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Phonotactic learning and phonological typology

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1. Introduction

(1) Why are some phonological patterns common across unrelated languages, while others are rare or nonexistent? Common patterns must be either innovated more often, or lost less often.

(2) Focus of this talk is on two main proposals as to the factors determining the innovation and extinction rates:

a. Analytic bias: Cognitive biases (such as Universal Grammar) facilitate the learning of some patterns and inhibit that of others.

E.g.: Jakobson, Fant, & Halle 1952:40–41; Chomsky & Halle 1968:4, 251, 296–297; Sagey 1990:1–2; Prince & Smolensky 1993:3, 201–202; Archangeli & Pulleyblank 1994:391–395; Clements & Hume 1995:245, 250; Hayes 1999; Tesar & Smolensky 2000:85–90; Steriade 2001:235–237; Davidson, Smolensky, & Jusczyk 2004; Hayes & Steriade 2004:1–2, 6; Wilson 2006; see also Saffran 2003, Newport & Aslin 2004.

b. Channel bias: Systematic phonetic errors in transmission of utterances favor innovation of some patterns and extinction of others.

i. Major role for phonetic precursors, giving rise to phonological patterns through phonologization (Hyman 1976). The more robust the phonetic precursor, the more frequent the phonological pattern.

Ohala 1994; Hale & Reiss 2000; Barnes 2002:151–159; Myers 2002; Kavitskaya 2002:123–133; Blevins 2004:108–109; Moreton & Thomas in press.

ii. Minor role (if any) for UG: May supply representational units, or regularize variability, but does not otherwise favor one phonological pattern over another

Ohala 1990, 2005; Haspelmath 1999:206–207; Buckley 2000:11; Hale & Reiss 2000; Hume & Johnson 2001; Kochetov 2002:186, 216, 226; Blevins 2004:19–21, 41, 281–285.

(3) These theories can be hard to distinguish on the basis of typological data. For example, vowel height harmony is common, while consonant continuancy harmony is nonexistent (Rose & Walker 2004).

a. Analytic-bias account: Universal Grammar includes a constraint AGREE-[HIGH] which can drive height harmony (Bakovic 2000), but no AGREE-[CONT].

b. Channel-bias account (after Ohala 1994b; Beddor, Krakow, & Lindemann 2001; Blevins 2002:142–144; Przezdziecki 2005): Vowel height coarticulation serves as a phonetic precursor for height harmony, but there is no phonetic precursor for continuancy harmony.

Both approaches can account for the typological asymmetry.

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(4) This talk: Can analytic bias alone cause a typological asymmetry? (*Yes*.)

§2 Identify a case of typological asymmetry (height-height versus height-voice patterns).

§3 Do the phonetic precursors differ in magnitude? (*No.)*

§4 Exp. 1: Is the height-height pattern easier to learn than a height-voice pattern in an artificial-language paradigm? (*Yes*.)

§5 Exp. 2: Is a voice-voice pattern easier to learn than a height-voice pattern? (*Yes*.)

§6 Exps 3 and 4: Is a height-backness pattern easier than height-voice? (*No*.)

§7 Discussion

(5) Novelty of this work is that it pins the typology squarely on analytic bias, controlling for precursor robustness.

a. Previous lab work on analytic bias focuses on analytic biases which recapitulate channel biases ("naturalness"), so can't tell which factor is responsible for typology (Schane, Tranel, & Lane 1974; Saffran & Thiessen 2003; Pycha, Nowak, Shin, & Shosted 2003; Seidl & Buckley 2005; Wilson 2006; Koo & Cole 2006; Peperkamp & Dupoux in press)

b. Previous studies which eliminated channel bias inferred an analytic bias, but did not demonstrate it directly in the lab (Kiparsky 1995, 2004, 2006).

2. Typology: Height-height outnumbers height-voice

(6) Compare two kinds of phonological pattern:

(HH) "Height-Height": Phonological dependency between the height of vowels in adjacent syllables (height harmony or height disharmony).

(HV) "Height-Voice": Phonological dependency between the height of a vowel and the voicing, aspiration, or fortis/lenis status of an immediately following obstruent.

Claim: HH patterns are typologically more frequent than HV patterns.

(7) Brute-force grammar search subject to the following criteria:

a. Limited to languages in which both HH and HV had the opportunity to occur, i.e., languages described as having a voicing, aspiration, or fortis-lenis contrast in obstruents.

b. Pattern was required to neutralize a contrast found elsewhere in the language. Thus, static phonotactic patterns and morphophonemic alternations qualified, but allophonic alternations did not. (This was to be sure that the patterns were phonological rather than phonetic.)

c. Consonant contrast had to be free of confounding phonetic factors, such as preglottalization, prenasalization.

d. Alternations limited to individual morphemes did not qualify.

e. Languages in the survey must have been described from work with living speakers, rather than reconstructed, as reconstructions can be contaminated by theoretical bias (Maddieson, 1976).

(8) Count language families (= top-level Ethnologue categories, Gordon 2005) rather than individual languages. Rationale: We are counting *surviving independent innovations* of the two pattern types, approximating an answer to the question of whether one of them is more likely to be innovated or retained.

(9) HH patterns: 5 language families fit the criteria.

Basque: Basque. In many dialects, /a/ raises to /e/ after a syllable containing a high vowel. Voicing contrast (Hualde 1991:10, 23–31).

Indo-European: Pasiego Spanish. Mid vowels become high before a syllable containing a stressed high vowel (Penny 1969a, §2.3). Voicing contrast "like Castillian" (Penny 1969b:55); presumably this means /b d g/ lenite to fricatives intervocalically.

Niger-Congo: C'Lela. Roots don't mix high and non-high vowels. Suffixes alternate. Voicing contrast (Dettweiler 2000).

Oto-Manguean: Maltinaltepec Tlapaneca:. /a/ unrestricted, but vowels of non-final syllable are mid or high depending on whether the final vowel is mid. Voicing contrast (Suaréz 1983:7–9, 12–16, 20–22, 48–49).

Sino-Tibetan: Lhasa Tibetan. Non-high vowels become high in the presence of a high vowel. Aspiration contrast in stops (Dawson 1982:3, 11–12, 63–80).

- If we relax the criteria slightly, we can add 4 more:

Afro-Asiatic: Kera. Non-high vowels become high in the presence of a high vowel. "Voicing" difference in stops is really aspiration Research in the 1970s reported that it was contrastive, but more recent and detailed fieldwork did not replicate this finding (Ebert 1976, 1979:14–18, Pearce 2003, 2005, p.c. 2007). The language seems to be changing rapidly (Pearce p.c. 2007).

Austronesian: Woleaian. /a/, the only low vowel, becomes [e] before a syllable containing [a], and also become [e] between two syllables containing high vowels. Voicing contrast marginal (only /ş/ vs /z̧/) (Sohn 1971, 1975).

Chukotko-Kamchatkan: Chukchee. /i u e/ lower to /e o a/ when in same morphological constituent as /e o/ or some kinds of /ə/. Voicing contrast marginal: /k/ vs. /g/ only (Bogoras 1922 [1969]). Later authors describe the /g/ as /ɣ/, making voicing entirely redundant with continuancy (Kämpfe & Volodin 1995).

Gulf: Tunica. Mid vowels do not co-occur in underived lexical items. /e o/ lower to /ɛ ɔ/ before /a/ in same morpheme. Voicing contrast marginal, mostly in loans; height contrast in mid vowels dubious (Haas 1946, Wiswall 1981:82–125).

(10) HV patterns: No families fit the criteria. There were three marginal cases:

Indo-European: (1) Polish. /ɔ/ raises to [o] before underlyingly voiced non-nasal coda. Productivity is doubtful (Sanders 2003). (2) Canadian English. [ʌɪ] and [aɪ] contrast before [ɾ], but in other environments [ʌɪ] is found only before voiceless obstruents and [aɪ] is found only elsewhere. Contrast is marginal (Chambers 1973).

Sino-Tibetan: Lungtu Fujien Chinese. Stops contrast for aspiration in onset. In codas, voiced stops occur after nonlow vowels, voiceless stops after low vowels. Coda voiced/voiceless redundant with preglottalised/glottalised, and not phonemically contrastive (Egerod 1956:27–51).

(11) ⇒ HH patterns outnumber HV patterns in survey by 5–0 (or 9–2 if marginal cases are counted).

Surprising when you consider that HV patterns relate phonetically-adjacent elements in the same syllable, while HH patterns relate phonetically-remote elements in different syllables. Long-range dependencies are usually *less* salient (Moreton and Amano, 1999; Newport and Aslin, 2004; Creel et al., 2004; but see Endress & Mehler 2006).

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3. Phonetics: HH and HV precursors are of about the same size

(12) First try at explaining the typological difference: High typological frequency of vowel harmony has been ascribed to channel bias caused by its phonetic precursor, vowel-to-vowel height coarticulation (Ohala 1994b; Blevins 2004:143, Przezdziecki 2005).

⇒ phonetic precursor of the HV pattern should be smaller than that of the HH pattern.

(13) Assumptions about precursors:

a. HH precursor is, uncontroversially, height coarticulation, expressed as F1-F1 correlation.

b. HV precursor is F1-voicing correlation. Origins are still incompletely understood.

   i. Pharyngeal-cavity expansion which occurs during the production of voiced obstruents (Kent & Moll 1969; Bell-Berti 1975; Westbury 1983; for a review, see Thomas 2000).

   ii. Auditory enhancement of voicing percept (Kingston & Diehl 1994).

   iii. Peripheralization of vocalic articulations before voiceless obstruents (Thomas 2000; Moreton 2004; Moreton & Thomas in press)

(14) Survey procedure:

(a) Find studies where vowel F1 was measured in the relevant contexts.

(b) Identify contexts likeliest to raise/lower target F1. For HH studies, Raising context is high vowels and Lowering context is low vowels. For HV studies, Raising context is voiced/unaspirated/lenis and Lowering context is voiceless/aspirated/fortis.

(c) <u>Effect of context</u> is defined to be target F1 in Raising context divided by that in Lowering context. (This automatically normalizes away inter-speaker difference in F1 range.)

(d) If study made measurements at multiple points in target, the point closest to the context was used.

Large effect of context →

Medium effect →

No effect (ratio = 1) →

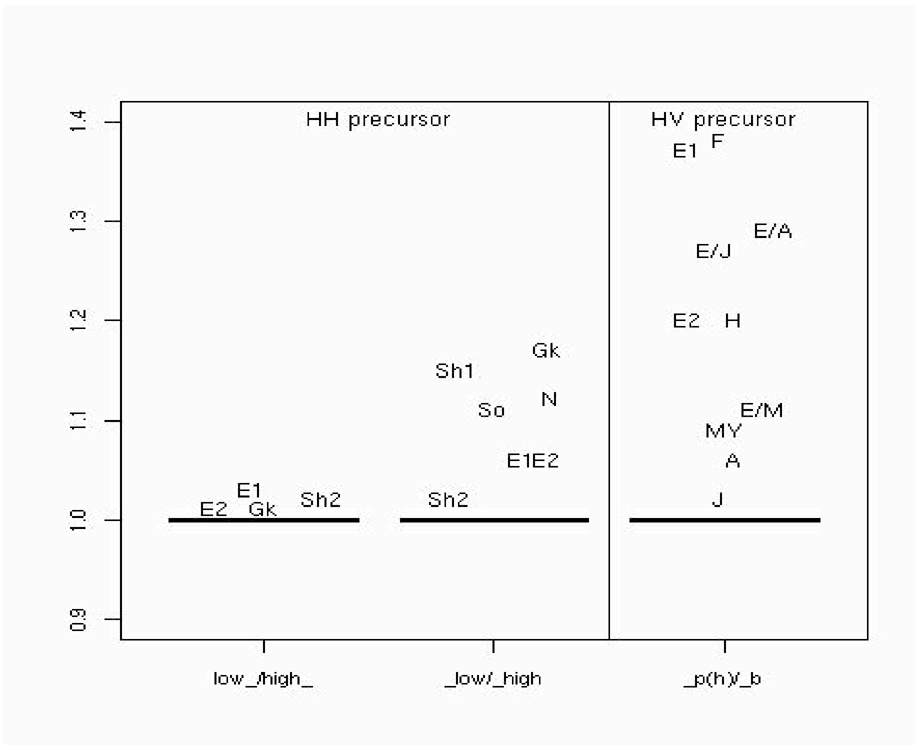

Table 1. Phonetic effect of context vowel height on target vowel F1.

Code	Study	Ratio
E1	English (Beddor, Harnsberger, & Lindemann 2002): 5 speakers. Stressed /i e a o u/.	
	Measured at target offset: [_Ca] vs. [_Ci]:	1.06
	Measured at target onset: [aC_] vs. [iC_]:	1.03
E2	English (Koenig & Okalidou 2003): 3 spkrs. Stressed /i e ɑ ɔ u/, at steady state.	
	[_Ca] vs. [_Ci]:	1.01
	[aC_] vs. [iC_]:	1.02
Gk	Greek (Koenig & Okalidou 2003): 3 speakers. Stressed /i ɛ a ɔ u/, at steady state.	
	[_Ca] vs. [_Ci]:	1.17
	[aC_] vs. [iC_]:	1.01
N	Ndebele (Manuel 1990): 3 speakers. /e/ and /a/ measured at target offset.	
	[_Ca] vs. [_Ci]:	1.12

Sh1	Shona (Manuel 1990): 3 speakers. /e/ and /a/ measured at target offset.	
	[_Ca] vs. [_Ci]:	1.15
Sh2	Shona (Beddor et al. 2002): 7 speakers. Stressed /i e a o u/.	
	Measured at target offset: [_Ca] vs. [_Ci]:	1.02
	Measured at target onset: [aC_] vs. [iC_]:	1.02
So	Sotho (Manuel 1990). 3 speakers. /e/ and /a/ measured at target offset.	
	[_Ca] vs. [_Ci]:	1.11

Table 2. Phonetic effect of context consonant "voicing" on target vowel F1.

Code	Study	Ratio
A	Arabic (De Jong & Zawaydeh 2002: Figure 5) Stressed /a/ at midpoint. [_t] vs. [_d]:	1.05
E1	English (Wolf 1978). 2 speakers, /æ/. Average F1 in last 30 ms. [_p/t/k] vs. [_b/d/g]:	1.37
E2	English (Summers 1987): 3 speakers. /æ ɑ/. At vowel offset: [_p/f] vs. [_b/v]:	1.20
E/A	L2 English (L1 = Arabic) (Crowther & Mann 1992): 10 speakers. /ɑ/ measured at vowel offset, [_t] vs. [_d]:	1.29
E/J	L2 English (L1 = Japanese) (Crowther & Mann 1992) 10 speakers. /ɑ/ measured at vowel offset, [_t] vs. [_d]:	1.27
E/M	L2 English (L1 = Mandarin) (Crowther & Mann 1992): 10 speakers. /ɑ/ measured at vowel offset, [_t] vs. [_d]:	1.11
F	French (Fischer-Jørgensen 1972): 1 spkr. /a/ just before closure. [_p/t/k] vs. [_b/d/g]:	1.38
H	Hindi (Lampp & Reklis 2004): 5 speakers. /ɔ/ just before closure. [_k] vs. [_g]:	1.16
J	Japanese (Kawahara 2005): 3 spkrs. /e a o/ just before closure. [_p/t/k] vs. [_b/d/g]:	1.02
MY	Mòbà Yoruba (Przezdziecki 2005): 1 spkr. /i/ at midpoint. [_t/k] vs. [_d/g]:	1.09

(15) ⇒ **Precursor robustness does *not* predict typological frequency.** Although HH phonological patterns are more frequent than HV ones, the HV precursor is not obviously smaller than the HH one. The HV precursor is ***underphonologized*** with respect to the HH precursor.

(16) This is not an isolated instance:

a. Vowel intrinsic F0 seems to be underphonolgized relative to voice-tone patterns (Hombert, Ohala, & Ewan 1979).

b. Tone-tone patterns are more common than voice-tone patterns (20 Ethnologue families vs. 8), but their phonetic precursors—about which much more phonetic data is available than in the HH/HV case—have similar magnitude (Moreton, to appear).

4. Experiment 1: Height-height vs. height-voice

(17) <u>Second try at explaining the typological difference:</u> Analytic bias: The HH pattern is easier to learn than the HV pattern. How can we test this?

(18) Patterns of segmental occurrence and co-occurrence can be acquired by learners in laboratory experiments.

Pattern-conformity effects have been found with adults in phoneme restoration (Ohala & Feder 1994), speech errors (Dell et al. 2000; Goldrick 2004), speeded-repetition latency (Onishi, Chambers, & Fisher 2002; Koo & Cole 2006; Chambers, Onishi, & Fisher submitted), segmentation of continuous speech (Newport & Aslin 2004; Bonatti, Peña, Nespor, & Mehler 2005), phonologically-conditioned allomorph selection in an artificial language (Schane et al. 1974; Pycha et al. 2003; Wilson 2003a, b), and language-game responses (Wilson 2006); and with infants in preferential listening (Saffran & Thiessen 2003; Chambers, Onishi, & Fisher 2003; Seidl & Buckley 2005).

(19) Artificial languages: cvcv words with inventory /t k d ɡ/ /i u æ ɔ/, spoken by MBROLA concatenative synthesizer using an American English voice.

(a) "HH Language": Vowels agree in height, instantiating the height-harmony pattern.

(b) "HV Language": First vowel high iff second consonant is voiced. This represents what *would* be phonologization of the HV precursor.

(20) Experimental paradigm :

(a) Study Phase: Listen to words of one Language through headphones, repeat into microphone (32 words, repeated 4 times, randomized within blocks).

(b) Test Phase: Listen to pairs of words, choose the one that you think is a word of the Language you've studied. (32 pairs in two blocks of 16, random order in block, no word repeated.) Each pair consists of one positive Test item (fitting pattern of Study-phase Language) and one negative (violating pattern). All are novel. Dependent measure: probability of choosing positive Test item.

(c) Break with music, then (a) and (b) again for the other Language.

(21) Each of the two Languages used 32 "words" for the training phase and 64 for the test phase. Each participant got their own randomly-selected HV and HH Languages, which contained no words in common.

(a) Stimuli for HV Language

Stimulus variables			Test Phase	
HV-conforming	HH-conforming	Study Phase	Pos	Neg
+	+	16	16	—
+	–	16	16	—
–	+	—	—	—
–	–	—	—	32

(b) Stimuli for HH Language

Stimulus variables			Test Phase	
HV-conforming	HH-conforming	Study Phase	Pos	Neg
+	+	16	16	—
+	–	—	—	—
–	+	16	16	—
–	–	—	—	32

(22) Properties of this design:

(a) All Study items matched the pattern of the Language condition, and were 50% likely to match or mismatch the pattern of the other Language condition. Likewise for the positive Test items.

(b) The negative Test items had the same properties in both Language conditions

(c) In both Languages, all of the permitted HV and HH sequences occurred with equal frequency.

(d) Does *not* test generalization to new combinations of vowels. I.e., does not distinguish between learning vowel harmony and learning a list of vowel-vowel patterns.

(23) Participants: 24 native American English speakers. 12 did the HV Language condition first, 12 did the HH Language condition first.

(24) Possible outcomes

(a) HH>HV. That would support the hypothesis that vowel height harmony is more easily learned than the height-voicing dependency.

(b) HH<HV. Easier to learn dependencies between adjacent than remote segments.

(25) Results:

a. Performance in HV condition was marginally better than chance

b. Performance in HH condition was considerably better than that in HV

Variable	Coefficient	SE	z	P(>|z|)	
HV (intercept)	0.1693	0.08624	1.964	0.0496	*
HH difference from HV	0.5087	0.13070	3.892	<0.00001	***
HV-nonconformity	-0.2608	0.15085	-1.729	0.0838	

Analyzed by mixed-effects logistic regression with Participant as a random effect. Initial model had terms {Condition, HH- and HV-nonconformity, Order (=before/after break)}, plus all possible interactions. HV was used as the reference category. Backwards elimination, deleting terms until next reduced model would have differed from the initial model at $p < 0.25$ by analysis of deviance.

(26) Interim conclusions:

a. There is a typological asymmetry favoring HH over HV patterns.

b. This asymmetry does not reflect a difference in the robustness of the phonetic precursors.

c. The HH pattern is learned more readily in a laboratory situation.

These results clearly favor analytic bias over precursor robustness as an explanation for the typology of vowel-height patterns

5. Experiment 2: Height-Voice vs. Voice-Voice

(27) Next question: What is the difference between the HH and HV conditions that causes the difference in learning? Exp. 1 left several possibilities open:

(a) (Uninteresting, but dangerous:) Stop voicing is harder to hear accurately than vowel height (e.g., Cutler et al. 2004). Misperception of voice could obscure the HV pattern. I.e., Exp. 1 was really about hearing, not cognition.

BUT: In a blind-coded sample of 500 voice responses from study phase, C_2 voicing was misperceived only 1.1% of the time (out of 364 where it was successfully recorded).

(b) The patterns favored by analytic bias are precisely the ones which are typologically common. (As expected if analytic bias is the *only* determiner of typological frequency).

⇒ a "VV" (voice-voice) pattern should have no advantage over the HV pattern, since both are rare (Hansson 2004, Rose & Walker 2004)

(c) Analytic bias favors HH over HV in some more general way:

(i) ... single-feature dependency (Chomsky & Halle 1968:334–335; Clements & Hume 1995; M. Gordon 2004)

(ii) ... within-tier (c or v) dependencies in general (Newport & Aslin 2004)

(iii) ... dependencies between phonetically similar segments (Frisch, Pierrehumbert, & Broe 2004, Rose & Walker 2004)

⇒ VV pattern should be learned more easily than HV pattern.

(28) Experiment 2: Height-voice vs. voice-voice.

(a) "VV Language": Consonants agree in voicing. This is very rare in natural language (Rose & Walker 2004, Hansson 2004).

(b) "HV Language": First vowel high iff second consonant is voiced (as in Exp. 1).

(29) Possible outcomes:

(a) If analytic bias favors only typologically common processes, we expect VV≤HV, since the VV pattern is no more frequent than the HV pattern.

(b) If analytic bias favors harmony in general, within-tier dependencies, or phonetic similarity, however, we expect VV>HV. And indeed, that is what we get:

Variable	Coefficient	SE	*z*	P(>|*z*|)
HV (Intercept)	0.1986	0.1032	1.9250	0.0542
VV difference from HV	0.3013	0.1478	2.0378	0.0416 *
Order=2nd	-0.1116	0.1529	-0.7298	0.4650
Order=2nd × Condition=VV	-0.4565	0.2158	-2.1153	0.0344 *

(30) Interim results can be summarized as follows:

	HV	HH	VV
Precursor robustness	+	+	–
Analytic bias	–	+	+
Typological frequency	–	+	–

6. Experiments 3, 4: Role of feature

(31) Second series of experiments using slightly different (better!) design and stimuli (clearer consonant voicing; identical test items in both conditions; one language per participant, 9 participants in each language condition). Report preliminary results from two here; same analysis procedure as before:

(32) Exp. 3 replicates Exp. 1, HH vs. HV, with the new paradigm. HV performance was significantly better than chance, and HH performance was significantly better than HV. Coefficients and standard errors were similar to those in Exp. 1.

Variable	Coefficient	SE	*z*	P(>|*z*|)
HV (Intercept)	0.2941	0.1192	2.468	0.01360 *
HH difference from HV	0.5105	0.1746	2.925	0.00345 **

(33) Exp. 4: Height-voice vs. Height-backness

a. Hypothesis: Within-tier dependencies are learned better than between-tier dependencies of equal featural complexity.

b. HV language as before, compared with "HB language" in which the second vowel was back iff the first vowel was low.

c. Results: HV performance better than chance, as before, but no difference between HV and HB conditions. ⇒ Hypothesis is not supported.

Variable	Coefficient	SE	*z*	P(>|*z*|)
HV (Intercept)	0.33655	0.12471	2.69859	0.006963 **
HB difference from HV	0.14486	0.17757	0.81578	0.414627

(34) ⇒ The advantage seems to be associated with patterns involving recurrence of the *exact same feature* (compare Wilson 2003a).

7. Discussion

(35) Differences in precursor robustness do not translate directly into differences in typological frequency: Height-height patterns are more frequent than height-voice patterns, despite their similar-sized precursors.

Like cases discussed by Hombert et al. 1979 (height/F0 vs. voice/F0), Moreton in press (voice/F0 vs. F0/F0).

Unlike cases discussed by, e.g., Ohala1994, Kavitskaya 2002:123–133, Barnes 2002:151–159, Myers 2002, Blevins 2004:108–109, Moreton & Thomas in press, in which the more frequent phonological pattern has the more robust phonetic precursor.

⇒ Phonological typology is not simply the imprint of phonetic typology.

(36) Mismatches between phonetic typology and phonological typology are informative: They point to areas of potential cognitive bias.

(37) Experiments 1 and 3 demonstrated a learning bias which, if it operated in nature the same way it does in the lab, could lead to the observed HH/HV typological skew.

⇒ Typology can be shaped by analytic bias in ways that cannot be explained by precursor robustness.

(38) ... and if analytic bias can affect typology when precursor robustness is equal, it may also affect typology when precursor robustness is *un*equal.

For example, phonetically substantive analytic bias may enhance the phonologization of a precursor.

(39) Experiment 2 found a learning bias which never has a chance to apply in nature: VV patterns are easy to learn compared to HV patterns, but the lack of phonetic precursors obscures the effect.

See also Endress & Mehler 2006 (CvccvC dependency beats cvCCvc)

⇒ Typology can be shaped by precursor robustness in ways that cannot be explained by analytic bias (Myers 2002).

(40) I.e., **Any adequate theory of phonological typology has to take into account the filtering effects of *both* factors** (Kiparsky 2005, 2006; see also Blevins 2006b:246).

	HV	HH	VV
Precursor robustness	+	+	–
Analytic bias	–	+	+
Typological frequency	–	+	–

Since there is independent evidence that both mechanisms are needed to explain typology, parsimony doesn't favor either "side".

(41) Agenda for factoring apart the contributions of analytic bias and precursor robustness in shaping phonological typology:

a. Identify mismatches between phonetic and phonological typology
   i. Underphonologization, i.e., cases like that of the HV pattern, in which a robust phonetic interaction persistently fails to be phonologized.
   ii. Overphonologization,, i.e., cases in which a phonological pattern is innovated in the absence of a phonetic precursor (e.g., in child language).

   This means focusing on the *magnitudes* of phonetic effects, rather than just to their existence or non-existence.

b. Map range and nature of selective pattern learning (e.g., advantage for single-feature dependencies) in the lab.

c. Devise theoretical models of the analytic biases; e.g., how does UG *make* some kinds of dependency easier (e.g., Wilson 2006, Moreton in press)

Selected references

Archangeli, Diana, and Douglas Pulleyblank (1994). *Grounded Phonology*. Cambridge: MIT Press.

Bakovic, Eric. 2000. Harmony, dominance, and control. Ph.D. dissertation, Rutgers University.

Barnes, Jonathan. 2002. Positional neutralization: a phonologization approach to typological patterns. Ph.D. dissertation, University of California, Berkeley.

Beddor, Patrice Speeter, James D. Harnsberger, and Stephanie Lindemann. 2002. Language-specific patterns of vowel-to-vowel coarticulation: acoustic structures and their perceptual correlates. Journal of Phonetics 30(4):591-627.

Bell-Berti, Frederica (1975). Control of pharyngeal cavity size for English voiced and voiceless stops. *JASA* 57(2):456–461.

Berg, Thomas. 1995. Sound change in child language: a study of inter-word variation. Language and Speech 38, 331-363.

Bermúdez-Otero, Ricardo. Forthcoming 2005. Phonological change in Optimality Theory. In Keith Brown (ed), Encyclopedia of language and linguistics, 2nd edition. Oxford: Elsevier.

Blevins, Juliette (1995). The syllable in phonological theory. In: John A. Goldsmith (ed.), *The handbook of phonological theory*, 206–244. Cambridge: Blackwell.

Blevins, Juliette (2004). *Evolutionary Phonology*. Cambridge: Cambridge University Press.

Blevins, Juliette (2006a). A theoretical synopsis of Evolutionary Phonology. Theoretical Linguistics 32(2):117–166.

Blevins, Juliette (2006b). Reply to commentaries. Theoretical Linguistics 32(2):245-256.

Bogoras, Waldemar. 1922 [1969]. Chukchee. In: Franz Boas (ed.), Handbook of American Indian languages, Part 2, 631-903. Oosterhout N.B., The Netherlands: Anthropological Publications.

Bonatti, Luca L., Marcela Peña, Marina Nespor, and Jacques Mehler. 2005. Linguistic constraints on statistical computations: the role of consonants and vowels in continuous speech processing. Psychological Science 16(6):451-459.

Buckley, Eugene (2000). On the naturalness of unnatural rules. In: *Proceedings from the Second Workshop on American Indigenous Languages, UCSB Working Papers in Linguistics, Volume 9*.

Chambers, J. K. 1973. Canadian Raising. Canadian Journal of Linguistics 18:113–135.

Chomsky, Noam, and Morris Halle (1968). *The sound pattern of English*. MIT Press.

Clements, G. N., and Elizabeth V. Hume (1995). The internal organization of speech sounds. In: John A. Goldsmith (ed.), *The handbook of phonological theory*, 245–306. Cambridge: Blackwell.

Crowther, Court S., and Virginia A. Mann. 1992. Native language factors affecting use of vocalic cues to final consonant voicing in English. Journal of the Acoustical Society of America 92:711-722.

Cutler, Anne, Andrea Weber, Roel Smits, and Nicole Cooper. 2004. Patterns of English phoneme confusions by native and non-native listeners. Journal of the Acoustical Society of America 116 (6):3668-3678.

Davidson, Lisa, Paul Smolensky, and Peter W. Jusczyk (2004). The initial and final states: theoretical implications and experimental explorations of Richness of the Base. In: René Kager, Wim Zonneveld, and Joe Pater (eds.), *Fixing priorities: constraints in phonological acquisition*, 321–368. Cambridge: Cambridge University Press.

Dawson, Willa. 1980. Tibetan phonology. Ph. D. dissertation, University of Washington.

de Jong, Kenneth, and Bushra Zawaydeh. 2002. Comparing stress, lexical focus, and segmental focus: patterns of variation in Arabic vowel duration. Journal of phonetics 30:53-75.

Dell, G. S. , K. D. Reed, D. R. Adams, and A. S. Meyer. 2000. Speech errors, phonotactic constraints, and implicit learning: A study of the role of experience in language production. Journal of Experimental Psychology: Learning, Memory, and Cognition, 26:1355-1367.

Dettweiler, Stephen H. 2000. Vowel harmony and neutral vowels in c'Lela. Journal of West African Languages 28:3-18.

Dutoit, T., Pagel, V., Pierret, N., Bataille, F. and Van der Vreken, O. (1996). The MBROLA Project: Towards a Set of High-Quality Speech Synthesizers Free of Use for Non-Commercial Purposes, *Proceedings of the International Conference on Spoken Language Processing (ICSLP)* 3:1393-1396.

Ebert, Karen. 1976. Sprache und Tradition der Kera (Tschad). Teil II: Lexikon/Lexique. Berlin: Reimer.

Ebert, Karen. 1979. Sprache und Tradition der Kera (Tschad). Teil III: Grammatik. Berlin: Reimer.

Egerod, Søren. 1956. The Lungtu dialect: a descriptive and historical study of a South Chinese idiom. Copenhagen: Ejnar Munksgaard.

Endress, Ansgar D., and Jacques Mehler. MS. Perceptual constraints in phonotactic learning. MS, downloaded 2006 Dec. 26.

Goldrick, Matthew. 2004. Phonological features and phonotactic constraints in speech production. Journal of Memory and Language 51:586–603.

Gordon, Matthew. 2004. Syllable weight. In: Bruce Hayes, Robert Kirchner, and Donca Steriade (eds.), Phonetically-based phonology, 277–312. Cambridge: Cambridge University Press.
Gordon, Raymond G., Jr. (ed.) 2005. Ethnologue: Languages of the World, 15th ed. Dallas: SIL International. http://www.ethnologue.com.
Haas, Mary. 1946. A grammatical sketch of Tunica. In: Cornelius Osgood (ed.), Linguistic Structures of Native America, 337-366. New York: The Viking Fund.
Hale, Mark, and Charles Reiss. 2000. "Substance abuse" and "dysfunctionalism": current trends in phonology. Linguistic Inquiry 31(1):157–169.
Hansson, Gunnar Ólafur (2001). *Theoretical and typological issues in consonant harmony.* Ph.D. dissertation, University of California, Berkeley.
Hansson, Gunnar Ólafur. 2004. Long-distance voicing agreement: an evolutionary perspective. Handout from a talk presented at the 30th annual meeting of the Berkeley Linguistics Society, Berkeley, CA, Feb. 13-16, 2004.
Hayes, Bruce. 1999. Phonetically-Driven Phonology: The Role of Optimality Theory and Inductive Grounding. In: Michael Darnell, Edith Moravscik, Michael Noonan, Frederick Newmeyer, and Kathleen Wheatly (eds.), Functionalism and Formalism in Linguistics, Volume I: General Papers, 243-285. John Benjamins, Amsterdam.
Hombert, Jean-Marie, John J. Ohala, and William G. Ewan. 1979. Phonetic explanations for the development of tones. Language. 55(1). 37-58.
Hualde, José Ignacio. 1991. Basque phonology. London: Routledge.
Hyman, Larry M. 1976. Phonologization. In: Alphonse Juilland (ed.), Linguistic Studies Offered to Joseph Greenberg: Second Volume: Phonology. Studia linguistica et philologica 4, 407–418. Saratoga, California: Anma Libri.
Kämpfe, Hans-Rainer, and Alexander P. Volodin. 1995. Abriss der tschuktschischen Grammatik auf der Basis der Schriftsprache. Wiesbaden: Harrassowitz Verlag.
Kavitskaya, Darya. 2002. Compensatory lengthening: phonetics, phonology, diachrony. New York: Routledge.
Kawahara, Shigeto. 2005. Voicing and geminacy in Japanese: an acoustic and perceptual study. In K. Flack and S. Kawahara (eds.) University of Massachusetts Occasional Papers in Linguistics 31, 87-120.
Kent, R. D., and K. L. Moll (1969). Vocal tract characteristics of the stop cognates. *JASA* 46:1549–1555.
Kingston, John, and Randy L. Diehl. 1994. Phonetic knowledge. Language 70:419-454.
Kiparsky, Paul (1995). The phonological basis of sound change. In: John A. Goldsmith (ed.), *The handbook of phonological theory*, 640–670. Cambridge: Blackwell.
Kiparsky, Paul (2004). Universals constrain change; change results in typological generalizations. MS, Stanford University.
Kiparsky, Paul (2006). The amphichronic program vs. Evolutionary Phonology. *Theoretical Linguistics* 32:217-236.
Kochetov, Alexei (2002). *Production, perception, and emergent phonotactic patterns: a case of contrastive palatalization.* New York: Routledge.
Koenig, Laura L., and Areti Okalidou. 2003. Stress effects on coarticulation in English and Greek. Poster presented at the 145th meeting of the Acoustical Society of America, Nashville, Tennessee, April 28-May 2, 2003.
Manuel, Sharon Y. 1990. The role of contrast in limiting vowel-to-vowel coarticulation in different languages. Journal of the Acoustical Society of America. 88(3). 1286-1298.
Moreton, Elliott, and Erik R. Thomas. In press. Origins of Canadian Raising in voiceless-coda effects: a case study in phonologization. To appear in J. Cole and J. I. Hualde (eds.), Papers in Laboratory Phonology 9.
Moreton, Elliott. Forthcoming. Underphonologization and modularity bias. To appear in: Steven Parker (ed.), Phonological argumentation. Equinox Press.
Myers, Scott. 2002. Gaps in factorial typology: The case of voicing in consonant clusters. MS, University of Texas at Austin.
Newport, E.L., and R. N. Aslin. 2004. Learning at a distance: I. Statistical learning of non-adjacent dependencies. Cognitive Psychology, 48, 127-162
Ohala, John J (1990). The phonetics and phonology of aspects of assimilation. In: John Kingston and Mary E. Beckman (eds.), *Papers in laboratory phonology I: between the grammar and physics of speech*, 258–275.
Ohala, John J (1993). The phonetics of sound change. In: Charles Jones (ed.), *Historical linguistics: problems and perspectives,* 237-278. Harlow: Longman.
Ohala, John J (1994a). Hierarchies of environments for sound variation; plus implications for 'neutral' vowels in vowel harmony. *Acta Linguistica Hafniensia* 27:371–382.
Ohala, John J (1994b). Towards a universal, phonetically-based theory of vowel harmony. In: *Proceedings of the International Conference on Spoken Language Processing (ICSLP)*, 491–494..

Ohala, John J. J. (2005). Phonetic explanations for sound patterns. Implications for grammars of competence. In W. J. Hardcastle & J. M. Beck (eds.) *A figure of speech. A festschrift for John Laver*. London: Erlbaum. 23-38.

Onishi, Kristine H., Kyle E. Chambers, and Cynthia Fisher. 2002. Learning phonotactic constraints from brief auditory experience. Cognition 83:B13–B23.

Pearce, Mary. 2003. Vowel harmony in Kera (Chadic). M.A. thesis, Department of Phonetics and Linguistics, University College London.

Pearce, Mary. 2005. Kera tone and voicing. In: M. Pearce and I. Topintzi (eds.), University College London Working Papers in Linguistics, Vol. 17. London: UCL.

Peperkamp, Sharon, and Emanuel Dupoux (In press). Learning the mapping from surface to underlying representations in an artificial language. In: J. Cole and J. Hualde (eds.), *Papers in Laboratory Phonology 9*.

Penny, Ralph J. 1969a. Vowel harmony in the speech of Montes de Pas (Santander). Orbis 18:148-166.

Penny, Ralph J. 1969b. El habla pasiega: ensayo de dialectología montañesa. London: Tamesis Books.

Prince, Alan, and Paul Smolensky. 1993. Optimality Theory: constraint interaction in generative grammar. MS, Rutgers University Department of Linguistics.

Przezdziecki, Marek. 2005. Vowel Harmony and Coarticulation in Three Dialects of Yoruba: Phonetics Determining Phonology. Ph.D. dissertation, Cornell University.

Pycha, Anne, Pawel Nowak, Eurie Shin, and Ryan Shosted. 2003. Phonological rule-learning and its implications for a theory of vowel harmony. WCCFL 22.

Rose, Sharon, and Rachel Walker. 2004. A typology of consonant agreement as correspondence. Language 80(3):475–531.

Saffran, Jenny R., and Erik D. Thiessen (2003). Pattern induction by infant language learners. *Developmental Psychology* 39(3):484-494.

Sanders, Nathan. 2003. Opacity and sound change in the Polish lexicon. Ph. D. Dissertation, UCSC

Seidl, Amanda, and Eugene Buckley (2005). On the learning of arbitrary phonological rules. *Language Learning and Development* (1):289–316.

Sohn, Ho-Min. 1971. A-raising in Woleaian. University of Hawaii Working Papers in Linguistics, 3(8):15-35.

Sohn, Ho-Min. 1975. Woleaian reference grammar. Honolulu: University Press of Hawaii.

Steriade, Donca (2001b). Directional asymmetries in place assimilation: a perceptual account. In: Hume & Johnson 2001: 219–250. San Diego: Academic Press.

Story, Gillian L. 1984. Babine and Carrier phonology: a historically oriented study. Summer Institute of Linguistics Publications in Linguistics, 70. Summer Institute of Linguistics and University of Texas at Arlington.

Suárez, Jorge A. 1983. La lengua tlapaneca de Malinaltepec. Mexico City: Universidad Nacional Autónoma de México.

Summers, W. V. 1987 Effects of stress and final-consonant voicing on vowel production: Articulatory and acoustic analysis. Journal of the Acoustical Society of America, 82:847–863.

Tesar, Bruce, and Paul Smolensky (2000). *Learnability in Optimality Theory*. Cambridge: MIT Press.

Wilson, Colin (2003a). Experimental investigation of phonological naturalness. In: G. Garding and M. Tsujimura (eds.), *WCCFL 22*, 533–546. Somerville: Cascadilla Press.

Wilson, Colin (2003b). Analytic bias in artificial phonology learning: consonant harmony vs. random alternation. Handout from presentation at the Workshop on Markedness and the Lexicon, Massachusetts Institute of Technology, January 25, 2003.

Wilson, Colin. 2006. Learning phonology with substantive bias: an experimental and computational study of velar palatalization. To appear in *Cognitive Science*.

Wiswall, Wendy Jeanne. 1991. Partial vowel harmonies as evidence for a Height Node. Ph. D. dissertation, University of Arizona.

Wolf, Catherine G. Voicing cues in English final stops. Journal of Phonetics 6:299-309.