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On the Naturalness of Unnatural Rules

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In the 1970's the approach of Natural Phonology focused on the observation that phonetically motivated ("natural") processes are common in the phonologies of the world's languages, while phonetically unmotivated ("unnatural") ones are uncommon (cf. Stampe 1969, Vennemann 1974, Hooper 1976, Donegan and Stampe 1979; for reactions at the time see, for example, Hellberg 1978 and Anderson 1981).

Much recent work, especially in Optimality Theory (Prince and Smolensky 1993), revives this general philosophy: the phonological system incorporates phonetic constraints on outputs, ranging from perceptibility of acoustic cues in particular contexts to the general principle of least effort (Flemming 1995, Steriade 1997, Myers 1997, Boersma 1998, Kirchner 1998). I present evidence that this approach makes false predictions regarding the historical development of phonological systems (cf. Ohala 1974, 1981, 1997, Kaye 1989, Hale and Reiss 1998, in press, Hyman 1998, Kingston 1999).

I argue that while phonetically driven approaches correctly identify the factors that lead to common alternations, it is problematic to incorporate these factors into the grammar itself. From the learner's (and the grammar's) point of view, the original cause of an alternation is irrelevant: the learner's only goal is to reproduce the language she hears around her.[*]

1. Phonetically motivated vowel lowering

Although most of the processes to be discussed in this paper are not well motivated from a phonetic point of view, I begin by presenting a phenomenon that has clear motivation. One case of a phonetically natural, and therefore widely attested, pattern is lowering of vowels in proximity to a uvular consonant. I illustrate with examples from three languages. In West Greenlandic Eskimo, the vowels /i, u/ lower to approximately [ɛ, ɔ] when followed by either of the uvular consonants /q, ʀ/ (Schultz-Lorentzen 1945, Fortescue 1984). This process is allophonic; the only phonemic vowels are /i, u, a/. The examples below show the final vowel of the stem changing depending on the following suffixal consonant.

(1) *WEST GREENLANDIC: Vowel lowering*

a.	sɛʀmi̲-t	'glaciers'	sɛʀmɛ̲-q	'glacier'
b.	uvdlu̲-t	'days'	uvdlɔ̲-q	'day'
c.	iki̲-t	'your wound'	ikɛ̲-ʀput	'our wound'

This lowering has clear motivation in the similar articulations of the low uvular consonants and the lowered vowels.[1]

A similar lowering is found as a distributional generalization in Peruvian Quechua, though in this case it occurs on either side of a uvular stop, not just before a uvular (examples from Daza 1983). The relevant consonants are /q, qʰ, q̇/, which can be constrasted with /k, kʰ, k̇/ that do not induce lowering.

(2) *QUECHUA: Vowel lowering*

a.	i̲kma	'widow'	e̲qe̲qo̲	'talisman'
b.	ki̲ru	'tooth'	qe̲ru	'ritual mug'
c.	u̲ku̲ku̲	'bear'	o̲nqo̲y	'sickness'
d.	ku̲ku̲li	'dove'	qo̲lqe̲	'money, silver'

This process, like that in Greenlandic, is also allophonic in origin, though widespread Spanish borrowing has introduced distinctive /e, o/ into the lexicon. Consequently there are many tokens of the mid vowels that have no triggering uvular consonant, and the distribution of high versus mid vowels is predictable only in the native vocabulary.

In Kashaya (Pomoan: N. California), all vowels collapse to [a] after a uvular stop /q, q^h, ɢ/ (Oswalt 1961, Buckley 1994a). This change neutralizes phonemic distinctions.[2]

(3) *KASHAYA: Vowel lowering*

a.	sima:q-eti	→	sima:qa̲tí	'although he's asleep'
b.	ʔusaq-in	→	ʔusá:qa̲n	'while washing the face'
c.	ht-aq-i	→	taqá̲	'stretch your leg out!'
d.	miku:ṭ-q-e:	→	mikuṭ^{h}qá̲:	'must have hummed'
e.	p^{h}i-ʔya:tq-w	→	p^{h}iyát^{h}qa̲w	'recognize (pl)'

Historically, this affinity exerted a complementary pressure: uvulars before /i, e, u/ became velars (McLendon 1973). Here the phonetic tendency has been granted categorical influence.

While this lowering in Kashaya has the same ultimate phonetic motivation that is more transparently observable in Greenlandic and Quechua, the process has expanded far beyond the original phonetic tendency. This is a fundamental fact about phonologization of phonetic processes (cf. Hyman 1976), and one that I believe makes it quite impossible to include phonetic motivations in the phonology: becoming divorced from phonetics is the very essence of phonology. Kashaya lowering by itself is a serious challenge to phonetically driven accounts of phonology, since the diachronic trend has clearly been to move away from the phonetic motivation. The following sections make this point more dramatically by means of processes that are quite unnatural, even if many of them originated in phonetically motivated alternations.

2. A "crazy rule" in Pomoan

Bach and Harms (1972) use the term "crazy rule" to describe rules that make no phonetic sense. An excellent example of such a rule is found in the Southern Group of Pomoan (Kashaya, Southern Pomo, and Central Pomo). According to this odd but quite productive rule, a vowel that normally surfaces as [i] occurs as [u] after [d] (Oswalt 1976). Examples here are from Kashaya (Oswalt 1961, Buckley 1994a).

(4) *KASHAYA: Singular imperative -i*

a.	šu-q̣a:ṭ-i	→	šuq̣a:ṭi	'groan!'
	du-ṡe:ḳ-i	→	duṡe:ḳi	'pleat it!'
b.	wa-ad-i	→	wa:d**u**	'come here!'
	cad-i	→	cad**ú**	'look!'

(5) *KASHAYA: Same-speaker simultaneous -in*

a.	mo-mul-in	→	momú:lin	'while running around'
	du-ḳis-in	→	duḳisín	'while scratching'
b.	mahsad-in	→	mahsad**ún**	'while taking away'
	mo-aq-ad-in	→	mo:qad**ún**	'while running out from here'

(6) *KASHAYA: Suppositional -inṡ*

a.	ʔ-inṡ-e:	→	ʔínṡe:	'I suppose'
b.	cad-inṡ	→	cad**únṡ**	'I wonder if he saw it'

(7) *KASHAYA: Conditional -iʔba*

a.	q̣o-c-iʔba-em	→	q̣ocíʔbem	'could drink that'
	da:qaċ-iʔba	→	daqa:ċíʔba	'would like it'
b.	ciċ-id-iʔba	→	ciċí:d**uʔba**	'would do'

The reconstruction of Pomoan aspectual suffixes by Mithun (to appear) points to the origin of this unusual pattern in a reanalysis of morphological juncture in one extremely common suffix, the Durative. Briefly, what began as **-adu* took on the variants [ad] and [adu] depending on whether the final vowel was necessary for syllabification. In this earlier stage, deletion of the /u/ in underlying /adu/ occurred whenever there was no adjacent consonant that would be stranded as a result. At a later stage, however, the morpheme was reinterpreted as underlying /ad/, with insertion of [u] where it was necessary to syllabify an adjacent consonant. Since this historical morpheme came to be part of many composite aspectual and movement suffixes, the phonological environment was generalized such that the epenthetic vowel, normally [i], became [u] after any [d] regardless of its origin. It was then a short step to change even underlying /i/ to [u] in this context.

Because this rule has spread widely to other suffixes, it must be encoded in the grammar just like the more phonetically motivated rule [i] → [a] after [q]. (The changes to [a] and to [u] are equally productive.) In fact, it is the organization of the grammar, or the learning process, that must have lead to the generalization of the rule beyond its original morphological context. For example, learners (like linguists) prefer purely phonological rules to morphologically conditioned ones. They apparently also prefer epenthesis to syllabically conditioned deletion. The [u] rule has remained in these languages for perhaps a thousand years despite its phonetic arbitrariness. If phonetic naturalness were a significant direct pressure on the phonology, this rule should have been abandoned rather that being extended to new domains. What rules like this (and those below) indicate is that naturalness is not an concern of the learner, nor of the mental grammar she constructs.

3. Zuni (hyper)palatalization

In Zuni, the velars /k, ǩ/ are palatalized to [kʸ, ǩʸ] before /i, e, a/ (Newman 1965, 1996, Walker 1966, 1972, Michaels 1971). Further, the /a/ in this context is fronted to [æ].[3]

(8) *ZUNI: fronting of velars before nonround vowels*

a.	kiwihcinne	→	kʸiwihcinne	'kiva'
	la:ǩi	→	la:ǩʸi	'today'
b.	kemme	→	kʸemme	'leather'
	ʔaǩe	→	ʔaǩʸe	'large metate'
c.	wehka	→	wehkʸæ	'Eastern Keres'
	ǩawe ʔ	→	ǩʸæwe ʔ	'water'

A related fact regarding the interaction of velars and vowels is that before a round vowel, the velars and labiovelars do not contrast. This situation arose, of course, because the velar is phonetically rounded by coarticulation with the following vowel, as is any consonant before [u, o]. But since in Zuni only /k, ǩ/ contrast with a rounded series, namely /kʷ, ǩʷ/, it is only here that the coarticulation has phonological consequences. Traditionally, a velar preceding a rounded vowel is transcribed as unrounded, since that is the phonologically unmarked value for this contrast (as in Newman 1965:20, the source of these examples); but to reflect articulatory reality, I show the noncontrastive velar as (phonetically) rounded. The important point is that neutralization of rounding occurs.

(9) *ZUNI: loss of rounding contrast before round vowels*

a.	łakʷi-ʔka	→	łakʷiʔkʸæ	'it was inserted'
	łakʷ-u-ka	→	łakʷukʸæ	'he caused it to be inserted'
b.	ʔehkʷi-ʔka	→	ʔehkʷiʔkʸæ	'he was first'
	ʔehkʷ ʔona	→	ʔehǩʷona	'one who is first'

These representations assume that sequences generally treated as (underlying) simple velars followed by rounded vowels have, phonetically, noncontrastive anticipatory rounding on the consonant.

(10) *ZUNI: noncontrastive rounding of velars before round vowels*

a.	ʔa:ku	→	ʔa:kʷu	'purple sage'
b.	ǩokši	→	ǩʷokši	'be good'

Thus the neutralization of the contrast between /ku/ and /kʷu/ is phonetically in favor of [kʷu], even if the transcription <ku> is more typical for the outcome of both sequences. It is important to remember that my use here of the notation [ʷ] before [u, o] merely indicates a degree of coarticulatory rounding on the consonant no greater than the lip rounding that occurs during the following vowel.

Although the lack of historical and comparative data for Zuni prevents a definitive scenario, I propose that the [kʸæ] pattern in (8c) began with a minor fronting of a velar

consonant before a non-back vowel to reduce articulatory effort in the transition from [k] to [i, e], but then generalized to /a/. Notably, the /a/ vowel itself now shows the fronting effect of the preceding [kʸ].

(11)	a.	*phonetic coarticulation*	kʸi	ka	kʷu
	b.	*generalization to unrounded vowels*	kʸi	kʸa	kʷu
	c.	*effect of consonant on vowel*	kʸi	kʸæ	kʷu

At step (a) the low vowel is alone in not causing some change in the preceding velar consonant. Since /a/ lacks the feature [+round], labialization is an unlikely development; instead, I suggest that at step (b) speakers eliminated the inertness of /a/ by extending the fronting pattern to all non-round vowels, including /a/. Eventually the frontness of the velar exerted an effect on the vowel, causing /a/ to surface as [æ] in exactly this context. Of course, since /kʸ/ does not exist as a phoneme in Zuni, no neutralization of contrast occurs before [i, e, æ], unlike with /kʷ/ before /u, o/ — perhaps another reason why /a/ joined the fronting rather than rounding pattern.[4]

Fronting of velars before front vowels is very common and phonetically unsurprising (cf. Ladefoged and Maddieson 1996: 33). But this originally natural effect has been extended and exaggerated so much that the result is quite unnatural. Both the strongly palatalized consonant [kʸ] and the low front vowel [æ] are cross-linguistically marked, in particular when compared to the other possible pronunciation, simple [ka]. The latter is attested in Zuni, especially in the pronunciation of loanwords (see Michaels 1971 and references therein).

(12) *ZUNI: non-fronting before [a] in loanwords*

a.	melika	'white man'
b.	ka:po	'cowboy'
c.	kaču:čan poʔyanne	'railroad (man's) cap'

The change in the native vocabulary from /ka/ to [kʸæ] is completely severed from its original phonetic motivation; synchronically it is an arbitrary rule that defies principles of articulatory ease and segmental markedness. (Cf. Modern Greek with the same vowel inventory and palatalization of velars before [i, e] but not before [a].)

A further example of the phonologized status of this rule is the opaque distribution of [k] and [kʸ] in cases of elision, where the (non)triggering vowel has been deleted (Davis 1966).

(13) *ZUNI: elision and its interaction with velar fronting*

a.	suskʸi ʔokʷikʸæ	⇏	suskʸ okʷikʸæ	'coyote woke up'
b.	łanakʔo ʔelaʔkʸæ	⇏	łanak elaʔkʸæ	'the fox stood up'

For additional discussion of how the Zuni pattern may have arisen, see section 7.

4. Reinterpretation of vowel length in Menominee

In Menominee (Bloomfield 1962, Hayes 1995), vowel length is subject to several changes depending on foot structure, which is iambic (right-strong quantity-sensitive), from left to right. The final consonant is extrametrical, so final syllables behave as open syllables.

(14) *MENOMINEE: lengthening of strong vowel in the first foot*

a.	natom-a:-w	□	(nato:)(ma:)w	'he is called'
	ne-natom-a:-w	□	(nena:)(toma)w	'I call him'
b.	nɛkan-a:-w	□	(nekɛ:)(na:)w	'he is left'
	ke-nɛkan-a:-w	□	(kenɛ:)(kana)w	'you$_{sg}$ leave him'

This uniform lengthening happens only in the first foot of the word. In later feet, a long vowel will actually shorten if the strong vowel is in an open syllable (cf. the previous examples). In a closed syllable, however, lengthening also happens in non-initial feet.

(15) *MENOMINEE: shortening of strong vowel in a non-initial foot (open syllable)*

a.	ahsam-a:-w	□	(ahsa:)(ma:)w	'he is fed'
	net-ahsam-a:-w	□	(neta:h)(samɑ:)w	'I feed him'
b.	nɛkan-ɛ:k	□	(nekɑ:)(nɛ:)k	'when you$_{pl}$ leave him'
	nɛ:kan-ɛ:k	□	(nɛ:)(kanɛ:)k	'when you$_{pl}$ left him'

(16) *MENOMINEE: lengthening of strong vowel in a non-initial foot (closed syllable)*

a.	payo:se-yan-en	□	(payo:)(seya)nen	'whenever I embark'
	payo:se-yahken	□	(payo:)(seyɑ:h)ken	'whenever we embark'
b.	nɛkan-ehtwa:ʔ	□	(nekɑ:)(nehtua)ʔ	'when they are left'
	nɛ:kan-ehtwa:ʔ	□	(nɛ:)(kanɪ:h)(tua)ʔ	'when they were left'

These last examples are quite surprising compared to iambic lengthening in other languages (Hayes 1995, Buckley 1998): more often it is closed syllables that resist lengthening, and we certainly do not expect shortening of the stressed vowel. Part of the answer is that coda consonants in Menominee do not make the syllable heavy, but it is still a "crazy rule".

Hayes (1995: 220) notes that "the best account of such rules often is to reconstruct their diachronic origins, explaining them away as the synchronically unnatural result of a sequence of natural changes." He proposes the following possible scenario.

STAGE 1: **Lengthen vowels** in the heads of disyllabic feet (normal iambic lengthening).

(17) (osá:)(mepé:h)(katá:)m = [osá:mepé:hkatá:m]

STAGE 2: Long vowels in non-initial feet are "somewhat reduced" in their phonetic duration. This is plausibly in contrast to a main stress on the first foot.

(18) (osá:)(mepè:h)(katà:)m = [osá:mepè·hkatà·m]

STAGE 3: By restructuring, the phonetically intermediate-length vowels in non-initial feet are analyzed as phonologically short, but just in open syllables. Long vowels are normally shorter in closed syllables (Maddieson 1985), so these remain phonologically long.

(19) (osá:)(mepé:h)(katá̲)m = [osá:mepé·hkatá·m]

At this stage the contrast in degree of stress is likely gone, so that the difference in phonetic duration between stressed vowels in initial and non-initial feet cannot be attributed to metrical structure, and has to be attributed to phonological length.

STAGE 4: Loss of the intermediate length in the phonetic realization of short stressed open syllables. Present rule system, with lengthening and shortening in crazy environments.

(20) (osá:)(mepé:h)(katá)m = [osá:mepé·hkat̲ám] 'he waters it to excess'

Thus while the modern situation may have resulted from small motivated changes, the end result is in some regards the opposite of the natural situation; yet the rules have remained vigorous.

5. Ojibwa palatalization

Eastern Ojibwa further illustrates the fact that what begins as a natural phonetic process often becomes part of a phonetically opaque alternation (Bloomfield 1946, 1957, Kaye 1978, Piggott 1980). In the proto-language, /t, □/ palatalized to [č, š] before [i, i:, y].

(21) *PROTO-ALGONQUIAN: palatalization*

a.	*pema:t-esi-wa	'he lives'
	*pema:č-ih-e:wa	'he makes him live'
b.	*mi:ka:□-e:wa	'he fights him'
	*mi:ka:š-i	'fight him!'

This place assimilation can be motivated on the grounds of ease of articulation. But various subsequent changes in the daughter languages have obscured the original phonetic plausibility; for example, in Ojibwa *□ became [l] and then [n], leading to the unusual alternation [n] ~ [š].

(22) *OJIBWA: sound changes*

a. *□ AND *l MERGE AS [l] (attested in 17th century)
palatalization extended to reflexes of *l in addition to *□

*na:□	ki-na:n-a:	'you fetch him'
	ki-na:š-i-mi	'you fetch us'
*mi:l̲	ki-mi:n-a:	'you give him'
	ki-mi:š-i-mi	'you give us'

b. [l] FROM *[l] AND *l MERGE WITH [n] (beginning of 19th century)
palatalization **not** extended to reflexes of *n; rule undergoer becomes **opaque**

*we:pin	ki-**we:pin**-a:	'you leave him behind'
	ki-**we:pin**-i-mi	'you leave us behind'

c. SHORT FINAL VOWELS DELETE
rule trigger becomes **opaque**: original **trigger** of palatalization is lost

*-i	ki-**mi:š**	'you give me' (from *ki-**mi:š**-i)

d. *e MERGES WITH [i]
rule trigger becomes **more opaque**: it applies only before some tokens of [i]

*i	ki-**mi:š**-i-mi	'you give us'
*e	ki-**mi:n**-in	'I give you'

The alternation between [n] and [š], though unnatural and opaque, remains quite productive in inflectional paradigms, while the natural alternation between [t] and [č] has been restricted in its range of application. For example, where we find stem-final [n]~[š] we find nonalternating [t].

(23) *OJIBWA: loss of t~č alternation*

a.	*nesič-i	>	nisit	'my foot'
b.	*nesit-ali	>	nisit-an	'my feet'

The natural rule was curtailed, rather than the unnatural one. Kaye (1978: 154) attributes this change to "historical accident":

(24) Recall that l-palatalization is well established in the inflectional morphology, particularly in the verbal morphology. This is due to the fact that many T[ransitive] A[nimate] verb stems ended in *[l] and *l. Within the TA paradigm there are several suffixes which began with *i. So it is here that the alternations show up. On the other hand, no TA verb stem ended in *t, and as a result, no *t~č* alternations appear within verbal paradigms. Perhaps it was because of this lack of support that all noun alternations involving *t~č* came to be lost.

In other words, what matters to the learner is how well attested an alternation is, not whether it is phonetically motivated. If the alternation is clear, it will be learned; otherwise it may be lost.

6. Belief systems

The processes discussed in this paper lead to the same conclusion that many others have reached before. An effective summation comes from Hyman (1975: 181f):

(25) Although sound changes are sometimes blocked by considerations within a paradigm [...] no corresponding force has been discovered which would strive to keep rules natural. Instead, the above examples show the great tendency for rules to become unnatural [...] that is, to lose their phonetic plausibility and become morphologically conditioned.

Under this sort of view, which we can call the Cognitive view, the phonology is a computational system that manipulates abstract categories and does not incorporate information about phonetic naturalness. The following two substitutions are therefore equally acceptable.

(26) a. i □ e / q __ *(cf. Greenlandic and Quechua)*
b. i □ u / d __ *(cf. Kashaya)*

Under a view that does incorporate information about phonetic naturalness into the grammar, which we can call the Phonetically Driven model, rule (a) is easy to express, while (b) must be treated as arbitrary. Quite schematically:

(27) a. i □ e / q __ ⑨ "Sacrifice vowel height to articulatory ease"
b. i □ u / d __ ⑨ ARBITRARY SUBSTITUTION *(however that is formalized)*

But this distinction is actually the same one that is expressed by markedness in standard generative approaches to phonology, such as feature geometry (cf. a distinction I made for these very rules in Buckley 1994a).

(28) a. i □ e / q __ ⑨ "Spread [+low] from a uvular to a following vowel"
b. i □ u / d __ ⑨ "Insert [+round] after /d/"

Natural assimilation rules are formalized by autosegmental spreading, while unnatural rules (to the extent they are discussed) require other operations, here arbitrary insertion. But if arbitrary insertion rules can be learned, and seem to be unpenalized in the historical development of languages, why create another, superfluous mechanism such as spreading?

It seems to me the matter hinges on two views that can be stated roughly as follows.

(29) a. *Principle of Phonetic Explanation*: Many or most phonological patterns are explained by detailed phonetic properties of human language, such as the robustness of acoustic cues and the ease of specific contextual articulations.

b. *Principle of Explanatory Phonology*: The explanations of phonological patterns are represented in the mental grammar. A phonological process is "natural" to the extent that it is easily expressed by the tools of the theory.

Phonetically Driven Phonology is the Standard Markedness model brought to its logical conclusion, taking seriously the question of what makes a process natural. A schematic analysis of views:

(30)

		Phonetic Explanation	*Explanatory Phonology*
a.	Standard Markedness Phonology	NO	YES
b.	Phonetically Driven Phonology	YES	YES
c.	Cognitive Phonology	YES	NO

I believe that Phonetically Driven phonology is correct is attributing the motivation of many phonological patterns to the phonetics; but mistaken in the further (traditional) step of incorporating this motivation into the mental grammar.

7. A Cognitive Approach

I use the term "Cognitive" to evoke a theory of phonology that takes seriously the ideas of cognitive science, in particular the mind as a computational system (cf. Kaye 1989, Lakoff 1993). For general discussion, see especially Hale and Reiss (1998, in press).

A basic point: If the child learner can master strange and complex alternations without apparent prejudice, there is no reason to think that natural processes are easier to learn (i.e. more easily accommodated by the tools of the mental grammar). In fact, the learner will treat natural alternations as if they are arbitrary — which is accurate, since no language exhibits every phonetic tendency in its phonology. The set of rules in a language, even if all are natural, is synchronically an arbitrary subset of all possible natural (and unnatural) rules.

The cross-linguistic frequency of "natural" processes is explained by the fact that all languages are produced in the same phonetic universe. Briefly, the nature of production and perception of phonetic signals exerts its influence in the transmission of language from generation to generation. If, for example, some featural distinction is difficult to perceive in some context, the child may fail to hear the distinction and constructs a grammar that neutralizes it.

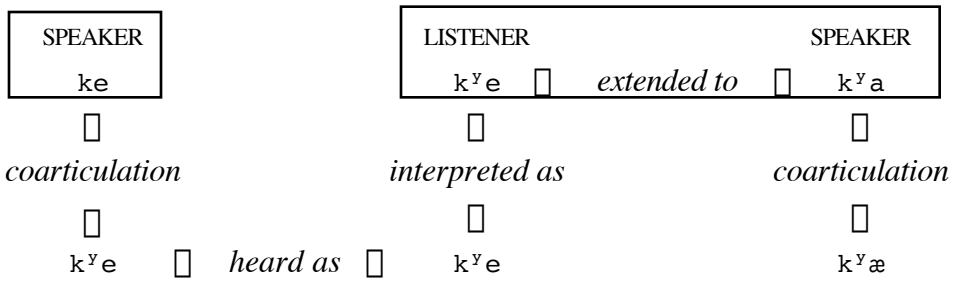
Optimality Theory — which, in its standard variety, falls into the Markedness category (32a) — is particularly welcoming to Phonetically Driven approaches. It is centered around the motivations of various phonological patterns, such as epenthesis being triggered by NoCoda ("Syllables do not have codas"). It is a relatively easy step to reformulate this motivation in more phonetic terms, referring to the difficulty of perceiving most consonantal cues without a release into a following vowel.

The question of interest is whether a grammar treats "natural" and "unnatural" processes differently, and the answer appears to be "no". The unnatural situations discussed above, and countless others, have persisted in their languages for many centuries, indicating that once an alternation comes about (whether for phonetic or other reasons), the child simply learns it without regard to its original motivation.

What remains for phonology to investigate is precisely the ways in which phonetic variation is structured by learners. For example, the extension of Zuni palatalization from [i, e] to [a] suggests the mental reality of distinctive features like [back] or [round]. And the restructuring of Menominee vowel length rules is just as dependent on the categories Foot and Syllable as is more usual iambic lengthening. Further, the special status of the first foot indicates that reference to a peripheral constituent is necessary — as opposed to unattested notions such as "third from the right".

Borrowing a style of diagram from Ohala (1981), here is an illustration of what may have happened in Zuni that led to the strange pattern /ka/ → [kʸæ].

(31)



Essentially, phonology proper — what requires cognitive explanation — is what happens "inside the box", such as the extension of the Zuni fronting pattern to /a/ on the basis of properties it shares with /i, e/, i.e. lack of rounding. The impetus for the extension is also cognitive, i.e. the desire to join /a/ in one of the existing patterns of velar+vowel interaction. The fact that velars are fronted before [i, e] has an easy physical explanation, which makes its representation in the cognitive domain unnecessary. In fact, the easy survival of unnatural rules indicates that facts with easy physical explanations should **not** be represented in the mental grammar.

In conclusion, our understanding of phonetic naturalness belongs in the physical context where sounds are transmitted from speaker to hearer, and not (redundantly and problematically) in the grammar that a learner constructs in response to these sound patterns. For the learner, all rules in her language are natural.

Notes

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[1] Maddieson and Ladefoged (1996: 36) discuss the acoustic effect of uvulars in the backing of vowels, but do not mention an acoustic lowering effect. The phenomenon here thus appears to be articulatory rather than auditory — the lowering of the tongue dorsum for the uvular closure brings with it lowering of the entire tongue body, including the anterior region chiefly responsible for the vowel articulation.

[2] A complication arises in certain morphemes that Buckley (1994a) analyzes as containing a rounded uvular /qʷ/; in this context any following vowel surfaces as [o], which differs phonologically from [a] only in the feature [round]. See also Buckley (1994a,b) for restricted contexts where the vowel /i/ raises the preceding uvular to [k], and where a nonlow vowel is permitted adjacent to an underlyingly rounded uvular.

[3] While the nature of Zuni palatalization has been much discussed, these discussions have focused on borrowings in which /ka/ surfaces without a fronted consonant (see (12)). The usual fronting effect on the vowel, though quite obvious to the ear, has generally been ignored in the literature; Walker (1972) is an exception in giving explicit representations of words with the fronted vowel [æ].

[4] An alternative scenario is that, at a previous stage in the history of Zuni, the low vowel had a front articulation [æ] in all contexts, causing fronting of the velar quite naturally; but later the vowel was in general backed, except when preceded by [k^y]. Even under this story, however, the conclusion remains that what began as a phonetically motivated process has become unnatural: underlying /ka/ must still surface as [k^yæ].

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