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HIERARCHIES OF ENVIRONMENTS FOR SOUND VARIATION; PLUS IMPLICATIONS FOR 'NEUTRAL' VOWELS IN VOWEL HARMONY.

by

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Introduction

Chen (1973) and Neeld (1973) maintain that there is a strict hierarchy of environments for the palatalization of consonants: palatalization occurs preferentially before high vowels (and glides) and if in a given language it occurs before a vowel of a certain height (other things being equal) it will occur before all higher vowels. Although statistically this is quite true, there are some exceptions to this principle. It is instructive to review the nature of these exceptions and to attempt to derive them from "first principles" – in this case, from speech perception. I will then connect these principles to other more general phonological phenomena especially "neutral vowels" in vowel harmony systems.

Palatalization of Consonants

Palatalization of velar consonants before front vowels is well known in the history of the Slavic and Romance languages and follows the hierarchic pattern described by Chen and Neeld. See (1).

(1) (From Pope 1934: 124ff, transcription modified.)

(1) Palatalization of velars before front vowels (but not back vowels) in French (from Pope 1934, transcription of intermediate forms altered to employ IPA symbols).

Gallo-Roman			**Modern French**		
radikiːna	*radicina	ratsinẹ	*racine*	[ʁasin]	*root*
gentem	*ɟente	dʒẽnt	*gent*	[ʒɑ̃]	*tribe*
karːum	*carːʊ	tʃar	*char*	[ʃaːʁ]	*chariot*
BUT					
kɔrpɔs	kɔrs	kɔrz	*corps*	[kɔʁ]	*body*

But the development of the Greek labiovelars constitutes an exception to this pattern (Lejeune 1947; Allen 1958). As shown in 2a-c, although the voiceless unaspirated labio-velar stops became fronted to [t] (one form of palatalization) before both of the front vowels [i e], in the case of the voiced and the aspirated labio-velars, the fronting occurred only before [e], not [i].

(2) (From Lejeune 1947: 39ff.)

(a) Palatalization of $*k^w$ before *ι* and *ε*.

$*k^w$is	*who*	:	*τίς*			
$*k^w$et-	*four*	:	Attic	*τέτταρες*	cf. Sanskrit	*catvāraḥ*

(b) Palatalization of $*g^w$ before *ε* but not *ι*.

$*g^w$i-	*life*	:	*βίος*	cf. Old English *cwic*, Mod. Engl. *quick*
$*g^w$elbh-	*womb*	:	*δελφύς*	cf. Sanskrit *gárbhaḥ*

(c) Palatalization of $*k^wh$ (< PIE *gwh) before *ε* but not *ι*.

$*og^{wh}$i-s	*serpent*	:	*ὄφις*	
$*g^{wh}$er	*to be hot*	:	*θέρος*	cf. English, German *warm*

Allen accounts for this pattern with a detailed argument, the principal component of which is that it is the fronting of $*k^w$ before [i] that is unusual, not the lack of it in the case of $*g^w$ and $*k^{wh}$ (< PIE $*g^{wh}$). Ancient Greek, particularly Attic Greek, did not permit sequences of homorganic *glide + vowel*, i.e., $*C^w$u, C^ji and since, Allen maintains, it is the presence of a palatal glide which precipitates fronting this would not occur before [i]. It occurred before [e] since in this environment a non-distinctive palatal glide (j < ɥ < w) could occur.

> ... before a fully palatal vowel (*ι*) palatalization of a preceding labiovelar would not be expected; the 'half-palatal' (mid front) vowel *ε* on the other hand would be sufficiently palatal to palatalize the preceding consonant, without qualifying phonologically as a carrier of palatality.

The reason *kwi fronted to *ti-* is said to be the fact that all original *ti-* sequences had changed to *si-* thus creating a "hole" in the pattern and precipitating a so-called "drag chain".

Leaving aside the "chain shift" part of this scenario, the tendency for languages to avoid sequences of homorganic *glide* + *vowel* has been extensively documented (Kawasaki 1982, 1992; Maddieson & Precoda 1992). As this affects the palatalization of velars before lower rather than higher front vowels, Allen provides two other examples (Allen 1950):

(3) In East Armenian, consonants in the initial and stressed syllables are accompanied by a palatal offglide, which is most marked in velars when followed by e, e.g., *xent'* = [xʲenth] but *xit* = [xith] (Allen 1950).

(4) Jutland Danish: "Hier is die Palatalisierung vor den gescholossensten Vokalen (*i* und *y*) geschwunden, während vor den offeneren Vokalen (*e*, *æ*) *kj* und *gj* gesprochen wird..." (Pedersen 1939).

There are abundant examples of the same phenomenon (some of the following culled from Bhat (1978)).

(5) Although the Tashkent dialect of Uzbek has several front unrounded vowels (approx. IPA [i, I, e, ɛ, a]), **b** and **k** are said to be palatalized only before **e** in certain conditions (Wurm 1947).

(6) In Western Ossetic there is a palatalized series of consonants which are characterized by a palatal off-glide which is more readily perceived before e than before i. Phonetically e is usually distinctively longer than i. (Similarly, a series of labialized and/or velarized consonants exhibits a **w** off-glide which is more evident before **o** than **u**.) (Henderson 1949)

(7) In Yerwa Kanuri there is reported to be slight palatalization of consonants before front vowels, esp. /e/. (Similarly, there is noticeable labialization of consonants, especially /k g/ before back vowels, especially /o/.) (Awobuluyi 1971).

(8) In Mõre palatalization and palatal consonants exist but these appear almost solely before **é**, rarely before **o**, and are scarcely perceptible before **i**. It is regular after **k g** (with a couple of exceptions) (Alexandre 1953).

(9) Bloomfield (1956) reports that in Eastern Ojibwa, the velar stops, *kk, k,* are more fronted before front vowels and have a *y* off-glide (IPA [j]) which is especially marked before *e.* In addition, a *y*-like off-glide is often prominent after *šš* and *š,* especially before e.

Now, it might be argued that in many of the above cases (excepting, of course, that of Greek) the presence of the palatalization before a non-high front vowel and absence before higher front vowel(s) is true at the phonetic level, not the phonological. Nevertheless, it is such phonetic palatal glides which often precipitate sound changes of sort seen in Greek – which sound changes unquestionably effect the phonology of languages.

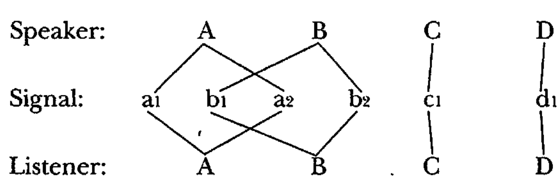
At the very least this suggests that the strict hierarchy of environments for palatalization advocated by Chen and Neeld is not without exception and that the exceptions are perhaps principled. The patterns cited above (in (6) and (7)) also show exceptions to a plausible parallel claim that labialization of a consonant before a rounded vowel of a given height implies labialization before all higher vowels. Nevertheless I don't think these exceptions invalidate Chen and Neeld's basic claim. To resolve this apparent paradox, I need to review briefly a recent phonetic account of sound change (Ohala 1981, 1985, 1986, 1989, 1992, 1993).

A Phonetically-Based Account of Sound Change

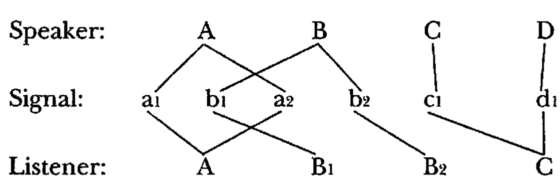
In the above-cited works an account of sound change is given which integrates it with synchronic processes of speech production and perception and which is, moreover, supported by phonetic and psycholinguistic experimental studies. Briefly, when speech is produced one can assume that in the mind of the speaker the utterance consists of a string of one or more discrete units, A, B, C, D ... See Fig. 1a. As extensive work in speech analysis and perception has shown, there are, however, multiple co-occurring phonetic events (cues) in the speech signal which are associated with these units and these events are spread out and overlapped both over time and over the frequency spectrum. This is represented schematically in the figure by the row labelled 'speech signal', a_1, b_1, a_2, b_2, c_1, d_1, ... For the sake of this exposition I intend the uppercase and lowercase equivalents to be related but of course in the stream of speech detected by the listener the acoustic phonetic events are not 'labelled' in any way which would unambiguously allow them to be traced back to the speaker's intended speech units. Rather this string of phonetic events (e.g., an amplitude drop, a stop burst, an abrupt change in the periodicity of the signal) has to be "parsed" in order that the units intended by the speaker may be reconstructed. The vast majority of the time the listener parses the signal correctly and the pronunciation norm of the speaker is recovered (lower part of Fig. 1a).

But the listener's parsing may not always be completely successful. Evidence for this is circumstantial but hard to deny: it has been shown that a great many of these co-occurring phonetic events have parallels in sound change. For example, voiced and voiceless consonants in non-tonal languages like English, French, Danish, Russian, etc. have slight differences in the F0 contour on following vowels; in the history of tone languages like Thai, Vietnamese, Chinese, Nama, etc. new tones developed due to the same apparent condi-

a.



b.



tioning of preceding voiced and voiceless consonants – usually accompanied by the neutralization of the voicing distinction – (Hombert, Ohala, & Ewan 1979). Synchronically, vowels are nasalized slightly in the environment of nasal consonants; this is the same environment where distinctively nasal vowels arise. Synchronically, stops released before high close vowels or glides show more intense noise in their burst and aspiration (if any); this is the same environment where diachronically stops develop into affricates (e.g., *actual* < [ækt + juəl] is [æktʃuəl]).

Although such synchronic co-variation of phonetic events parallels sound change it does not constitute sound change *per se* because listeners learn to expect such co-variation and thus reconstruct the pronunciation norm intended by the speaker. The sound changes can come about if listeners fail to associate the separate co-occurring phonetic events and instead take one or more of them as independent. This type of perceptual error can be called an error of *dissociation*[1]. Such mis-parsings, which can be found in controlled listening tests in the laboratory, apparently occur at some modest rate in all exchanges between speaker and hearer. Most such errors are corrected but those that are not are potential **sound changes.**

Another type of misparsing, where two phonetic events that should have been parsed separately are parsed together represent a mis-application of listeners expectations. For example, in the history of English, some [w] glides have disappeared before rounded vowels: sword is now [sɔrd] (American) or [sɔəd] (British); *ooze*, once pronounced [wo:s] (cognate with Lat. *virus*), is now [u:z]. The original /w/ glide was lost because some listeners presumably thought it was a predictable consequence of the rounded vowel and therefore parsed it with the vowel instead of parsing it separately. I call this type of error *false association*[2]. This is the basis, I claim, of all dissimilations (and certain other sound changes not usually classified as dissimilations).

Fig. 1b gives a graphical representation of these two types of parsing errors.

An important part of this account of sound change is the role of the listener. True, much of the co-variation of phonetic events is due to the physical constraints of the speech production mechanism but I believe that speakers do not intentionally introduce variations which are beyond their estimate of listeners' ability to successfully parse and thus recover the speakers' intended norms. Speakers are responsible for much of the *variation* in speech but not for *sound change* itself, i.e., not for the emergence of a new pronunciation norm. It is listeners, through perceptual parsing errors, who unknowingly create pronunciation norms different from those maintained by the speakers they attend to.

1. I have also referred to this as 'hypo-correction' or 'under-correction'.
2. I have also called this 'hyper-correction' or 'over-correction'.

Application of the Above Account of Sound Change to the Patterns of Palatalization

The likelihood with which a palatal transition appears between a consonant and a following front vowel should be greater the higher and thus more palatal the following vowel or glide. But if this is the case, then it is also true that if listeners dissociate the transition from the surrounding segments, it is more likely to develop as a glide before higher front vowels than lower front vowels. This is what Chen's and Neeld's generalization maintains. But if the glide is more likely to develop in this environment then it is equally more likely that listeners will expect it there and remove it (as apparently happened in the case of the original /w/ in sword and *ooze*, cited above). If listeners' expectations exactly matched the probabilities of the appearance of such a palatal transition, it would not be reinterpreted as palatal glide and there would be no sound change (which is undoubtedly what happens in the vast majority of cases). But it can probably be taken as self-evident that listeners expectations about the appearance of "automatic" transitional elements between speech sounds can at most exactly match the external probabilities of such events – they can never exceed them (if based on experience) – but they undoubtedly could – and do – fall short. In such a case, a listener could successfully parse out the palatal transition before a high front vowel but neglect it before a lower front vowel. This scenario, given by Allen in the quote above, seems to be what happened in the cases cited above, (2) through (9).

The resolution of the paradox then is that Chen's and Neeld's generalization is true in the domain of *speech production* and thus, if listeners commit a dissociation parsing error, becomes true in the phonological domain. However, the reverse pattern (where lower front vowels trigger palatalization but not higher front vowels) is true in the domain of *speech perception* and this may also manifest itself in the phonological domain, too, blocking potential palatalization before the higher vowels.

In general, this is a further illustration of the opposite directionality that sound changes can exhibit if caused by the two types of perceptual parsing errors: most assimilations are the result of dissociation errors, most dissimilations, of false association errors.

The 'Neutral' Vowels in Vowel Harmony Systems

As is well known, languages exhibiting vowel harmony often have one or more vowels which are indifferent to the harmonizing principle. For example, Finnish has the back harmonic vowels /a, o, u/ and front harmonic vowels /æ, ø, y/ and the neutral vowels /i, e/. Within a polysyllabic word stem the vowels must be from the same harmonic set except that the neutral vowels can appear with vowels of either harmonic set. The harmonic set of the word stem determines the harmonic set of the vowels in affixes. See (10), from Ringen (1988: Chapt. 5).

(10)	pøytæ	*table*	pøydæ+llæ	*on the table*
	pouta	*fine weather*	pouta+lla	*in good weather*
	men+o	*going*		
	men+køøn	*let him go*		

In the first two examples the vowels of the stem and affix are all either from the back or front harmonic set; in the last two examples, the phonetically front vowel /e/, one of the neutral vowels, can be found with the back vowel /o/ in the suffix or the front vowel /ø/.

From a phonetic point of view, vowel harmony – i.e., the vowel in one syllable influencing or being influenced by the vowel in an adjacent syllable – is understandable. It is a form of assimilation and has been found phonetically, i.e., non-distinctively, in many languages, e.g., Swedish (Öhman 1967), and English (Fowler 1981). In fact there is persuasive evidence that for many V_1 to V_2 transitions, the influence a front vowel like /i/ would be quite strong, i.e., in imparting an elevated F2 – the auditory cue for vowel frontness – during a substantial portion of the transition (Carré, in press). But this makes it strange that in vowel harmony systems using [±palatal] the vowels with the highest F2 would be neutral vowels – as is the case not only in Finnish but in other Uralic and Altaic languages, e.g., Hungarian, Mongolian. To resolve this paradox we can apply the same principle educed above for exceptions to the posited hierarchical vocalic environment for consonant: although high F2 vowels like palatal [i, e] would have the greatest fronting effect on adjacent vowels this is precisely the case where the listener would be most aware of such a phonetically mechanical effect and thus be able to parse it out of the signal. Listeners' expectations of the V_1-V interaction when one of the vowels is the F2-extreme [i] or [e] could either prevent incipient vowel harmony in these cases or neutralize it once it had become phonological.

General Discussion

There is a long history in phonology of phonetic explanations for speech sound behavior in terms of opposing forces, e.g., contrast-reducing ease of articulation which benefits the speaker vs. enhancement of contrasts to benefit the listener. These accounts can justifiably be criticized as being capable of explaining anything and being invoked at will with little or no empirical constraint no matter what particular sound pattern is focussed on. The above two perceptual parsing errors, *dissociation* and *false association*, may seem to suffer from the same weakness. But unlike the ease-of-articulation arguments the mechanisms of dissociation and false association are supported by – indeed, can be duplicated by – lab-based experiments. For example, Kawasaki (1986) showed that a phonetically nasalized vowel is judged by listeners to be more nasal when flanking nasal consonants have their amplitude attenuated than when they are left intact. Beddor, et al. (1986) showed that spectral perturbations of vowels caused by nasalization lead listeners to report a vowel quality change when there is no nasal present (on which to blame the perturbations) whereas these same vowels are "restored" (occasionally over-restored) to their equivalent non-nasalized quality when a nasal is adjacent to them. In general, when contextually caused variations in speech sounds are presented to listeners in a way that obscures the connection between the conditioning environment and the variation, listeners make judgements about the sounds that duplicate dissociation parsing errors. When, on the other hand, the same stimuli are presented in a way that retains or enhances the connection between the conditioning environment and the variation, listeners make judgements that parallel false association parsing errors. Such experimentation is still in its infancy (Ohala et al. 1992) and has not yet been extended to stimuli which parallel the posited mechanisms underlying consonantal palatalization or vowel harmony but a relatively simple test is possible: given a language which uses palatalization of consonants before all possible vowels, a confusion study (like that of Miller and Nicely 1955) should show more *palatalized* > *non-palatalized* errors before the higher front vowels. It is a significant advance in phonology that it is even possible to present a laboratory-testable phonetic account for given phonological patterns.

Summary

Based on intuitions about the mechanisms of speech production phonologists are led to posit that palatalization of consonants should occur with decreasing probability (from left to right) in the environment of following [j, i, e, ɛ, æ]. Similarly the focus of the incidence of palatal vowel harmony should be the higher, more front vowels [i, e]. Yet there are exceptions to both patterns: palatalization of consonants before lower front but not higher front vowels; [i, e] being the most common neutral vowels in palatal vowel harmony. The resolution of this problem requires a recognition of the role of the listener in parsing the speech signal. The more probable a form of non-distinctive synchronic variation is, the more should the listener be aware of it and thus parse it out. Partial or complete failures of the listener to parse these predictable events accounts for the different patterns found in sound change.

References

Alexandre, R P 1953 *La langue more* Dakar Memoires d'Institut Français d'Afrique Noire No 34

Allen, W S 1950 Notes on the phonetics of an Eastern Armenian speaker *Transactions of the Philological Society* (London) 180-206

Allen, W S 1958 Some problems of palatalization in Greek *Lingua* 7 113-133

Awobuluyi, 1971 The phonology of Yerwa Kanuri *Research Notes* Dept of Linguistics, Univ of Ibadan 4 1 1-21

Beddor, Patrice S , Krakow, Rena A , & Goldstein, Louis M 1986 Perceptual constraints and phonological change A study of nasal vowel height Phonology Yearbook 3 197-217

Bhat, D N S 1978 A general study of palatalization In Joseph H Greenberg, Charles A Ferguson & Edith A Moravcsik (eds), *Universals of human language* Stanford, CA Stanford University Press 47-92

Bloomfield, Leonard 1956 *Eastern Ojibwa* Ann Arbor

Carre, Rene In press Vowel transitions, vowel systems, and the distinctive region model To appear in *Hommages a Max Wajskop*

Chen, Matthew 1973 Predictive power in phonological description *Lingua* 32 173-191

Fowler, Carol A 1981 Production and perception of coarticulation among stressed and unstressed vowels *Journal of Speech & Hearing Research* 46 127-149

Henderson, E J A 1949 A phonetic study of western Ossetic (Digoron) *Bulletin of the School of Oriental and African Studies* 13 1 36-79

Hombert, Jean-Marie, Ohala, John J , & Ewan, William G 1979 Phonetic explanations for the development of tones *Language* 55 37-58

Kawasaki, Haruko 1982 *An acoustical basis for universal constraints on sound sequences* Univ Calif , Berkeley, Unpub doctoral dissertation

Kawasaki, Haruko 1986 Phonetic explanation for phonological universals The case of distinctive vowel nasalization In J J Ohala & J J Jaeger (eds), *Experimental Phonology* Orlando, FL Academic Press 81-103

Kawasaki-Fukumori, Harkuo 1992 An acoustic basis for universal phonotactic constraints *Language & Speech* 35 73-86

Lejeune, Michel 1947 *Traite de phonetique grecque* Paris Librairie C Klincksieck

Maddieson, Ian and Precoda, Kristin 1992 Syllable structure and phonetic models *Phonology* 9 45-60

Miller, George A and Nicely, Patricia E 1955 Analysis of perceptual confusions among some English consonants *J Acoust Soc Am* 27 338-353

Neeld, Ronald L 1973 Remarks on palatalization *Working Papers in Linguistics* (Ohio State University) 14 37-49

Ohala, John J 1981 The listener as a source of sound change In C S Masek, R A Hendrick, & M F Miller (eds), *Papers from the Parasession on Language and Behavior* Chicago Chicago Ling Soc 178-203

Ohala, John J 1985 Linguistics and automatic speech processing In R De Mori & C - Y Suen (eds), *New systems and architectures for automatic speech recognition and synthesis* [NATO ASI Series, Series F Computer and System Sciences, Vol 16] Berlin Springer-Verlag 447-475

Ohala, John J 1986 Phonological evidence for top-down processing in speech perception In J S Perkell & D H Klatt (eds), *Invariance and Variability in Speech Processes* Hillsdale, NJ Lawrence Erlbaum 386-397

Ohala, John J 1989 Sound change is drawn from a pool of synchronic variation L E Breivik & E H Jahr (eds), *Language Change Contributions to the study of its causes* [Series Trends in Linguistics, Studies and Monographs No 43] Berlin Mouton de Gruyter 173-198

Ohala, John J 1992 What's cognitive, what's not, in sound change In Gunter Kellermann & Michael D Morrissey (eds), *Diachrony within synchrony Language history and cognition* [Duisburger Arbeiten zur Sprach- und Kulturwissenschaft 14] Frankfurt/M Peter Lang Verlag 309-355

Ohala, John J 1993 The phonetics of sound change In Charles Jones (ed), *Historical Linguistics Problems and Perspectives* London Longman 237-278

Ohala, John J , Busa, Maria Grazia, & Harrison, Karen 1992 Phonological and psychological evidence that listeners normalize the speech signal *Proceedings, International Conference on Spoken Language Processing, Banff,* 12-16 Oct 1992 Edmonton University of Alberta 1303-1306

Ohman, Sven E G 1966 Coarticulation in VCV utterances Spectrographic measurements *J Acoust Soc* Am 39 151-168

Pedersen, Holger 1939 Zur Theorie der altgriechischen Palatalisierung *Travaux du Cercle Linguistique de Prague* 8 289-291

Pope, Emily K. 1934 *From Latin to Modern French with especial consideration of Anglo-Norman* Manchester Manchester University Press

Ringen, Catherine O 1988 *Vowel harmony Theoretical implications* New York Garland

Wurm, Stefan 1947 The Uzbek dialect of Qizil Qujaš *Bulletin of the School of Oriental and African Studies* 12 1 86-105