Phonotactic learning and phonological typology

Elliott Moreton, University of North Carolina, Chapel Hill

One line of recent work has suggested that phonological typology arises from phonetic typology via phonologization, and hence that how common a phonological pattern is across languages depends on the robustness of its phonetic precursor (Ohala 1994, Kavitskaya 2002:123–133, Barnes 2002:151–159, Blevins 2004:108–109). Evidence presented here suggests that this is not the whole story: Typology is shaped by cognitive biases which make learners more receptive to some patterns than others (Chomsky & Halle 1968:296f., Archangeli & Pulleyblank 1994:391ff., Hayes et al. 2004, Kiparsky 2005). We show that (A) phonological patterns relating the height of two neighboring vowels are typologically more frequent than patterns relating vowel height to consonant voicing; (B) the phonetic precursors of the height-height and height-voice patterns are equally robust, eliminating that explanation for the typological difference; (C) in two experiments, English speakers learned a height-height pattern and a voice-voice pattern better than a height-voice pattern.

Typological frequency To estimate the relative frequency of height-height and height-voice patterns, the descriptive literature was searched for cases meeting the criteria listed in (1). To guard against double-counting cases of shared inheritance, we counted families (defined as top-level categories in Ethnologue) rather than individual languages. Phonological height-height patterns were found in 7 families, while height-voice patterns were found in only 3 (see (2) and (3)).

Phonetic precursor robustness Are height-height patterns more common because their phonetic precursor is more robust? The phonetic literature was searched for estimates of the effect on F_1 of, first. vowel-to-vowel coarticulation, and, second, the interaction between obstruent voicing and vowel height. These estimates, plotted in (4), show that the phonetic height-height and height-voice effects are of about the same size.

A similar picture is found when vowel height is replaced by tone height: Tone-tone interactions outnumber tone-voice interactions, 19 families to 8, though the phonetic precursors are of about the same size (not shown). Hence, the typological frequency of a phonological pattern cannot in general be predicted from the magnitude of its phonetic precursor.

Experiment 1: CVCV vs. C VCV Since precursor robustness does not explain the difference in typological frequencies, we hypothesized that learners are more receptive to height-height patterns than height-voice patterns. This was tested in an experiment using two artificial languages built on the phonetic inventory [t d k g i u _ a]. In the "Height-Height" language condition, participants listened to, and repeated aloud, 32 synthesized $C_1V_1C_2V_2$ words in which V_1 and V_2 were both high or both low. They then heard 32 pairs of novel test words, one conforming to the height pattern and one violating it, and judged which one sounded likelier to be a word of the language. The "Height-Voice" condition was the same, only this time the pattern was that V_1 was low if and only if C_2 was voiceless. 24 native English speakers participated; 12 did the Height-Height condition first; 12 did the Height-Voice condition first. When other factors were controlled, the conforming word was chosen more often in the Height-Height condition than in the Height-Voice condition ($p < 0.001$, mixed-effects logistic-regression model, combined analysis of Experiments 1 and 2), as predicted. Height-harmonic test items were preferred only in the Height-Height condition, while items fitting the height-voice pattern were not preferred in either condition. Thus, participants showed better learning of the typologically more-frequent pattern, suggesting that the typological asymmetry is caused by a learning bias.

Experiment 2: CVCV vs. C VCV As to the nature of this bias, we considered two possibilities. One is that the patterns which learners detect most readily are precisely the ones which are typologically common—in this case, vowel harmony. The other is that a pattern is apprehended faster if it is simpler in terms of features or autosegmental tier structure. To distinguish these alternatives, the Height-Height condition of Exp. 1 was replaced with a Voice-Voice condition, in which C_1 and C_2 were both voiceless or both voiced — a pattern which is typologically quite rare (Rose & Walker 2004). A different group of 24 native English speakers participated in this experiment. The conforming word was chosen more often in the Voice-Voice condition than the Height-Voice condition ($p < 0.01$, same model as above) This effect was numerically smaller than that of the Height-Height condition in Exp. 1, but not significantly so.

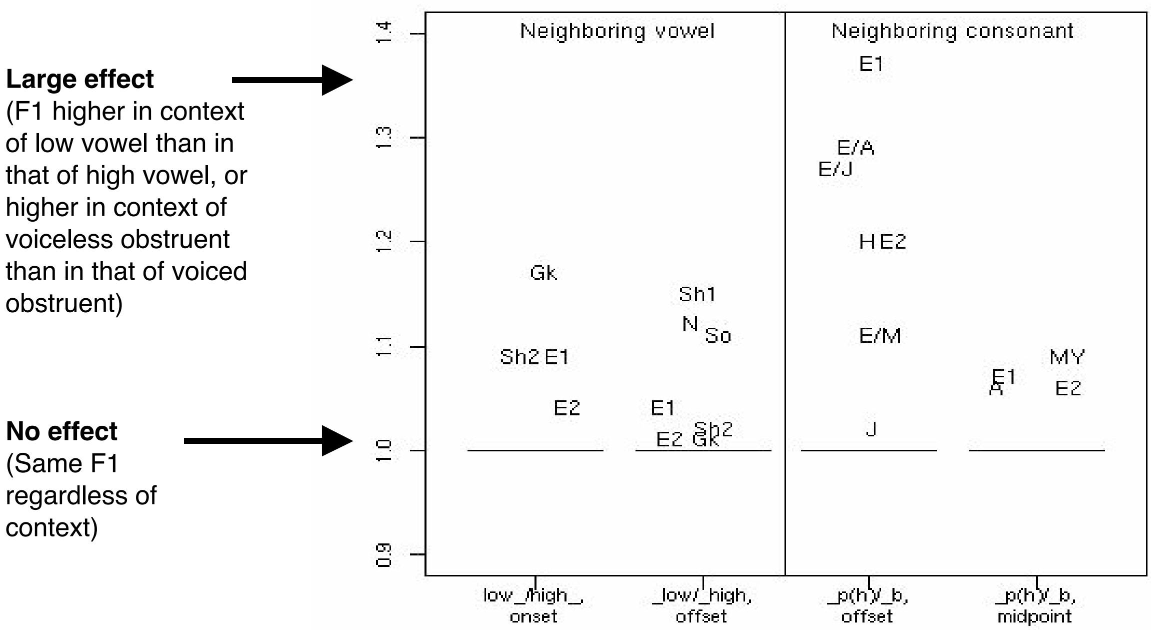
Conclusion These results are consistent with the hypothesis that typology is influenced by a learning bias which retards the acquisition of patterns in proportion to their featural complexity, irrespective of their phonetic precursors. This bias can be derived via a learning algorithm in which the learner chooses between OT constraint sets based on how probable they make the training data ("Bayesian Constraint Addition"). Other alternatives will be discussed.

(1) Criteria for typological survey:
(a) Language must have height contrast and voicing or aspiration contrast
(b) Pattern (process or phonotactic restriction) must neutralize one of those contrasts
(c) Patterns that apply only to a single morpheme were not counted
(d) Language must be described alive (reconstructed languages were excluded)

(2) Language families in survey with height-height interactions (1 ex. each):
(a) Afro-Asiatic: Modern Hebrew: Penultimate V of "segolate" nouns assimilates to last vowel (Bat-El 1989:174–182).
(b) Niger-Congo: C'Lela: Productive height harmony (Dettweiler 2000).
(c) Sino-Tibetan: Tibetan: Non-high vowels become high when concatenated with a morpheme that has a high vowel (bidirectional spreading) (Parkinson 1996:122–125).
(d) Basque: Basque: /a/ raises to /e/ following a high vowel (Hualde 1991:10, 23–3).
(e) Indo-European: Many cases from Romance (McCarthy 1984, Hualde 1989).
(f) Gulf: Tunica: mid vowels lower before a low /a/ in the next syllable of the same morpheme (Wiswall 1991:82–125). (Voicing contrast marginal; height contrast restricted.)
(g) Chukotko-Kamchatkan: Chukchee: Height harmony between "weak" [i e u] and "strong" [ɛ a ɔ]. Marginal voicing contrast (Bogoras 1969:644ff., 646ff).

(3) Language families in survey with height-voice interactions (1 ex. each)
(a) Sino-Tibetan: Lungtu Fujien Chinese: Before final voiced stops, vowels are non-low; before final voiceless stops, vowels are low (Egerod 1956:27–51). [Voicing redundant with glottalization]
(b) Indo-European: Polish: In native vocabulary, /o/ is raised to /u/ before underlyingly voiced word-final obstruents (Gussman 1980, Chapter 4). [Productivity is doubtful (Sanders 2003:53–57).]
(c) Athapaskan: Babine: Vowels are lower after voiced than voiceless C. Attaching voiceless-final prefix to vowel-initial stem raises /a e/ to /e i/, morphophonologically (Story 1984:29–32).

(4) **Phonetic effect** of an adjacent vowel (high vs. low), and the effect of an adjacent consonant (voiced vs. voiceless). Each plotting symbol is one study of one language. Y-axis shows ratio of vowel F1 in raising context (e.g., high_ or _high) to F1 in lowering context (e.g., low_ or _low). Measurements were made at the point in the target vowel as indicated (onset/offset/midpoint).



Key: Left panel: *So* = Sotho, *Sh1* = Shona, *N* = Ndebele (Manuel 1990); *Sh2* = Shona, *E1* = English (Beddor et al. 2002); *J* = Japanese (Kuwabara 1985); *Gk* = Greek, *E2* = English (Koenig & Okalidou 2003). Right panel: *H* = Hindi (Lampp & Reklis 2004); *A* = Arabic (de Jong & Zawaydeh 2002); *J* = Japanese (Kawahara 2005); *E1* = English (Wolf 1978); *E2* = English (Summers 1987); *E3* = English, *E/J* = L2 English (Japanese), *E/M* = L2 English (Mandarin), *E/A* = L2 English (Arabic) (Crowther & Mann 1992), *MY* = M_b_ Yoruba (Przezdziecki 2005).