

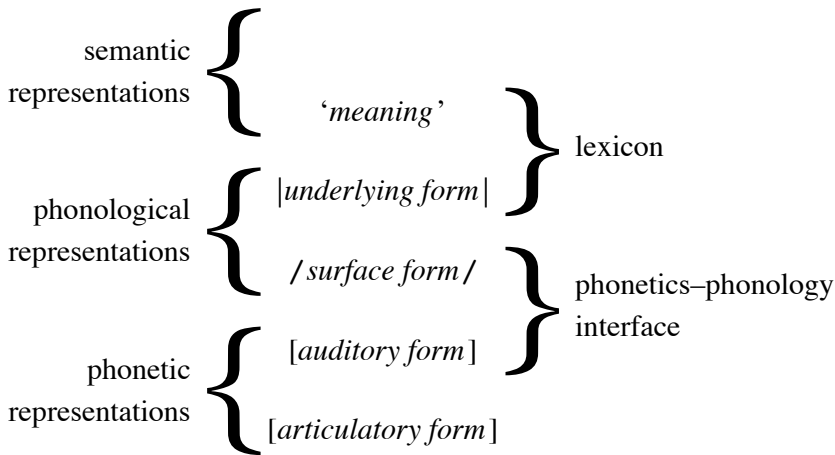
The evolution of phonotactic distributions in the lexicon

Paul Boersma

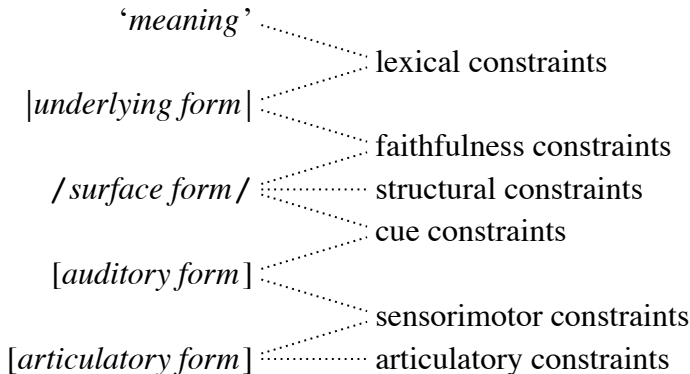
Workshop on Variation, Gradience and Frequency in Phonology
Stanford, July 8, 2007

Multiple levels of representation:

phonology and phonetics are separate but connected



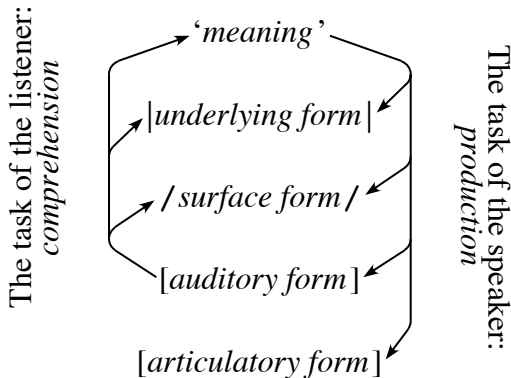
Multi-level bidirectionality: local connections



(constraints & connections by: Prince & Smolensky 1993; Kirchner 1998; Boersma 1998, 2001, 2005; Escudero 2005; Apoussidou 2007)

(bidirectionality by: Smolensky 1996; Tesar 1997; Boersma 1998, 2005)

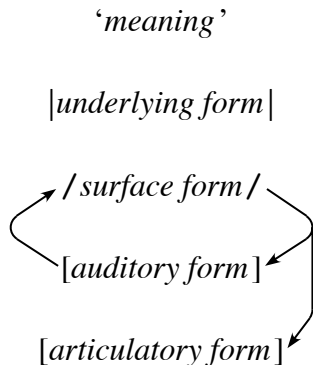
Parallel multi-level bidirectionality: local connections but global evaluation



(multi-level parallelism by: Boersma 2005; Apoussidou 2007)

Previous simulation result 1 (Boersma & Hamann 2007): emergent auditory dispersion without teleological devices

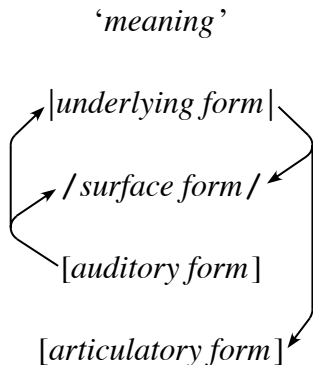
If acquisition optimizes the ranking of cue constraints for *comprehension*, **then** in *production* these same cue constraints (with the same rankings) will lead to a repulsive force between the phonological elements in auditory space. Within several generations, this will lead to a stable balance between auditory contrast and articulatory ease.



Required for this to work: bidirectionality (OT/HG).

Previous simulation result 2 (Boersma 2006): emergent markedness without markedness constraints

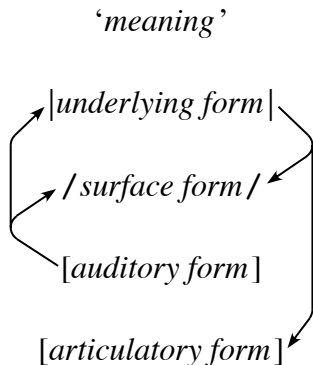
If acquisition optimizes the ranking of cue and faithfulness constraints for *comprehension*, **then** faithfulness will end up being ranked higher for infrequent than for frequent phonological elements. In *production* this leads to a differential phonological activity of these elements (e.g. [lab] > [cor]; [+round] > [-round]).



Required for this to work: bidirectionality & parallelism (OT/HG).

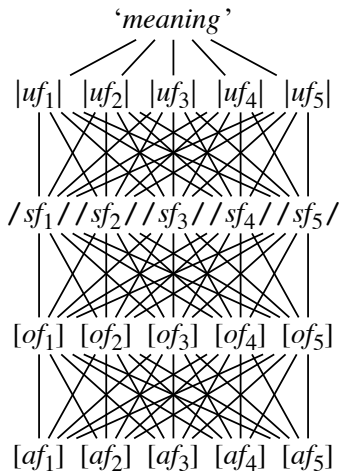
Previous simulation result 3 (Boersma 2006): emergent licensing-by-cue and positional faithfulness

If acquisition optimizes the ranking of cue and faithfulness constraints for *comprehension*, **then** faithfulness will end up being ranked higher for phonological elements with good than for those with poor auditory cues. In *production* this leads to differential phonological activity: plosive place > nasal place. No P-map required.



Required for this to work: bidirectionality & parallelism (OT/HG).

Today we go all the way up: lexical selection in OT/HG



(separation of meaning and underlying form: Apoussidou 2007)

1. Perceptual merger in reanalysis

The first source of lexical skewings is obvious in any (not necessarily parallel) bidirectional multi-level model, namely, innocent misapprehension (e.g. Ohala 1981, Blevins 1994). Well, it is obvious only in a model with multiple levels (it requires at least the auditory, surface, and underlying forms).

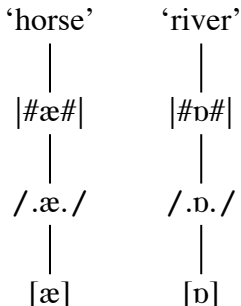
Example:

Auditory [æ] and [ɒ] are closer together than [ɛ] and [ɔ]. They may be so close together that a child cannot hear them apart. She will then assign them to the same category, say /a/.

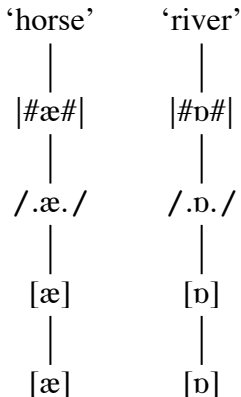
This selective merger will lead to vowel inventories with fewer place distinctions for low than for mid vowels.

1. Perceptual merger in reanalysis: the parent

Comprehension

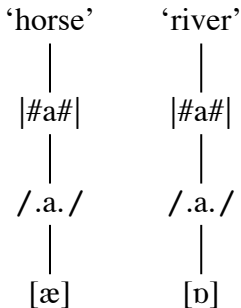


Production

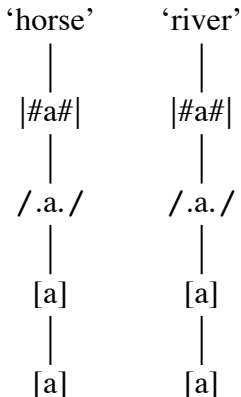


1. Perceptual merger in reanalysis: the child

Comprehension



Production



1. Perceptual merger in reanalysis: evolution

	æ ɒ	a a
Speaker generation 1	100%	0%
Speaker generation 2	0%	100%
	æ ɒ	a a
Population generation 1	80%	20%
Population generation 2	60%	40%
Population generation 3	40%	60%
Population generation 4	20%	80%

Ultimately, this leads to underlying forms that connect to:
auditory forms that contrast well with others

(by merger, not by chain shift; cf. De Boer 1999, Oudeyer 2006)

2. Lexical and cue (and/or faithfulness) constraints

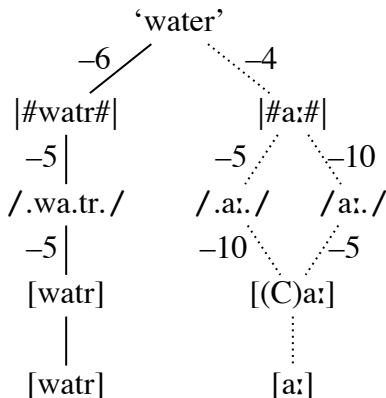
Example:

Proto-Indo-European had two underlying forms meaning ‘water’, namely |#wodr#| and |#ak^wa#|.

In Proto-Germanic, regular phonological sound changes changed these into |#watr#| and |#a:#|.

The increased difficulty of mapping an utterance-internal auditory [a:] to the meaning ‘water’ in *comprehension* will lead (at least in a bidirectional model) to a bias against choosing the underlying form |#a:#| in *production*. This bias may overcome any lexical preference for |#a:#| if evaluation is parallel across multiple levels.

2. Lexical and cue constraints: vertical tableau



The solid lines depict the optimal path both in OT (minimize maximum problem) and in HG (minimize sum of problems).

2. Lexical and cue (and faith) constraints: acquisition

The shift under discussion is most likely to occur in languages where most words start with a consonant (a fact that itself can be explained if syllables are costly) *and* where most word boundaries are realized as syllable boundaries.

Children who grow up in such an environment will rank high two constraints (both ranked at ‘10’ on slide 14):

1. the cue constraint *[CV]/C.V/ (Cornulier 1981);
2. the ‘faithfulness’ constraint /./|#| (or /.V./|#V#|)

Illustration: in French, ‘water’ is still |#o#|. But in French the constraint /./|#| is ranked low, because that is required by the independent processes of liaison and elision.

2. Lexical and cue constraints: evolution

Learners who optimize their *comprehension* must interpret their parents' *production* biases as lexical preferences:

	#watr#	#a:#
Generation 1	20%	80%
Generation 2	40%	60%
Generation 3	60%	40%
Generation 4	80%	20%

Ultimately, this leads to underlying forms that connect to:

- auditory forms with auditory salience;
- auditory forms that contrast well with others.

(by chain shift, not merger; cf. Wedel 2004, 2006 in exemplar theory, and Boersma & Hamann 2007 in OT)

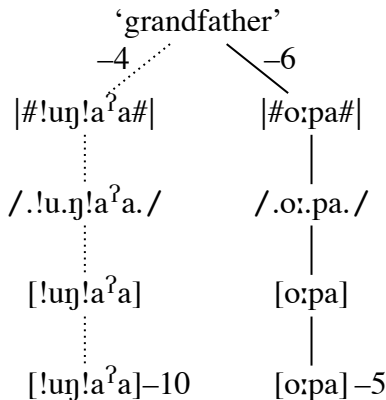
3. Lexical and articulatory constraints

Example: suppose a language has two forms meaning ‘grandfather’: $|\#!u\eta!a^?a\#|$ and $|\#o:pa\#|$.

$[!V]$ requires a synchrony of apical and dorsal gestures, whereas $[pV]$ requires just a single uncritically timed labial gesture.

The higher difficulty of pronouncing $[!u\eta!a^?a]$ as compared to $[o:pa]$ leads to a bias against choosing the underlying form $|\#!u\eta!a^?a\#|$ in production. This bias may overcome any lexical preference for $|\#!u\eta!a^?a\#|$, but only if evaluation is parallel across multiple levels (in a serial model, articulation can have no influence on the earlier process of lexical selection in production).

3. Lexical and articulatory constraints: tableau



The solid lines depict the optimal path both in OT (easily) and in HG (with some effort, because of the double violation of $*[!V]$).

3. Lexical and articulatory constraints: acquisition

In an environment where clicks occur but are not predominant, a child would learn to rank $*[!V] \gg *[pV]$.

Illustration: in !Xũ, where clicks *are* predominant, ‘grandfather’ is $|\#!u\eta!a^?a\#|$ (Snyman 1970: 54).

3. Lexical and articulatory constraints: evolution

Learners who optimize their *comprehension* must interpret their parents' *production* biases as lexical preferences:

	#!uŋ!a ² a#	#o:pa#
Generation 1	80%	20%
Generation 2	60%	40%
Generation 3	40%	60%
Generation 4	20%	80%

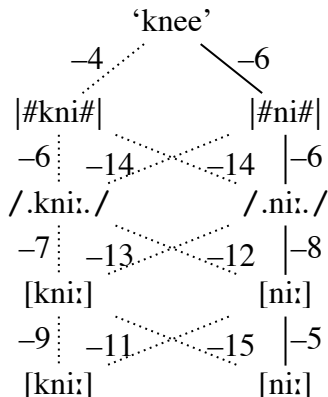
Ultimately, this leads to underlying forms that connect to:
articulatory forms that are easy to pronounce.

4. Lexical and sensorimotor constraints

Example: in the history of English, the underlying form |#kni:#| ‘knee’ turned into |#ni:#|. The two underlying forms may have coexisted for some time.

The low audibility of dorsal plosive cues before /n/ in *comprehension* leads to a bias against choosing the underlying form |#kni:#| in *production*, at least in a bidirectional model. This bias may overcome any lexical preference for |#kni:#|, but only if evaluation is parallel across multiple levels (in a serial model, low-level sensorimotor knowledge can have no influence on the earlier process of lexical selection in production).

4. Lexical and sensorimotor constraints: vertical tableau



The solid lines depict the optimal path both in OT and in HG.

4. Lexical and sensorimotor constraints: acquisition

Sensorimotor learning in a noisy environment will lead to the knowledge that a pronounced $[k]_{\text{Art}}$ before $[n]_{\text{Art}}$ is likely not to generate any dorsal plosive cues.

In other words, the sensorimotor constraint

$*[\text{tongue-body closure} / _n]_{\text{Art}} [\text{dorsality \& plosion} / _n]_{\text{Aud}}$

which can be abbreviated as

$*[k / _n]_{\text{Art}} [k / _n]_{\text{Aud}}$

will end up being ranked high.

4. Lexical and sensorimotor constraints: evolution

Learners who optimize their *comprehension* must interpret their parents' *production* biases as lexical preferences:

	#kni:	#ni:
Generation 1	80%	20%
Generation 2	60%	40%
Generation 3	40%	60%
Generation 4	20%	80%

Ultimately, this leads to underlying forms that connect to:

- articulatory forms with predictable auditory results (salient sounds, and Stevens' 1989 "quantal theory");
- auditory forms with unambiguously recoverable articulations (salient and contrastive sounds).

If both OT and HG work, which is best?

Comparison of convergence of learning algorithms
as a function of the number of levels of representations:

	Categorical OT ¹ (EDCD ²)	Stoch.OT ³ (GLA ³)	Stoch.HG ^{8,9} (BMLA ⁴)
two levels	100% ²	97% ^{7,9}	100% ⁹
three levels	60% ⁵	70% ⁶	80% ⁹

(¹Prince & Smolensky 1993; ²Tesar 1995; ³Boersma 1997;

⁴Soderstrom, Mathis & Smolensky 2006; ⁵Tesar & Smolensky 2000;

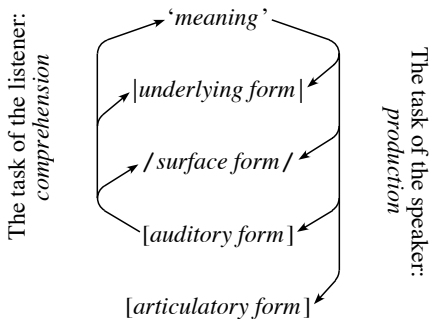
⁶Boersma 2003; ⁷Pater to appear; ⁸Boersma & Escudero to appear;

⁹Boersma & Pater in progress)

The correct learning algorithm...

is the one whose misconvergences coincide with those of humans.

The crucial leap of thought: the Input



From Prince & Smolensky (1993) on, the *Input* and *Richness of the Base* have been thought to be located in Underlying Form. I propose they are both instead located in Auditory Form for *comprehension*, and in Meaning for *production*.

Conclusion

Parallel bidirectional multi-level constraint satisfaction predicts six types of lexical skewings:

1. auditory contrast by selective merger;
2. auditory contrast by chain shift;
3. auditory salience;
4. articulatory ease;
5. auditory predictability;
6. articulatory recoverability.

(Some cases discussed in this talk could be due to several of these causes, not just to the cause(s) proposed in the example tableaux)

My suspicion: there aren't any more types of lexical skewings.

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