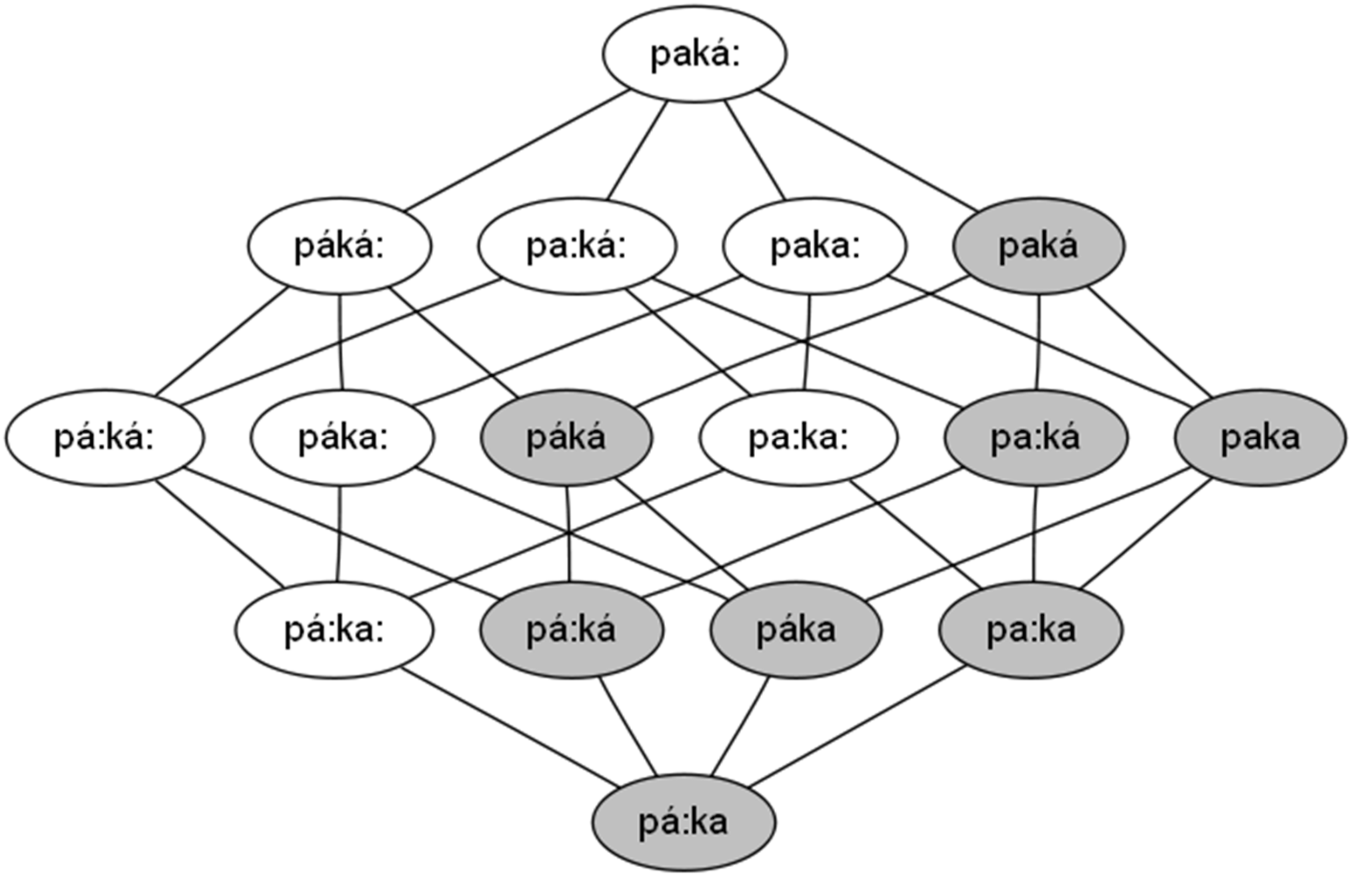
Testing Individual Disparities

- Observed output (r1s4): *paká:*
- What is the underlying length of suffix s4?

- *paká→paká:* disparity for s4 length only.

- If *paká→paká:* is inconsistent
  - no other input with s4 set to short maps to *paká:*
  - s4 can be set to long (+).

Setting s4 to +long



Exponential to Linear

- The learner only needs to test one input for each unset feature.
- Linear in the number of unset features
  - rather than exponential.

Features Are Set When Contrastive

- *paká→paká:* is inconsistent
- because length is contrastive in stressed position
- which the learner knows via ID[l] ≫ *V:
- as determined by phonotactic learning.

Non-Phonotactic Ranking Information

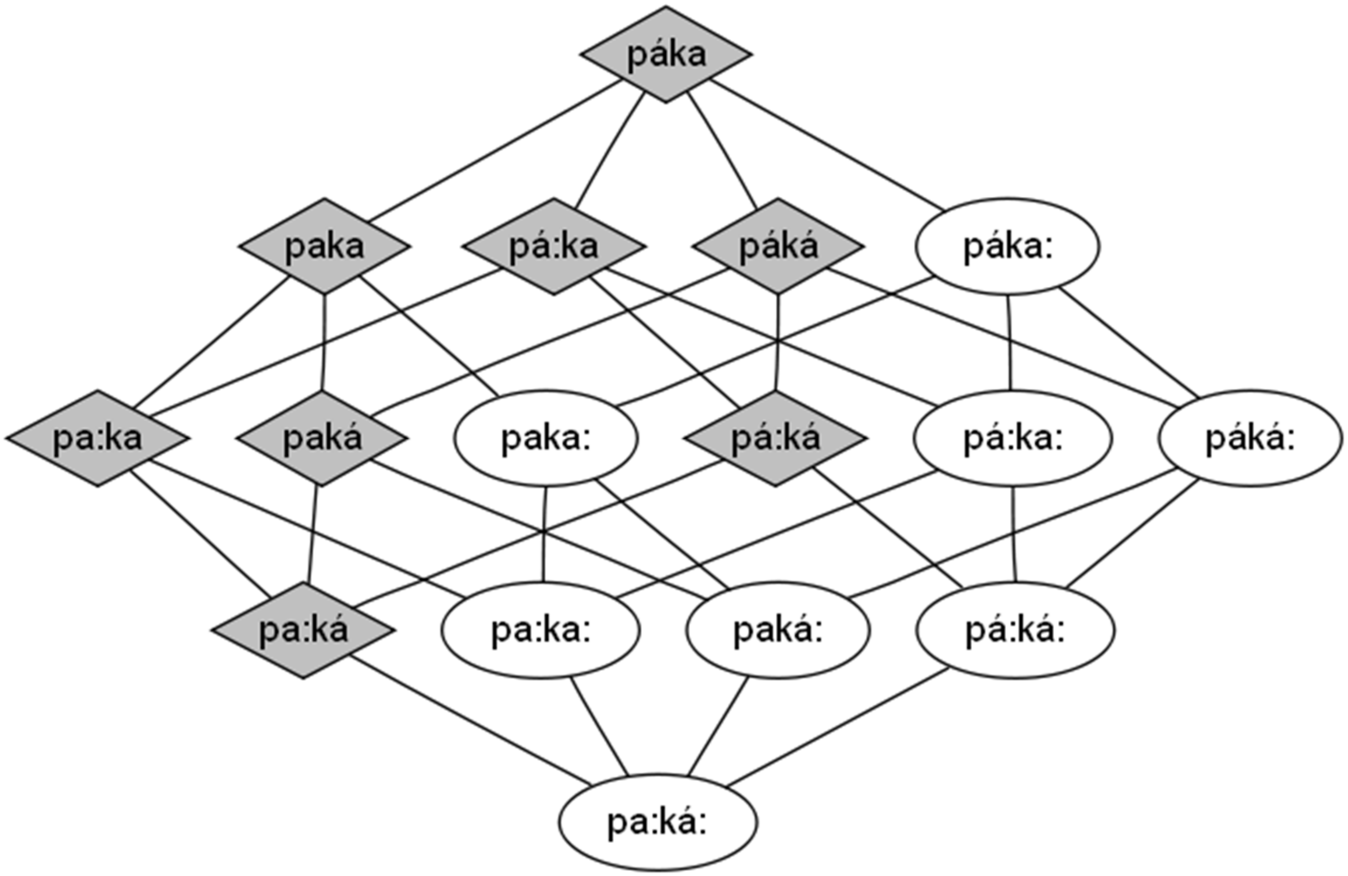
- Find forms in which a set feature is not faithfully realized (Tesar 2006b).
  - Where the feature **alternates**.

- Indicates neutralization.

Unfaithful Features

- Observed output (r3s4): *páka*
- s4 has already been set to +long.
- Minimal disparity mapping: *páka:* → *páka*

Viable Inputs for r3s4



Ranking Info from r3s4

/páka:/	WSP	ML	MR	*V:	ID[s]	ID[l]
páka winner						*
páka: loser	*			*		
ERC	W			W		L
paká: ~ paká				L		W
Fusion	W			L		L

WSP ≫ ID[l] ≫ *V:

Obtained despite incomplete input knowledge.

Contrast and Neutralization

- Underlying feature values are learned in positions of contrast.
- Non-phonotactic ranking information is learned in positions of neutralization.
- In learning, each feeds the other.

Underlying Forms, Not Surface Allomorphs

r1=/*pa*/	r2=/*pa:*/	r3=/*pá*/	r4=/*pá:*/	
páka	*pá:ka*	*páka*	*pá:ka*	s1=/-*ka*/
páka	*pá:ka*	*páka*	*pá:ka*	s2=/-*ka:*/
paká	*paká*	*páka*	*pá:ka*	s3=/-*ká*/
paká:	*paká:*	*páka*	*pá:ka*	s4=/-*ká:*/

r2 always surfaces as *pá:* or *pa* (never as *pa:*)

Learning Conspiracies: L9

r1=/pa/	r2=/pa:/	r3=/pá/	r4=/pá:/	
paká	pá:ka	páka	pá:ka	s1=/-ka/
paká:	paká:	paká:	pá:ka	s2=/-ka:/
paká	pá:ka	paká	pá:ka	s3=/-ká/
paká:	paká:	paká:	paká:	s4=/-ká:/

r1s1: /paka/ → paká — default final stress

r2s3: /pa:ká/ → pá:ka — WSP, via stress shift

r4s2: /pá:ka:/ → pá:ka — WSP, via vowel shortening

L9 Phonotactic Learning

- L9 includes contrasts in stress and length.

- ID[l] ≫ *V: (contrast in length)
  - *paká* *paká:*

- ID[s] ≫ {ML,MR} (contrast in stress)
  - *paká* *páka*

L9 UF Learning(1)

- r1s2: */paká/* cannot map to *paká:*
  - ID[l] $\gg$ *V:
- s2 can be set underlyingly to +long.
  - Because –long is inconsistent.
  - s2 now has lexical entry /?,+/

L9 Non-phonotactic Ranking Info(1)

- r4s2 surfaces as *pá:ka*
  - s2 surfaces as –long
  - */pá:ka:/* → *pá:ka*

- WSP ≫ ID[l] (vowel shortening)

L9 Contrast Pair UF Learning

- r1s1 *paká*
- r3s1 *páka*

- r1 and r3 must contrast in underlying stress.
  - Set r1 to –stress.
  - Set r3 to +stress.

L9 Non-phonotactic Ranking Info(2)

- r3s3 surfaces as *paká*
  - r3 surfaces as –stress.
  - */páká/* → *paká*

- MR ≫ ML (default final stress)

L9 UF Learning(2)

- r4s2: */pá:ká:/* cannot map to *pá:ka*
  - MR $\gg$ ML
- s2 can be set underlyingly to –stress.
  - Because +stress is inconsistent.
  - s2 now has lexical entry /–,+/

L9 Non-phonotactic Ranking Info(3)

- r3s2 surfaces as *paká:*
  - s2 surfaces as +stress.
  - */páka:/* → *paká:*

- ID[l] ≫ ID[s] (stress shift)

Just Another Grammar

- No special mechanisms for learning conspiracies.
- No special mechanisms for non-allomorphic UFs.

Conclusions

- ODM structure makes much more efficient learning possible.
  - Reduction from exponential to linear.
  - Both underlying forms and ranking information.
- Phono-LOGICAL reasoning: entailment over algebraic lattices.
- Jointly leveraging the two forms of paradigmatic information.
  - contrast
  - alternation