Syntagmatic simplicity

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(1) Preview:

a. We've seen evidence that there exist analytic biases which look like typological asymmetries (last time—featural vs. arbitrary).

b. What we haven't seen is evidence that analytic bias *contributes* to typological asymmetries. We'll try to find some today.

c. Usefulness of "underphonologization" cases for finding promising places to look for typologically-effective analytic bias.

d. We'll focus on "syntagmatic simplicity bias" (favoring single-feature dependencies like harmony over dependencies between two features). This may be connected to the featural/arbitrary distinction that came up last time.

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1 Strategy

(2) Last time: It isn't easy to distinguish contributions of analytic and channel bias to typology, even when we have lab evidence of both.

a. Typological asymmetry: When natural languages treat two sets of phonemes differently, the division tends to be phonetically systematic ("featural") rather than phonetically arbitrary.

(How strong is the evidence for this tendency? What would the chance distribution be, i.e., if there were no such tendency?)

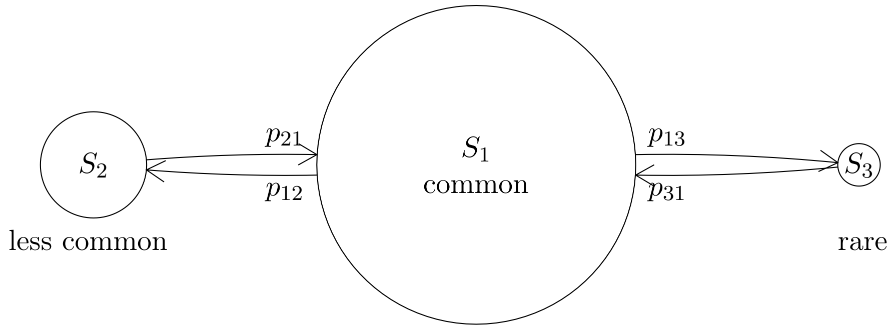
b. Analytic bias: Phonetically-definable classes are often easier, and never harder, than phonetically-arbitrary classes in lab-learning experiments with adults and infants (see references on last time's handout).

c. Channel bias: Channel effects, such as misperception (Miller and Nicely, 1955; Singh and Black, 1966; Wang and Bilger, 1973; Cutler et al., 2004) and misrecollection (Wickelgren, 1966), tend to have similar effects on segments that share phonetic features.

d. ⇒ Problem: Analytic and channel bias respecting the featural vs. arbitrary distinction are *confounded*. At least one of them must have some responsibility for the typological skew, but we can't *in general* tell which one.

The featural-vs.-arbitrary data doesn't give us evidence that either channel or analytic bias can be typologically effective. What to do?

(3) Discussion from last time : Need to find a typological asymmetry where the relevant channel and analytic biases oppose each other.



$$
\begin{aligned}
\frac{\pi_2}{\pi_3} &= \frac{p_{12}}{p_{13}} \cdot \frac{p_{31}}{p_{21}} \\
&= \frac{lrn(out(S_1) \cdot \mathbf{C}_1)(S_2)}{lrn(out(S_1) \cdot \mathbf{C}_1)(S_3)} \cdot \frac{lrn(out(S_3) \cdot \mathbf{C}_3)(S_1)}{lrn(out(S_2) \cdot \mathbf{C}_2)(S_1)}
\end{aligned}
$$

(4) Since data on typology and phonetics can be found relatively easily in the library, the first place to look for analytic bias is "underphonologization"—typological asymmetries which are not matched by a corresponding asymmetry in phonetic precursors.

First noted by Hombert et al. (1979), though they interpret their case (vowel F_0 as affected by vowel height vs. consonant voicing) as a consequence of perceptual channel bias.

(5) Idea from last time: "Crazy classes". (No Astute Comment Card — who?!)

a. Related to Hayes (1999): Mismatch between phonetic and phonological classes.

b. Here is some duration data from Rosen (2005, Table 1) ("V" means "vowel"):

Segment	Glides	Fricatives	Short V	Nasals	Liquids	Stops	Long V
Duration (ms)	57	59	61	62	64	81	116

As far as I know, no natural language distinguishes "short" segments (defined as having a canonical duration < 75ms) from "non-short" ones. Suppose that's true.

c. Suppose we could find a channel bias that affected all "short" segments more than any "long" segments (what could that be?)

d. What would we need to do next? What conclusions could we draw depending on the outcome?

(6) Another idea from last time (again, no card, so I don't know who to credit): Maybe the featural-vs.-arbitrary bias is a special case of a more general bias towards "simple" patterns — a bias that might extend to *syntagmatic* simplicity, such as within-stimulus agreement or disagreement. Evidence is thin:

a. Kuo (2009), from last time: No difference between the Place condition (place of glide depends on place of obstruent) and the Laryngeal condition (place of glide depends on aspiration of obstruent).

b. Wilson (2003): L1 English speakers familiarized on "stem + suffix", in one of four conditions. Tested on recall. How often did they (wrongly) say "yes" to previously-unheard stimuli? More for a nasal spreading pattern than for a two-feature pattern.

	Dependency		"Familar" responses to novel stimuli		
	-na	-la	Conforming	|	Nonconforming
1A: Nasal harmony	/[+nas]V_	[–nas]V_	0.53	>	0.44
2A: Nasal disharmony	/[-nas]V_	[+nas]V_	0.50	>	0.35
1B: Dorsal/Nasal	/[Dor]V_	[Lab, Cor]/V_	0.46	=	0.38
2B: Dorsal/Oral	/[Lab, Cor]V_	[Dor]/V_	0.47	=	0.41

c. Seidl and Buckley (2005, Exp. 2): Familiarized L1 English-learning infants with $C_1V_1C_2V_2(C_3)$ pseudowords, using two patterns of dependency between C_1 and V_1. Both patterns were learned.

	$C_1 \leftrightarrow V_1$		Mean looking time		
Condition	/v p m/	/s d n/	Conforming	|	Nonconforming
Labial agreement	/o u/	/i e/	6.27	<	7.57
Labial/high	/i u/	/e o/	5.85	<	6.95

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2 Underphonologization cases: TT vs. VT, HH vs. HV

(7) Two parallel cases of underphonologization in which a single-feature dependency is more common than a related two-feature dependency, without a corresponding difference in precursors.

a. *TT vs. VT*: "Tone-tone" dependency (between tone height in adjacent syllables) outnumbers "voice-tone" dependency (between tone height and voicing, aspiration, or fortis-lenis status of a preceding consonant).

b. *HH vs. HV*: "Height-height" dependency (between vowel height in adjacent syllables) outnumbers "height-voice" dependency (between vowel height and voicing, aspiration, or fortis-lenis status of a following consonant).

(8) Typological surveys: Brute-force search, aided by secondary literature and p.c.s. Restrictions:

a. Limited to languages in which both patterns have opportunity to occur, i.e., languages with lexical contrasts in both relevant features.

b. No phonetic confounds (glottalization, prenasalization, etc.).

c. Pattern must neutralize contrast in some environment (excludes allophony, insures pattern isn't just phonetic).

d. Alternations limited to single morphemes did not qualify.

e. Language must have been described while still alive.

f. Counted "families" (= top-level Ethnologue categories) rather than individual languages, to prevent double-counting cases of shared inheritance.

For details, see Moreton (2008a,b).

(9) TT outnumbers VT, 20 families to 8. Difference from equal frequency significant by one-sided exact binomial test, $p < 0.018$; 95% one-sided CI for ratio = (0,0.46).

Tone-Tone	Afro-Asiatic (Gashua Bade), Andoke (Andoke), Caddoan (Caddo), Creole [English-based] (Saramaccan), Hmong-Mien (Hmong Daw), Huavean (San Mateo Huave), Indo-European (Chakma), Iroquoian (Oklahoma Cherokee), Khoisan (‖Ani), Kiowa-Tanoan (Kiowa), Nilo-Saharan (Zarma), Niger-Congo (Tsonga), Oto-Manguean (Zapotec), Sino-Tibetan (numerous Chinese exx.)x, Sko (Skou), Tai-Kadai (Lue), Tukanoan (Barasana), Witotoan (Bora)	19
Voice-Tone	Afro-Asiatic (Lamang), Austro-Asiatic (Bolyu), Hmong-Mien (Highland Yao), Niger-Congo (Ewe), Sino-Tibetan (Wuyi), Sko (Skou), Tai-Kadai (Mulao)	7
Both	Na-Dene (Dakelh/Carrier)	1

95% confidence intervals (using R's `binom.bayes` function in the `binom` package, with Jeffreys prior):

	$\frac{\pi_2}{\pi_2+\pi_3}$			Equvalent $\frac{\pi_2}{\pi_3}$		
Sample	Lower	Mean	Upper	Lower	Mean	Upper
20:28	0.532	0.707	0.855	1.13	2.40	5.89

(10) For the HH/HV survey, *no* HV cases fit the criteria perfectly, so results are presented in two tiers, "strict" (clearly fits criteria) and "lax" (questionable on one or more criteria).

(11) HH outnumbers HV, 7 families to 0 (strict) or 14 to 2 (lax).

Height-Height (S_2)	*Strict*: Afro-Asiatic (Awngi), Altaic (Udihe), Basque (Basque), Indo-European (Buchan Scots), Niger-Congo (C'Lela), Oto-Manguean (Malinaltepec Tlapaneca), Sino-Tibetan (Lhasa Tibetan). *Lax*: Austronesian (Woleiaian), Chukotko-Kamchatkan (Chukchee), Dravidian (Tamil), Gulf (Tunica), Hokan (Washo), Korean (Korean), Penutian (Wintu)	7 *+7*
Height-Voice (S_3)	*Strict*: None. *Lax*: Indo-European (Polish, Canadian English), Sino-Tibetan (Lungtu Fujien Chinese)	0 *+2*
Both (S_4)	*Strict*: None. *Lax*: Nilo-Saharan (Murle)	0 *+1*

95% confidence intervals (using R's `binom.bayes` function in the `binom` package, with Jeffreys prior):

	$\frac{\pi_2}{\pi_2+\pi_3}$			Equvalent $\frac{\pi_2}{\pi_3}$		
Sample	Lower	Mean	Upper	Lower	Mean	Upper
Strict (7:0)	0.768	0.938	1	3.31	15.1	∞
Lax (14:16)	0.656	0.853	0.973	1.91	5.80	36.0

(12) TT and HH patterns occur more frequently than VT and HV patterns. ⇒ They are either innovated more often, or lost less often.

(13) Channel bias in innovation rate: Large phonetic precursors may be phonologized more often than smaller ones (Ohala, 1994a; Hale & Reiss, 2000; Barnes, 2002:151–159; Kavitskaya, 2002:123–133; Blevins 2004:108–109). Can that explain these two asymmetries?

(14) Phonetic-precursor surveys (for details see Moreton (2008a,b))

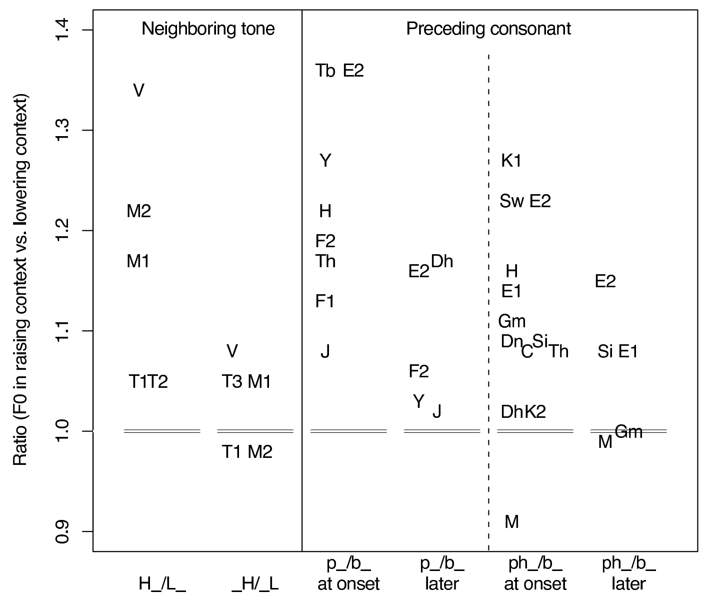
a. Find studies where vowel F_0 or F_1 is measured in the relevant contexts.

b. Identify contexts likeliest to raise or lower target F_n

c. Effect of context is defined to be (F_n in raising context)/(F_n in lowering context).

d. If F_n was measured at multiple points, the one closest to the context was used.

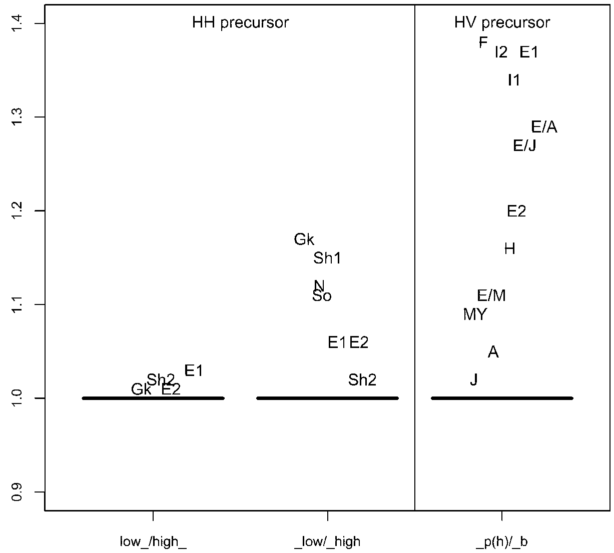
(15) TT and VT precursors:[1]



(16) HH and HV precursors:[2]

[1] C = Cantonese; Dh = Dakelh/Carrier; Dn = Danish; E1–E3 = English; F1, F2 = French; Gm = German; H = Hindi; J = Japanese; K1, K2 = Korean; M1, M2 = Mandarin; Si = SiSwati; Sw = Swedish; T1–T3 = Taiwanese; Tb = Lhasa Tibetan; Th = Thai; V = Vietnamese; Y = Yoruba.

[2] A = Arabic; E1, E2 = English; E/A, E/J, E/M = L2 English (L1 = Arabic, Japanese, Mandarin); F = French; Gk = Greek; H = Hindi; I1, I2 = Italian; J = Japanese; MY = Mòbà Yoruba; N = Ndebele; Sh1, Sh2 = Shona; So = Sotho.



(17) In both cases, single-feature, within-tier dependencies are typologically more frequent than two-feature, cross-tier dependencies, despite similar precursor size. That leaves us with …

a. … no explanation in terms of channel bias.

b. … no explanation in terms of substantive (phonetically-grounded) analytic bias (each pair of patterns is equally "phonetically natural").

(Are these conclusions valid? If not, what is missing from the empirical or logical chain?)[3]

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3 Looking for analytic bias: HH vs. HV

(18) Stimuli: MBROLA-synthesized $C_1V_1C_2V_2$ words with inventory /t k d g/ /i u æ ɔ/. Two patterns:

a. "HH pattern": Vowels agree in height, instantiating a height-harmony pattern.

b. "HV pattern": V_1 high iff C_2 voiced, instantiating what *would* be a phonologization of the HV precursor.

(19) Experimental paradigm (based on Moreton (2008a, Exps. 1 and 2)):

a. *Study Phase*: Listen to pattern-conforming words through headphones, repeat into microphone. 32 words × 4 repetitions, randomized in blocks.

Pattern conformity		Training condition	
HH	HV	HH	HV
+	+	16	16
+	−	16	
−	+		16
−	−		

[3] Some references that may come up: Plevyak (1982); Parucci (1983); Yavas (1994, 1997); Bruner (2005).

b. *Test Phase*: Listen to pairs of new words, choose the one that you think is "a word of the language you studied". 32 pairs in two counterbalanced blocks of 16, random orders in block and pair. Each pair pits one pattern-conforming item against one pattern-nonconforming item:

Pattern conformity					Studied pattern	
HH	HV		HH	HV	HH	HV
+	+	*vs.*	−	−	16	16
+	−	*vs.*	−	+	16	16

(20) Properties of this design:

a. For half of the Test pairs, the correct response depends on the Study pattern; for the other half, it does not. Allows effects of learning to be separated from those of pre-existing preferences.

b. Does *not* test generalization to new vowels or new combinations of vowels (i.e., does not distinguish between learning vowel harmony and learning a list of vowel-vowel sequences).

(21) Participants: 18 native speakers of American English. None had studied or otherwise learned a language with vowel harmony. One explicitly noticed pattern (post-experiment questionnaire) and was replaced.

(22) Results of Experiment 1[4].

a. Performance in HV condition was not distinguishable from chance.

b. Participants in HH condition nearly doubled their odds of a correct response, in both the first and second half of the Test phase.

Coefficient	Estimate	SE	z	$Pr(>\mid z \mid)$	
(Intercept)	0.27419	0.19609	1.39830	0.162024	
Studied HH	0.71606	0.27884	2.56804	0.010228	*
$V_1 = V_2$	–0.25962	0.20536	–1.26420	0.206160	
2nd half	–0.27877	0.24170	–1.15339	0.248750	
Studied HH × *2nd half*	–0.05977	0.35390	–0.16889	0.865882	
HH-nonconforming	0.10146	0.13140	0.77217	0.440015	
1st in pair	0.46502	0.17679	2.63042	0.008528	**

(23) Interim summary:

a. There is a typological asymmetry in favor of HH over HV patterns.

b. This asymmetry is not matched by a corresponding difference in the phonetic precursors.

c. An HH pattern was learned better than an HV one in the lab.

These results favor the hypothesis that the typological asymmetry is due to analytic bias. But what *is* that analytic bias?

[4]Analyzed by mixed-effects logistic regression with Participant as a random effect. The independent variables were chosen as follows: Each of the 6 experiments in this series was modelled using a larger set of terms. The models were then reduced by backwards elimination. Any term which could not be eliminated from at least *one* of the 6 models was retained (mutatis mutandis) in the analysis of all of them.

4 What is the content of the bias?

(24) Some possible explanations for the results of Exp. 1:

a. Voicing is harder to hear than height, or consonants are harder to hear than vowels (Cutler et al., 2004). Alternatively, voicing or consonants might be less "salient" to the pattern-extraction process.

b. Bias for typologically-common patterns. This is what we would expect if analytic bias is the *only* factor determining typological frequency.

c. Bias for "phonetically grounded" patterns, i.e., those with robust phonetic precursors (Wilson, 2006).

d. Bias for dependencies which involve one feature over those which involve two (Chomsky and Halle, 1968; Clements and Hume, 1995; Gordon, 2004).

e. Bias for dependencies on a single autosegmental/Feature-Geometric tier (e.g., consonantal or vocalic) over those which cross tiers (Goldsmith, 1976; McCarthy, 1981; Newport and Aslin, 2004).

f. Bias for dependencies between featurally-similar units (Frisch et al., 2004; Rose and Walker, 2004; Onnis et al., 2005).

g. Bias for dependencies involving word edges (Endress et al., 2005; Endress and Mehler, 2008).

(25) Subsequent experiments try to find evidence for or against each of these hypotheses. Exps. 2–6 are just like Exp. 1, except that the HH pattern is replaced by something else.

4.1 Experiment 2: Voice-voice vs. height-voice

(26) Perhaps HH beat HV in Experiment 1 because participants couldn't hear the C_2 voicing accurately, or weren't paying attention to it. When participants' spoken responses were transcribed (in ignorance of the intended stimulus), voicing was indeed reported somewhat less accurately than height.

	Response							
Stimulus	t	d	k	g	Other C	Cluster	No data	Total
C_1 Position								
t	1695	25	20	1	8	0	93	1842
d	63	1471	0	5	6	1	87	1633
k	23	4	1466	89	9	4	92	1687
g	0	25	101	1393	1	7	105	1632
C_2 Position								
t	1647	11	7	1	4	1	28	1699
d	137	1518	2	4	17	0	34	1712
k	6	4	1614	18	1	4	25	1672
g	3	8	124	1529	5	9	33	1711

	Response								
Stimulus	i/ɪ	u/ʊ	æ	ɔ/a	ɛ	ʌ/ə	Other	No data	Total
V_1 Position									
i	1676	7	0	0	0	1	6	29	1716
u	6	1654	0	0	0	3	7	42	1712
æ	0	3	1100	352	88	4	52	35	1659
ɔ	0	0	47	1497	0	2	103	39	1707
V_2 Position									
i	1635	6	0	0	0	0	0	9	1650
u	9	1561	0	0	0	2	6	15	1593
æ	0	2	898	509	211	140	62	26	1848
ɔ	3	2	44	1439	30	138	27	20	1703

(27) Exp. 2 was like Exp. 1, except that a voice-voice pattern replaced the height-height one:

a. "VV pattern": C_1 and C_2 agree in voicing. This pattern is very rare in natural language (Rose and Walker, 2004; Hansson, 2004). What research there is suggests that its phonetic precursor is weak (Weismer, 1979; Port and Rotunno, 1979; Port, 1981; Beardsley and Cullinan, 1987).

b. "HV pattern": V_1 high iff C_2 voiced, as in Exp. 2.

(28) Results of Experiment 2.

a. Participants in the HV condition were again at or near chance.

b. Those who studied the VV pattern doubled their odds of a correct response. The effect did not diminish significantly over the course of testing.

Coefficient	Estimate	SE	z	$Pr(>\mid z \mid)$	
(Intercept)	0.157994	0.225038	0.70208	0.482631	
Studied VV	0.736347	0.309506	2.37911	0.017355	*
$C_1 = C_2$	–0.480821	0.199329	–2.41219	0.015857	*
2nd half	0.022876	0.246716	0.09272	0.926125	
StudiedVV × 2nd half	–0.540257	0.348545	–1.55004	0.121133	
VV-nonconforming	0.271081	0.132973	2.03862	0.041488	*
1st in pair	0.468015	0.174332	2.68462	0.007261	**

(29) These results clearly contradict the first three hypotheses:

		Experiment						
		1	2	3	4	5	1/2 vs.	6
	Hypothesis	HH	VV	Random	HB	PV	4/5	V. . . H
a.	Voicing harder to hear or process than height, or consonants than vowels.	√	×					
b.	Bias for typologically-common patterns.	√	×					
c.	Bias for patterns with robust phonetic precursors.	√	×					
d.	Bias for featurally-simpler dependencies	√	√					
e.	Bias for within-tier dependencies.	√	√					
f.	Bias for dependencies between featurally-similar segments.	√	√					
g.	Bias for dependencies involving word edges.	√	√					

Key: √ = found predicted positive result. — = did not find predicted positive result. × = found contradictory positive result.

4.2 Experiment 3: Vowel-vowel vs. vowel-consonant

(30) Perhaps HH and VV are easier than HV because they are confined to the vocalic or consonantal tier, whereas HV is a cross-tier dependency (McCarthy, 1981).

(31) Experiment 3 compared arbitrary vowel-vowel and vowel-consonant dependencies.

a. "Vowel-Vowel pattern": For each participant, 8 of the 16 possible vowel-vowel combinations were chosen at random and defined to be pattern-conforming. Familiarization and Test stimuli were then constructed as in Exps. 1 and 2.

b. "Vowel-Consonant pattern": Similarly for 8 of the 16 possible vowel-consonant combinations.

(32) Results of Experiment 3.

a. Participants who studied a vowel-consonant pattern performed at chance.

b. Those who studied a vowel-vowel pattern did better, but only for the first half of the Test phase.

Coefficient	Estimate	SE	z	$Pr(>\mid z \mid)$	
(Intercept)	0.0083411	0.2053128	0.04063	0.96759	
Studied vowel-vowel	0.5536371	0.2658435	2.08257	0.03729	*
2nd half	0.1225018	0.2539052	0.48247	0.62947	
Studied vowel-vowel × 2nd half	−0.7492885	0.3642230	−2.05722	0.03966	*
1st in pair	0.4017423	0.1822764	2.20403	0.02752	*

(33) Even featurally-arbitrary dependencies were easier to learn if they involved two vowels than if they involved a vowel-consonant sequence.

The effect was numerically smaller than that in Exps. 1 and 2, and wore off in the second half of the Test phase, indicating that the vowel-vowel/vowel-consonant difference was weaker than the HH/HV and VV/HV differences.

		Experiment						
		1	2	3	4	5	1/2 vs.	6
	Hypothesis	HH	VV	Random	HB	PV	4/5	V...H
a.	Voicing harder to hear or process than height, or consonants than vowels.	√	×					
b.	Bias for typologically-common patterns.	√	×	×				
c.	Bias for patterns with robust phonetic precursors.	√	×	×				
d.	Bias for featurally-simpler dependencies	√	√					
e.	Bias for within-tier dependencies.	√	√	√				
f.	Bias for dependencies between featurally-similar segments.	√	√	√				
g.	Bias for dependencies involving word edges.	√	√	√				

Key: √ = found predicted positive result. — = did not find predicted positive result. × = found contradictory positive result.

4.3 Experiments 4 and 5: Height-backness and place-voice vs. height-voice

(34) HH is a single-feature dependency; HV involves two different features. When the number of features is controlled, are featurally-systematic cross-tier dependencies still harder than within-tier ones?

(35) Exp. 4 was like Exp. 1, except that a height-*backness* pattern replaced the height-height one:

a. "HB pattern": V_1 high iff V_2 back (unknown in natural language; no known precursor).

b. "HV pattern": V_1 high iff C_2 voiced.

(36) Results of Experiment 4.

a. Once again, those who studied the HV pattern performed at chance.

b. Those who studied the HB pattern did *marginally* better, but the difference did not reach the conventional 5% criterion, and disappeared entirely in the second half of the Test phase.

Coefficient	Estimate	SE	z	$Pr(>\mid z \mid)$	
(Intercept)	–0.099234	0.197518	–0.50241	0.61538	
Studied HB	0.495776	0.284555	1.74228	0.08146	.
2nd half	0.104045	0.239182	0.43500	0.66356	
Studied HB × 2nd half	–0.583042	0.343219	–1.69875	0.08937	.
HB-nonconforming	–0.115660	0.119626	–0.96685	0.33362	
1st in pair	0.455936	0.171834	2.65335	0.00797	**

(37) Exp. 5 was similar, but used a place-voice dependency:

a. "PV pattern": C_1 velar iff V_2 voiced (unknown in natural language; no known precursor).

b. "HV pattern": V_1 high iff C_2 voiced (as in Exp. 2).

(38) Results of Experiment 5.

a. Yet again, studying the HV pattern led to near-chance performance.

b. Those who studied the PV pattern did *marginally* better, but only in the first half of the Test phase.

Coefficient	Estimate	SE	z	$Pr(>\mid z \mid)$	
(Intercept)	–0.21116	0.19910	–1.06054	0.288901	
Studied PV	0.48402	0.28433	1.70231	0.088697	.
2nd half	0.16938	0.24039	0.70461	0.481052	
Studied PV × *2nd half*	–0.42830	0.33915	–1.26286	0.206640	
PV-nonconforming	0.21102	0.12021	1.75546	0.079181	.
1st in pair	0.49330	0.16986	2.90418	0.003682	**

(39) Exps. 4 and 5 show that when other factors are controlled, one-feature dependencies are learned better than two-feature dependencies.

a. The results of 1 and 2 resemble each other, as do those of 4 and 5. Apparently the content of the features doesn't matter, only their formal arrangement.

	1	2	4	5	3
Coefficient	HH	VV	HB	PV	vowel-vowel
(Intercept)	0.274	0.157	–0.099	–0.211	0.008
Studied XY	0.716 *	0.736 *	0.495 .	0.484 .	0.553 *
$V_1 = V_2$ *or* $C_1 = C_2$	–0.259	–0.480 *	—	—	—
2nd half	–0.278	0.022	0.104	0.169	0.122
Studied XY × *2nd half*	–0.059	–0.540	–0.583	–0.428	–0.749 *
XY-nonconforming	0.101	0.271 *	–0.115	0.211 .	—
1st in pair	0.465 **	0.468 **	0.455 **	0.493 **	0.401 *

The non-HV pattern is learned better in 1/2 than in 4/5.

b. ⇒ Dependencies between two instances of the same feature are learned better than dependencies between different features on the same tier.

c. Remarkably, in all five experiments (plus the two in Moreton (2008a)), the worst performance was on a phonetically-motivated pattern involving two phonetically-adjacent segments.

(40) Interim summary:

	Hypothesis	Experiment 1 HH	2 VV	3 Random	4 HB	5 PV	1/2 vs. 4/5	6 V…H
a.	Voicing harder to hear or process than height, or consonants than vowels.	$\surd$	$\times$					
b.	Bias for typologically-common patterns.	$\surd$	$\times$	$\times$			$\surd$	
c.	Bias for patterns with robust phonetic precursors.	$\surd$	$\times$	$\times$				
d.	Bias for featurally-simpler dependencies	$\surd$	$\surd$				$\surd$	
e.	Bias for within-tier dependencies.	$\surd$	$\surd$	$\surd$	—	—		
f.	Bias for dependencies between featurally-similar segments.	$\surd$	$\surd$	$\surd$	—	—		
g.	Bias for dependencies involving word edges.	$\surd$	$\surd$	$\surd$	—	—		

Key: $\surd$ = found predicted positive result. — = did not find predicted positive result. $\times$ = found contradictory positive result.

4.4 Experiment 6: Voice…height vs. height-voice

(41) Patterns involving segments at word edges may be easier to detect than those involving only word-medial segments (Endress et al., 2005; Endress and Mehler, 2008). If that is true, then a pattern involving *two* edge segments should be even easier.

(42) Exp. 6 compared the height-voice dependency between V_1 and C_2 with a voice-height dependency between C_1 and V_2.

a. "V…H pattern": V_2 is high iff C_1 is voiced.

b. "HV pattern": V_1 high iff C_2 voiced (as in Exp. 2).

(43) Results of Experiment 6.

a. This time, participants who studied the HV pattern did significantly better than chance, in the first half of the Test phase only.

b. Those who studied the V…H pattern were at or near chance in both halves of the Test phase.

Coefficient	Estimate	SE	z	$Pr(>\mid z \mid)$	
(Intercept)	0.47056	0.18921	2.4869	0.0128848	*
Studied V…H	–0.82661	0.27722	–2.9818	0.0028659	**
2nd half	–0.69871	0.24691	–2.8298	0.0046577	**
Studied V…H × 2nd half	1.09659	0.34672	3.1628	0.0015627	**
V…H-nonconforming	–0.10436	0.12279	–0.8499	0.3953559	
1st in pair	0.57627	0.17404	3.3111	0.0009292	***

(44) ⇒ Results of Exps. 1–5 are not due to the participation of word-edge segments.

(45) Synopsis of results and their implications for hypotheses:

	Hypothesis	1 HH	2 VV	3 Random	4 HB	5 PV	1/2 vs. 4/5	6 V…H
		Experiment						
a.	Voicing harder to hear or process than height, or consonants than vowels.	√	×					
b.	Bias for typologically-common patterns.	√	×	×			√	
c.	Bias for patterns with robust phonetic precursors.	√	×	×				
d.	Bias for featurally-simpler dependencies	√	√				√	
e.	Bias for within-tier dependencies.	√	√	√	—	—		
f.	Bias for dependencies between featurally-similar segments.	√	√	√	—	—		
g.	Bias for dependencies involving word edges.	√	√	√	—	—		×

Key: √ = found predicted positive result. — = did not find predicted positive result. × = found contradictory positive result.

5 Discussion

(46) What factors other than a syntagmatic simplicity bias could contribute to the observed typological asymmetries?

(47) The HH/HV study focuses on differences in the innovation rate, rather than the extinction rate, yet as we saw on the first day, both are equally important in determining typological frequency.

a. What could be true about the extinction rates that would invalidate the proposed explanation for the HH/HV (and TT/TV) differences?

b. What kind of experiments would be necessary to test that hypothesis?

(48) Do the arguments made respecting HH/HV carry over to TT/VT? Is it suspicious that both of them involve voice? If so, what exactly is the suspicion?

(49) These results can be used to argue that channel, not analytic, bias makes long-range voice-voice dependencies rarer than long-range height-height dependencies. Is the argument sound?

(50) Aside from underphonologization, other phenomena that have been pointed out as likely indicators of typologically-effective analytic bias include

a. "Diachronic conspiracies": Some typological gaps could be filled by otherwise-common sound changes, but aren't (Kiparsky, 1995; de Lacy, 2006; Kiparsky, 2008). Final-obstruent voicing (Bermúdez-Otero, 2006):

Initially	a.tá.ta	a.tá.da	a.dá.ta	a.dá.da
Foot-internal lenition	a.tá.da	---	a.dá.da	---
Apocope	a.tád	a.tád	a.dád	a.dád

b. Mismatch between perceptual confusions and actual sound changes (Steriade, 2001). For instance, in confusion experiments, coda nasals tend to sound like [n], but what they actually change to is a homorganic nasal (Hura et al., 1993).

What kind of analytic-bias experiment does each of these motivate?

References

Barnes, J. (2002). *Positional neutralization: a phonologization approach to typological patterns*. Ph. D. thesis, University of California, Berkeley.

Beardsley, A. N. and W. L. Cullinan (1987). Speech sample type and children's segmental durations. *Journal of Phonetics 15*, 19–38.

Bermúdez-Otero, R. (2006). Phonological change in optimality theory. In K. Brown (Ed.), *Encyclopedia of language and linguistics* (2nd ed.), Volume 9, pp. 497–505. Oxford: Elsevier.

Blevins, J. (2004). *Evolutionary phonology*. Cambridge: Cambridge University Press.

Bruner, J. (2005). Supralaryngeal mechanisms in the voicing contrast in velars. MS, Zentrum für Allgemeine Sprachwissenschaft Publications in Linguistics (ZASPiL) No. 39.

Chomsky, N. and M. A. Halle (1968). *The sound pattern of English*. Cambridge, Massachusetts: MIT Press.

Clements, G. N. and E. V. Hume (1995). The internal organization of speech sounds. In J. A. Goldsmith (Ed.), *The handbook of phonological theory*, Chapter 7, pp. 245–306. Boston: Blackwell.

Cutler, A., A. Weber, R. Smits, and N. Cooper (2004). Patterns of English phoneme confusions by native and non-native listeners. *Journal of the Acoustical Society of America 116*(6), 3668–3678.

de Lacy, P. (2006). Transmissibility and the role of the phonological component. *Theoretical Linguistics 32*(2), 185–196.

Endress, A. D. and J. Mehler (2008). Perceptual constraints in phonotactic learning. MS, International School for Advanced Studies, Trieste. (Submitted).

Endress, A. D., B. J. Scholl, and J. Mehler (2005). The role of salience in the extraction of algebraic rules. *Journal of Experimental Psychology: General 134*(3), 409–419.

Frisch, S., J. B. Pierrehumbert, and M. B. Broe (2004). Similarity avoidance and the OCP. *Natural Language and Linguistic Theory 22*(1), 179–228.

Goldsmith, J. A. (1976). *Autosegmental phonology*. Ph. D. thesis, Massachusetts Institute of Technology.

Gordon, M. (2004). Syllable weight. In B. Hayes, R. Kirchner, and D. Steriade (Eds.), *Phonetically-based phonology*, pp. 277–312. Cambridge, England: Cambridge University Press.

Hale, M. and C. A. Reiss (2000). 'Substance abuse' and 'dysfunctionalism': current trends in phonology. *Linguistic Inquiry 31*(1), 157–169.

Hansson, G. Ó. (2004). Long-distance voicing agreement: an evolutionary perspective. Handout, 30th annual meeting of the Berkeley Linguistics Society, Berkeley, California, February 13–16.

Hayes, B. (1999). Phonetically driven phonology: the role of optimality in inductive grounding. In M. Darnell, E. Moravcsik, M. Noonan, F. Newmeyer, and K. Wheatly (Eds.), *Functionalism and Formalism in Linguistics*, Volume 1: General Papers, pp. 243–285. Amsterdam: John Benjamins.

Hombert, J.-M., J. J. Ohala, and W. G. Ewan (1979). Phonetic explanations for the development of tones. *Language 55*(1), 37–58.

Hura, S., B. Lindblom, and R. Diehl (1993). On the role of perception in shaping phonological assimilation rules. *Language and Speech 35*, 59–72.

Kavitskaya, D. (2002). *Compensatory lengthening: phonetics, phonology, diachrony*. New York: Routledge.

Kiparsky, P. (1995). The phonological basis of sound change. In J. A. Goldsmith (Ed.), *The handbook of phonological theory*, Chapter 21, pp. 640–670. Cambridge, Massachusetts: Blackwell.

Kiparsky, P. (2008). Universals constrain change, change results in typological generalizations. In J. Good (Ed.), *Linguistic universals and language change*, Chapter 2, pp. 23–53. Oxford, England: Oxford University Press.

Kuo, L. (2009). The role of natural class features in the acquisition of phonotactic regularities. *Journal of psycholinguistic research 38*(2), 129–150.

McCarthy, J. J. (1981). A prosodic theory of nonconcatenative morphology. *Linguistic Inquiry 12*, 373–418.

Miller, G. A. and P. E. Nicely (1955). An analysis of perceptual confusions among some English consonants. *Journal of the Acoustical Society of America 27*, 338–352.

Moreton, E. (2008a). Analytic bias and phonological typology. *Phonology 25*(1), 83–127.

Moreton, E. (2008b). Underphonologization and modularity bias. In S. Parker (Ed.), *Phonological argumentation: essays on evidence and motivation*. London: Equinox.

Newport, E. and R. N. Aslin (2004). Learning at a distance i: statistical learning of non-adjacent dependencies. *Cognitive Psychology 48*, 127–162.

Ohala, J. J. (1994). Hierarchies of environments for sound variation; plus implications for 'neutral' vowels in vowel harmony. *Acta Linguistica Hafniensia 27*, 371–382.

Onnis, L., K. Richmond, and N. Chater (2005). Phonology impacts segmentation in online speech processing. *Journal of Memory and Language 53*, 225–237.

Parucci, R. L. (1983). Effects of vowel height on final stop voicing. Master's thesis, University of Maryland.

Plevyak, T. (1982). Vocalic effects on children's final stop voicing. Master's thesis, University of Maryland.

Port, R. F. (1981). Linguistic timing factors in combination. *Journal of the Acoustical Society of America 69*(1), 262–274.

Port, R. F. and R. Rotunno (1979). Relation between voice-onset time and vowel duration. *Journal of the Acoustical Society of America 66*, 654–662.

Rose, S. and R. Walker (2004). A typology of consonant agreement as correspondence. *Language 80*(3), 475–531.

Rosen, K. M. (2005). Analysis of speech segment duration with the lognormal distribution: a basis for unification and comparison. *Journal of Phonetics 33*(4), 411–426.

Seidl, A. and E. Buckley (2005). On the learning of arbitrary phonological rules. *Language Learning and Development 1*(3 & 4), 289–316.

Singh, S. and J. W. Black (1966). Study of twenty-six intervocalic consonants as spoken and recognized by four language groups. *Journal of the Acoustical Society of America 39*(2), 372–387.

Steriade, D. (2001). Directional asymmetries in place assimilation: a perceptual account. In E. Hume and K. Johnson (Eds.), *The Role of Speech Perception in Phonology*, pp. 219–250. San Diego: Academic Press.

Wang, M. D. and R. C. Bilger (1973). Consonant confusions in noise: a study of perceptual features. *Journal of the Acoustical Society of America 54*(5), 1248–1266.

Weismer, G. (1979). Sensitivity of voice-onset-time (vot) measures to certain segmental features in speech production. *Journal of Phonetics 7*, 197–204.

Wickelgren, W. A. (1966). Distinctive features and errors in short-term memory for English consonants. *Journal of the Acoustical Society of America 39*(2), 388–398.

Wilson, C. (2003, January). 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.

Wilson, C. (2006). Learning phonology with substantive bias: an experimental and computational study of velar palatalization. *Cognitive Science 30*(5), 945–982.

Yavas, M. (1994). Final stop devoicing in interlanguage. In M. Yavas (Ed.), *First and second language phonology*, pp. 267–282. San Diego: Singular Publishing Group.

Yavas, M. (1997). The effect of vowel height and place of articulation in interlanguage final stops. *International Review of Applied Linguistics in Language Teaching (IRAL) 35*(2), 115–125.