Creating natural and unnatural constraints: the case of Canadian raising

Paul Boersma, November 9, 2007
(joint work with Joe Pater, UMass,
who is not responsible for the views on
underlying forms expressed here)

Natural and unnatural processes

- In Canadian English, we find two natural situations and one unnatural situation:
  - natural: Canadian raising;
  - natural: flapping;
  - unnatural: their interaction.

Natural and unnatural processes

- Our research question today:
  - how is it possible for phonological grammars to prefer universal-looking natural processes and at the same time allow non-natural rules?

Today's assumed grammar model

|*underlying form*|

faithfulness constraints

/*surface form*/

structural constraints

cue constraints

[*phonetic form*]

articulatory constraints

(Boersma 1997-, Escudero 2005-, Apoussidou 2006-)

Canadian raising: basics

- In Canadian English, the earlier diphthong /ai/ is nowadays pronounced [ʌi] before voiceless consonants:
    - [ʌis] ‘ice’
    - [saiz] ‘size’
    - [ai] ‘I’, ‘eye’, ‘(the number) *i*’

Canadian raising is natural

- A natural explanation:

  1. English vowels are shortened before voiceless consonants;

  2. short vowels are difficult to combine with an open jaw;

  3. hence, an original short [ai] can be later raised to [ʌi].

Not just phonetic

- Conditioned by phonological boundaries such as syllable and word boundaries:
  - [sʌik] ‘psych’, [saikɒlədʒi] ‘psychology’, [maisʌn] ‘my son’
- Hence the contrast must be in the phonological surface form: /.sʌik./, /.sai.kɒ.lə.dʒi./, /.mai.sʌn./

Not just lexical

- Synchronically conditioned by the voicing of the consonant:
  - [ai] ‘(the number) *i*’ vs. [ʌiθ] ‘*i*th’
- The interpretation of this is: the grammar changes an underlying |ai| into /ʌi/ on the surface if it is followed by /-voi/.

Hence, structural constraints must be involved

	10.0	10.0	5.0
	/ai;+voi/	/ʌi;-voi/	Faith
☞ |ai+θ| /ʌiθ/		+	
|ai+θ| /aiθ/			+

These constraints can be regarded as ‘natural’.

Flapping: basics

- Earlier /d/ and /t/ are nowadays pronounced [ɾ] between vowels:
    - [læɾɚ] ‘latter’
    - [læˑɾɚ] ‘ladder’
- (there may still be duration differences)

Flapping is natural

- A natural explanation:

  1. the tongue tip is the fastest articulator, and is actually capable of rebouncing passively from the roof of the mouth if the airflow before and after is unimpeded;

  2. hence, coronal stops may shorten into a flap intervocalically;

  3. flaps are too short to easily maintain a voicing contrast.

Not just phonetic

- Conditioned by phonological boundaries and stress:
    - [lˈɒɾou] ‘lotto’ vs. [ət^{h}ˈounmənt] ‘atonement’, [ɪɾˈɪz] ‘it is’ vs. [ət^{h}ˈoun] ‘a tone’
- Hence the contrast must be in the phonological surface form somehow, e.g.: /.ɪɾ.ɪz./, /.ə.toun./

Not just lexical

- Synchronically conditioned by position:
  - [hæt] ‘hat’ vs. [hæɾɚ] ‘hat + er’
  - [wɛˑd] ‘wed’ vs. [wɛˑɾɚ] ‘wed + er’
- The interpretation of this is: the grammar changes underlying |t| and |d| into /ɾ/ on the surface if it is followed by /V/.

Hence, structural constraints must be involved

	10.0	10.0	10.0	5.0
	/V;ɾ;V/	/V;t;C/	/V;d;C/	Faith
|hæt+ɚ| /hætɚ/				+
☞ |hæt+ɚ| /hæɾɚ/	+			

These constraints can be regarded as ‘natural’.

The interaction

- The only position in which we can have a contrast between /ʌi/ and /ai/ is before /ɾ/:
    - [vʌipɚ] ‘viper’, *[vʌibɚ]
    - [faibɚ] ‘fibre’, *[faipɚ]
    - [mʌiɾɚ] ‘mitre’, [saiɾɚ] ‘cidre’
    - [ɹʌiɾɚ] ‘write + er’, [ɹaiɾɚ] ‘ride + er’

Structural constraints must be involved

- A parallel constraint-based analysis (OT, HG) seems to requires the structural constraints /ʌi;ɾ;V/ and /ai;ɾ;V/.
- These constraints are not ‘natural’; hence, they must be specific to Canadian English.

Where do structural constraints come from?

- Many OT researchers claim they are innate.
- The Canadian-English-specific constraints cannot be innate; they have to be learned.
- Using Occam's razor, we must assume that any universal-looking structural constraints are learned as well, from the language data.

(Boersma, Escudero & Hayes 2003: 1016)

How come languages tend to have natural constraints?

- Our proposal: they ultimately arise from phonetic biases.
- In the Canadian English case (and if the explanation given earlier is correct), the bias is articulatory: there are strong articulatory constraints against short open vowels.

How does an articulatory bias work precisely?

- We perform computer simulations of multiple generations of learners of English.
- The learners induce categories along the lines of Boersma, Escudero & Hayes (2003), then optimize their bidirectional grammar for comprehension and reuse it in production (Boersma 2006, Boersma & Hamann 2007).

Simulation:
categories for generation 1

- Generation 1 is given unbiased data in the form of sound-meaning pairs:
    - [ɐ̆is] ‘ice’, [sɐˑiz] ‘size’
- Although there is a duration difference, the distribution for F1 has only one peak, so the learners create one category for vowel height.

(for details, see Boersma, Escudero & Hayes 2003)

Constraint creation by generation 1

- Generation 1 creates *cue constraints* that link auditory F1 values to the single phonological category /ɐ/.

(for details, see Boersma, Escudero & Hayes 2003)

|*underlying form*|

faithfulness constraints

/*surface form*/

structural constraints

cue constraints

[*phonetic form*]

articulatory constraints

Comprehension optimization by generation 1

- Generation 1 optimizes her perception: the cue constraints get ranked optimally under the guidance of the lexicon (underlying form).

(for details: Escudero & Boersma 2003; Boersma & Hamann 2007)

|*underlying form*|

faithfulness constraints

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structural constraints

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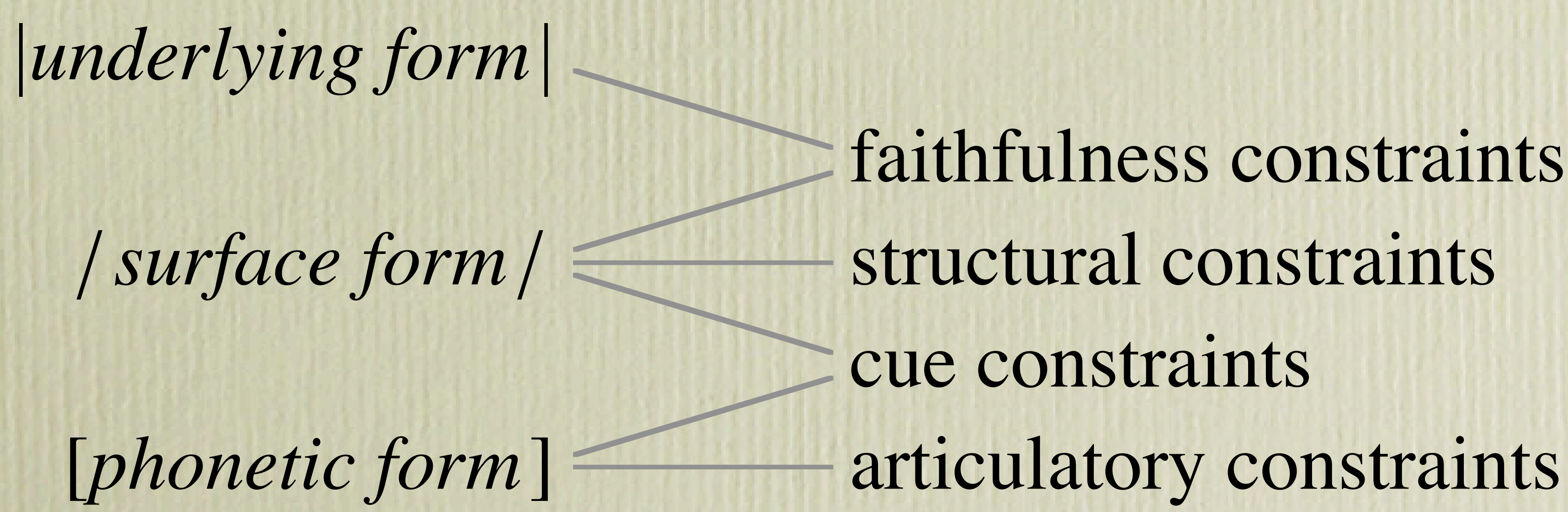
[*phonetic form*]

articulatory constraints

Production by generation 1

- When generation 1 starts to talk, she uses the same cue constraints, with the same weights, as had optimized her comprehension. The result is a preference for peripheral realizations such as [ai]: the *prototype effect*.

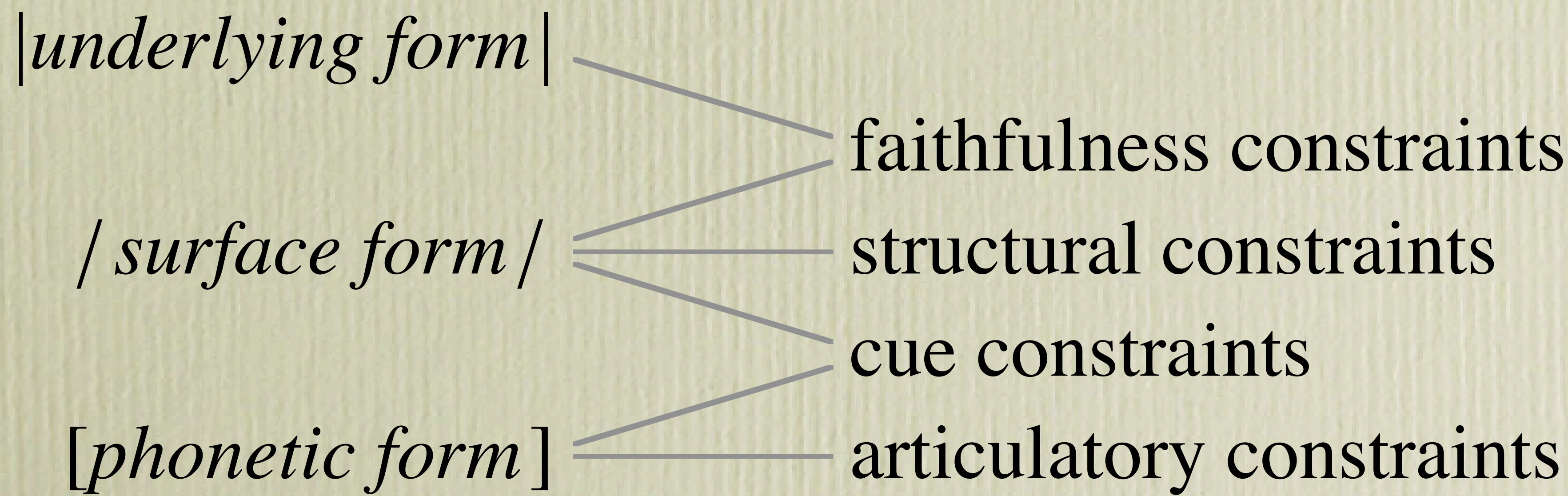
(for details: Boersma 2006; Boersma & Hamann 2007)



Production by generation 1

- The prototype effect is counteracted by the articulatory constraints, which work more strongly for short than for long realizations. The result is [ɐ˕˘is] and [sɐ˔ˑiz].

(for details: Boersma 2006; Boersma & Hamann 2007)



Categories for generation 2

- Generation 2 is given biased data:
    - [ɐ˔˘is] ‘ice’, [sɐ˕ˑiz] ‘size’
- The distribution for F1 still has only one peak, although it is broader than before. So the learners again create one category for vowel height.

Constraint creation by generation 2

- Generation 2 creates separate cue constraints for voiced and voiceless environments.

|*underlying form*|

faithfulness constraints

/ *surface form* /

structural constraints

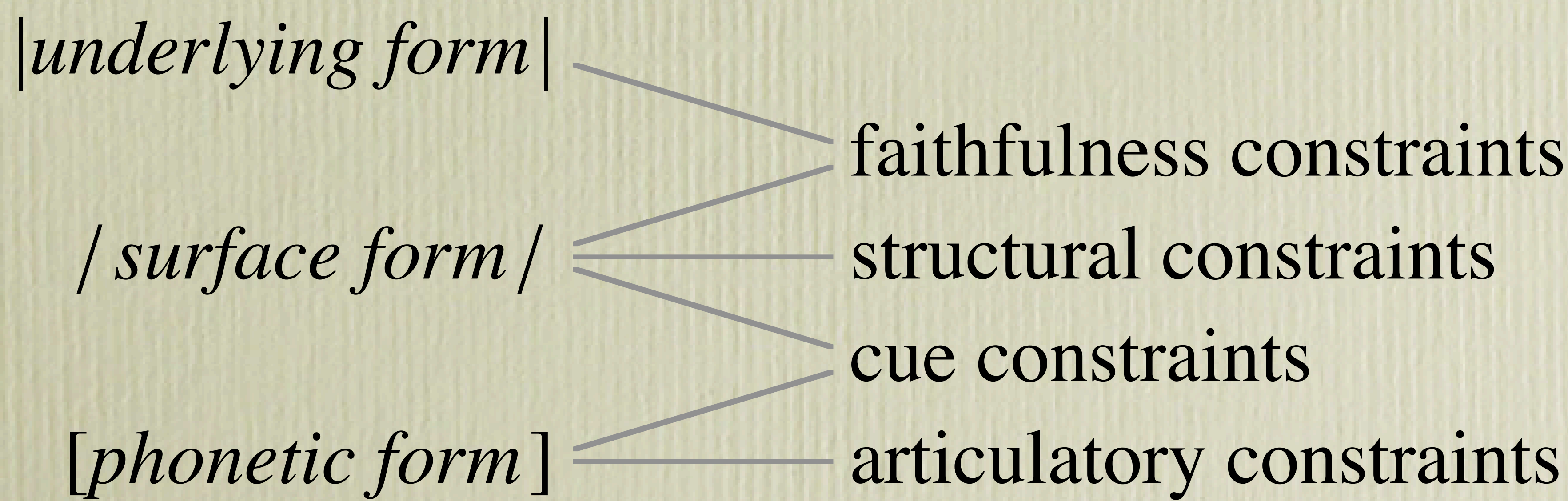
cue constraints

[*phonetic form*]

articulatory constraints

Comprehension optimization by generation 2

- Generation 2 optimizes her perception: the cue constraints get different optimal ranking depending on the voicing of the consonant.



Production by generation 2

- When generation 2 starts to talk, she uses the two sets of cue constraints, optimized for her comprehension. The resulting preference for peripheral realizations is greater for the voiced than for the voiceless environment.

|*underlying form*|

faithfulness constraints

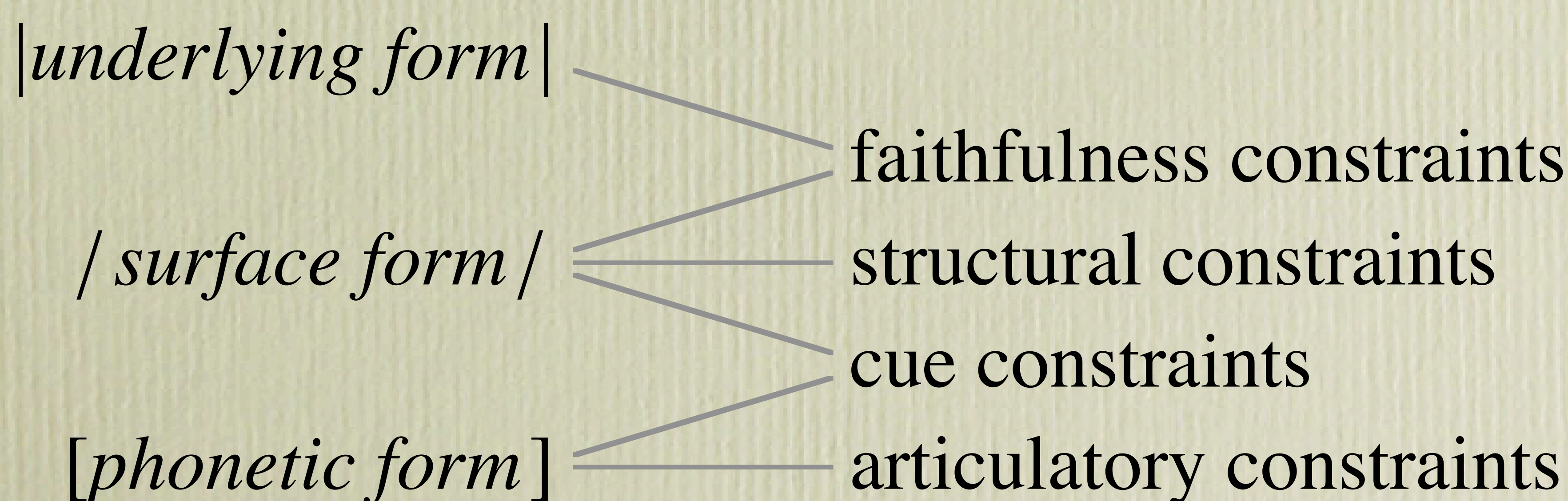
/*surface form*/ structural constraints

cue constraints

[*phonetic form*] articulatory constraints

Production by generation 2

- The articulatory constraints have the same bias as before, which now combines with the differential prototype effect. The result is [ʌ˘is] and [saˑiz].

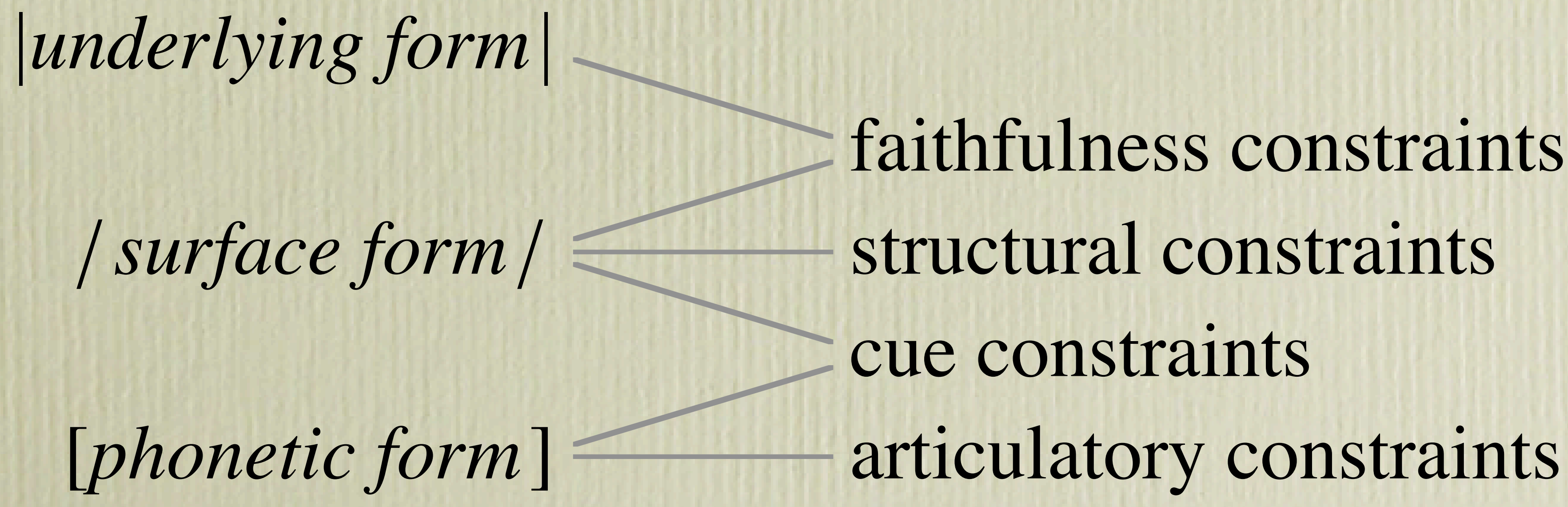


Categories for generation 3

- Generation 3 is given strongly biased data:
    - [ʌ˘is] ‘ice’, [saˑiz] ‘size’
- The distribution for F1 now has two peaks. So the learners create two categories for vowel height.

Constraint creation by generation 3

- Generation 3 creates two sets of cue constraints: one for /ʌi/, one for /ai/.



Phonologization has occurred

Generation 3 finally creates the natural-looking structural constraints. This is how phonetic biases percolate up into the phonology.