Phonotactic learning and phonological typology

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1. Introduction

(1) Some phonological patterns are common across languages, while others are rare or nonexistent. It must be the case that some patterns are more likely than others to be innovated or retained across ages of language change. This talk addresses the two main proposals as to the source of this long-term bias:

   (a) Pattern selectivity: Cognitive biases (e.g., Universal Grammar) make some patterns difficult or impossible to acquire.

   Jakobson, Fant, & Halle 1952:40–41; Chomsky & Halle 1968:251, 296–297; Sagey 1990:1–2; Prince & Smolensky 1993:3, 201–202; Archangeli & Pulleyblank 1994:391–395; Clements & Hume 1995:245, 250; Tesar & Smolensky 2000:2–6; Hayes, Kirchner, & Steriade 2004:1–2

   (b) Phonetic precursor robustness: Phonological patterns are innovated when subtle phonetic precursors are reinterpreted as phonologicical ("phonologized", 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.

(2) 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) Pattern-selectivity explanation: Universal Grammar includes a constraint AGREE-[HIGH] which can drive height harmony (Bakovic 2000), but no AGREE-[CONT].

   (b) Phonetic-precursor explanation: Vowel height coarticulation serves as a precursor for height harmony (Przezdziecki 2005), but there is no phonetic precursor for continuancy harmony.

(3) This talk: Can pattern selectivity cause a typological asymmetry?

   §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 Discussion

2. Typological asymmetry: Height-Height outnumbers Height-Voice

(4) Focus on 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 consonant.

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

(5) Survey (brute-force grammar search), subject to following criteria:

(a) Language must have both a height contrast and a postvocalic voicing, aspiration, or "fortis-lenis" contrast, so that HH and HV patterns are given equal opportunity to occur.

(b) As a crude precaution against double-counting cases of shared inheritance, language *families* were counted rather than individual languages. "Family" was defined as "top-level category in Ethnologue" (R. Gordon 2005).

(c) Both static phonotactic patterns and morphophonemic alternations qualify. Allophonic (i.e., non-neutralizing) patterns are excluded, because we cannot be sure that they are phonological.

(d) Language must have been described while still alive (i.e., no reconstructions).

(e) Alternations limited to a single affix do not qualify.

(6) HH patterns (6 solid cases + 3 marginal):

Afro-Asiatic: *Kera*. Non-high vowels become high in the presence of a high vowel. "Voicing" contrast in stops is really aspiration (Ebert 1976, 1979, Pearce 2003, 2005).

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

Indo-European: *Pasiego Spanish*. Mid vowels become high before a syllable containing a stressed high vowel (Penny 1969).

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).

Sino-Tibetan: *Lhasa Tibetan*. Non-high vowels become high in the presence of a high vowel. Aspiration contrast in stops (Dawson 1982).

These are the solid cases. Marginal cases include:

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 /ʂ/ 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 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 (Haas 1946, Wiswall 1981).

(7) HV patterns (0 solid + 2 marginal):

No solid cases found. Marginal ones include

Indo-European: (1) *Polish*. /ɔ/ raises to [u] 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 preglottalized/glottalized, and not phonemically contrastive (Egerod 1956).

(8) ⇒ HH patterns outnumber HV patterns in survey by 6–0 (or 9–2 if marginal cases are counted).

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3. Precursor robustness: Height-Height is no more robust than Height-Voice

(9) First try at explaining typological difference: The smaller the phonetic interaction between X and Y, the less opportunity the listener has to reinterpret it as phonological, and hence the less often the X-Y pattern should become phonologized (Ohala 1994; Kavitskaya 2002:123–133; Barnes 2002:151–159; Myers 2002; Blevins 2004:108–109; Moreton and Thomas in press).

(10) ⇒ Cross-linguistically, the phonetic precursor of HH should be substantially larger than that of HV. Is it?

(a) HH precursor is, uncontroversially, vowel-height coarticulation.

(b) HV precursor is tendency for vocalic articulations to be more extreme before voiceless obstruents (Thomas 2000; Moreton 2004; Moreton & Thomas in press).

(c) Compare effects on vowel F1: phonological height of a neighboring vowel, vs. phonological voicing/aspiration of an immediately following consonant.

(11) 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) Effect of context 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.
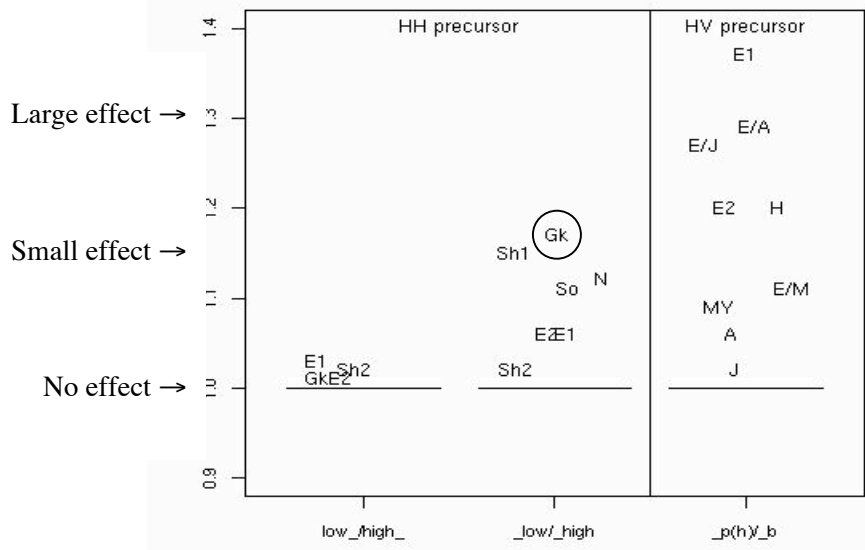
(12) Effects of context vowel height on target vowel F1

(E1) English (Beddor et al. 2002): 5 speakers. Stressed /i e a o u/. Measured at target offset: [_Ca] vs. [_Ci]: 1.06. Measured at vowel onset: [aC_] vs. [iC_]: 1.03

(E2) English (Koenig & Okalidou 2003): 3 speakers. Stressed /i e ɑ ɔ u/, measured 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/, measured 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.

(13) Effects of context consonant voicing on target vowel F1

(A) Arabic (De Jong & Zawaydeh 2002: Figure 5) Stressed /a/ measured 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. In first 50 ms: 1.07.

(E2) English (Summers 1987): 3 speakers. /æ ɑ/. Measured at vowel offset: [_p/f] vs. [_b/v]: 1.20. At vowel steady state: 1.06.

(E/J) L2 English (Japanese) (Crowther & Mann 1992) 10 speakers. /ɑ/ measured at vowel offset, [_t] vs. [_d]: 1.27

(E/M) L2 English (Mandarin) (Crowther & Mann 1992): 10 speakers. /ɑ/ measured at vowel offset, [_t] vs. [_d]: 1.11

(E/A) L2 English (Arabic) (Crowther & Mann 1992): 10 speakers. /ɑ/ measured at vowel offset, [_t] vs. [_d]: 1.29

(H) Hindi (Lampp & Reklis 2004): 5 speakers. /ɔ/ measured just before closure. [_k] vs. [_g]: 1.16. [_kh] vs. [_gh]: 1.24.

(J) Japanese (Kawahara 2004): 3 speakers. /e a o/ measured just before closure. [_p/t/k] vs. [_b/d/g]: 1.02. [_pp/tt/kk] vs. [_bb/dd/gg]: 1.04.

(MY) Mòbà Yoruba (Przezdziecki 2005): 1 speaker. /i/ measured at midpoint. [_t/k] vs. [_d/g]: 1.09.

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(14) ⇒ **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.

> Not an isolated case. Tone-tone patterns are more common than tone-voice patterns (19 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

(15) Second try at explaining the typological difference: Pattern selectivity. The HH pattern is easier to learn than the HV pattern. How can we test this?

(16) New phonotactic restrictions can be learned readily in the lab (Dell et al. 2000; Onishi et al 2002; Pycha et al. 2003; Newport & Aslin 2004;Goldrick 2004; Bonatti et al. 2005).

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

  (a) "HH Language": Vowels agree in height.

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

(18) Experimental paradigm :

  (a) Study Phase: Listen to words of one Language through headphones, repeat into microphone (32 words repeated 8 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.

(19) 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-harmonic	HH-harmonic	Study Phase	Pos	Neg
+	+	16	16	—
+	–	16	16	—
–	+	—	—	—
–	–	—	—	32

  (b) Stimuli for HH Language

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

(20) 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 fixed set of V-V patterns.

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

(22) Possible outcomes

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

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

(23) Results

    (a) Large and highly significant main effect of Language: better performance in the HH condition ($p < 0.0001$)

    (b) Near-chance performance in the HV condition ($p = 0.174$).

	coefficient	se(coef)	z	Pr(>|z|)	
(Intercept)	0.17426	0.1281	1.3606	0.17400	⇐ *HV Lang.*
isSecond	0.03629	0.1810	0.2005	0.84100	
Lang	0.71692	0.2151	3.3326	0.00086	⇐ *HH Lang.*
HVdis	-0.51706	0.2184	-2.3680	0.01790	
sameV	0.06458	0.1608	0.4016	0.68800	
isSecond:Lang	-0.35173	0.3253	-1.0814	0.28000	
isSecond:HVdis	0.49489	0.3033	1.6315	0.10300	
isSecond:sameV	-0.31250	0.2252	-1.3880	0.16500	

Logistic regression with a random effect for Participant intercepts. Reference category is HV Language, HH-harmonic, HV-harmonic, non-identical vowels; note use of HH- and HV *dis*harmonic as variables. Model was fit by backwards elimination.

(24) ⇒ **Learning bias matches typological bias.** This finding together with the lack of difference in precursor robustness, supports the hypothesis that the typological bias is due to pattern selectivity and not to precursor robustness.

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

(25) 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 (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, voicing of first and second consonant was correct over 98% of the time.

    (b) The patterns favored by selective bias are precisely the ones which are typologically common. (Expected, if pattern selectivity is the sole determinant of typological frequency.)

    (c) Pattern selectivity favors HH over HV in some more general way:

        (i) ... harmony in general (recurrence of same feature)

        (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)

        (iv) ... representational simplicity (Chomsky & Halle 1968:334–335; Clements & Hume 1995; M. Gordon 2004) or related ideas such as "modularity bias" (Moreton, to appear).

(26) 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). Also rare.

(27) Possible outcomes:

    (a) If pattern selectivity favors only typologically common processes, we expect VV≤HV, since

    (b) If pattern selectivity favors harmony in general, within-tier dependencies, or phonetic similarity, however, we expect VV>HV.

(28) Results:

    (a) Better performance in the VV condition ($p = 0.022$).

    (b) Near-chance performance again in the HV condition ($p = 0.353$).

	coefficient	se(coef)	z	Pr(>|z|)	
(Intercept)	0.1190	0.1281	0.9289	0.3530	⇐ *HV Lang.*
isSecond	-0.1122	0.1537	-0.7299	0.4650	
Lang	0.3812	0.1665	2.2896	0.0220	⇐ *VV Lang*
CCdis	0.1602	0.1514	1.0582	0.2900	
isSecond:Lang	- 0.4560	0.2178	-2.0941	0.0363	

6. Discussion

(29) 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. (The same goes for tone-tone and voice-tone patterns; Moreton to appear).

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.

Hence, phonological typology is not simply the imprint of phonetic typology.

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

(31) Experiment 1 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 is shaped by pattern selectivity in ways that cannot be explained by precursor robustness.

(32) Experiment 2 found a learning bias which never has a chance to apply in nature: VV patterns are readily learnable, but cannot arise for lack of a precursor.

⇒ Typology is shaped by precursor robustness in ways that cannot be explained by pattern selectivity.

(33) I.e., **Any adequate theory of phonological typology has to take into account the filtering effects of *both* factors** (Kiparsky 2005). It is unproductive to focus on one or the other alone as the only important determinant of typological frequency. Moreover, since there is independent evidence that both mechanisms are needed to explain typology, parsimony doesn't favor either "side".

(34) Much typological research in UG-based frameworks focuses on "phonetically natural" patterns, which are explained in terms of pattern selectivity. But this introduces a confound: Since "natural" patterns, almost by definition, have phonetic precursors, it isn't clear whether the typology is telling us something about UG, or something about the precursors. This confound can be removed by focusing on

    (a) Underphonologization, i.e., cases like that of the HV pattern, in which a robust phonetic interaction persistently fails to be phonologized.

    (b) Overphonologization, i.e., cases in which a phonological pattern is innovated in the absence of a phonetic precursor (e.g., in child language).

(35) Agenda for factoring apart the contributions of pattern selectivity and precursor robustness in shaping phonological typology:

    (a) Identify mismatches between phonetic and phonological typology (under-/overphonologization).

    (b) Map out range and nature of selective pattern learning.

    (c) Work out the theoretical relation between learning biases and Universal Grammar.

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