Velar palatalization-revisited

Joo-Kyeong Lee
(Korea University)

Lee, Joo-Kyeong. 2000. Velar palatalization-revisited. *Studies in Phonetics, Phonology and Morphlogy* 6.2, 415-430. In this paper, I present a substantial phonetic basis for various patterns of velar palatalization, focusing on articulatory and perceptual roles. I argue that velar palatalization in phonology fundamentally arises from phonetic coarticulation between a velar consonant and a palatal vocoid and that the various patterns are appropriately characterized in terms of different degrees of coarticulation; greater coarticulation gives rise to a greater extent of modification of the velar constriction, resulting in a greater constrictional movement toward the palatal region. Moreover, a listener's perceptual factors also play a prominent role in determining some patterns; the patterns which are not predicted by the coarticulatory mechanisms may be attributed to the listener's misperception. This suggests that phonological patterns and processes can be satisfactorily explained when we consider phonetic details underlying sound production and perception. (Korea University)

Keywords: velar palatalization, coarticulation, production, perception

1. Introduction

Phonology has been recently re-examined from more substantial perspectives with a great emphasis on various extralinguistic factors such as speech production and perception, and it has been claimed that phonological structures and patterns do not directly reflect human being's grammatical competence and that phonology may not be the formal process operated by rules and principles. Such non-formalists rather focus on speaker's and listener's distinctive roles in speech communication, assuming that phonology is their interactive complicated output. The substantive and extralinguistic roles have been investigated through various phonetic instruments, and non-formalists have indeed shown that phonetic naturalness strongly influences phonological patterning. For example, Ohala (1990, 1993) attributes historical sound changes to a listener's auditory factors through acoustic and perceptual experiments, and Articulatory Phonology (Browman & Goldstein 1986, 1989, 1990) shows that various temporal coordinations of the articulatory gestures underlying a sequence of sounds invoke phonological assimilation and deletion. Furthermore, along with the perceptual and articulatory phonetic studies, phonological patterns are also functionally interpreted as facilitating effort minimization in articulation and maximum distinctness of contrasting forms in perception (Boersma 1997; Flemming 1995; Steriade 1995a, 1995b, 1996; Hayes 1995, 1996).

In this paper, I argue that velar palatalization, arbitrarily described in theoretical phonology or incorrectly analyzed even in non-formalist approaches, fundamentally stems from phonetic coarticulation, a process to avoid an extreme articulatory cost. I also show that the principle of minimizing articulatory effort effectively operates upon the phonological patterns of velar palatalization, concomitantly interacting with perceptual attributes. This supports the non-formalist's claim that phonology directly reflects dynamic and complex interactions between a speaker's articulation and a listener's perception rather than the static grammatical competence of a speaker alone.

Table 1 shows the cross-linguistically attested various patterns of velar palatalization observed in my literature review. There are four distinctive outputs in the palatalization of a velar stop as shown in the left column, and the triggers are front vowels [i] and [e] and glide [j], which I call 'palatal vocoids'.[1] There are many cases that a velar stop simply acquires a palatal off-glide ($k \rightarrow k^j$), and a velar stop changes to a palatal stop ($k \rightarrow c$). Moreover, a velar stop is palatalized to an alveo-palatal affricate (k → tç) and to a palato-alveolar affricate (k → tʃ). Note that the palatal stop [c] and the alveo-palatal affricate [tç] seem to be somewhat limited in prevalence in comparison of the velar stop with an off-glide [k^j] and the palato-alveolar affricate [tʃ].

Table 1. Attested patterns of velar palatalization and their languages

patterns	Languages
$k \rightarrow k^j$	Chiricahua Apache (Hoijer 1946), Bulgarian (Foley 1973), Cheyenne (Davis 1962), Greek (Foley 1973), Icelandic (Gussman 1986), Kirundi (Swift 1965), Polish (Rubach 1981), Proto-Algonquian (Kaye 1978), Proto-Athapaskan (Cook 1978), Russian (Jones & Ward 1969), Tupi-Gruarani (Firestone 1965), Turkish (Underhill 1986)
$k \rightarrow c$	Akan (Boadi 1988), Kinyarwanda (Kimenyi 1979), Lamba (Doke 1938), Margi (Hoffman 1963), Modern Icelandic (Arnason 1978), Ogoni (Brosnahan 1964)
k → tç	Italian (Maiden 1995), Kannada (Murthy 1984), Kirundi (Broselow & Niyondaraga 1990), Polish (Rubach 1981), Portuguese (Malkiel 1963; Williams 1962), Rumanian (Ruhlen 1972), Russian (Hamilton 1981), Slovak (Rubach 1993), Uzbek dialect of Qizil Qujas (Wurm 1947), Vote (Collinder 1957)
$k \rightarrow t$	Chinese (Chen 1972)

[1] The actual examples are presented in the Appendix

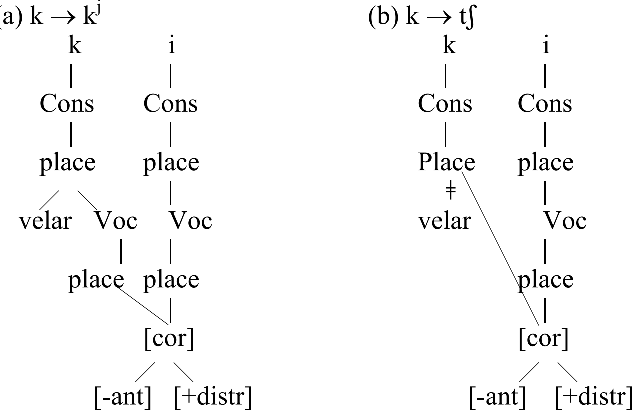
In section 2, I discuss some previous analyses of velar palatalization and their problems. In section 3, I present the coarticulatory mechanisms between a velar stop and a palatal vocoid in detail under the assumption that consonant-to-vowel phonological assimilation like palatalization stems from phonetic coarticulation (Lee 1999). In section 4, I deal with the outputs that cannot be satisfactorily explained in terms of articulatory/physiological structures, and claim that perceptual factors also play as significant a role as the articulatory principles in velar palatalization.

2. Previous analyses and their problems

2.1. Hume (1994)

In this section, I review Hume's analysis of velar palatalization and point out some theoretical problems arising from the assimilatory description in her autosegmental-featural approach. Although Hume successfully describes the distinction of the palatalization acquiring a palatal glide (k → k^j) from the velar to palato-alveolar palatalization (k → tʃ) in the framework of the unified feature theory, I show that two processes such as k → c, and k → tɕ are incorrectly predicted by feature spreading.

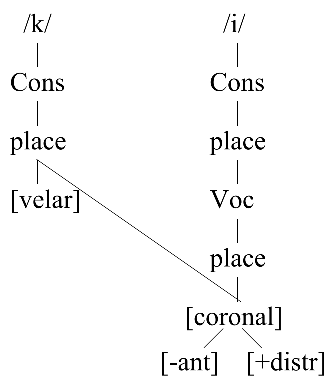
(1) (a) k → k^j (b) k → tʃ



Hume suggests that front vocoids be characterized as [coronal] and sees palatalization as a spreading process of the feature [coronal] onto a consonant. Following Clements (1976, 1990), she assumes that the [-ant] and [+distributed] features are best viewed as redundant values for vowels unlike for consonants, which can have the features [anterior] and [distributed] operating contrastively. When the feature [coronal] of a vocoid spreads to the place node of the consonant's *Vocoidal* plane, the vocoidal place feature is superimposed on the original major articulation of the consonant. Consequently, the *Vocoidal* plane is added, and the velar stop acquires the palatal off-glide [j] as shown in (1a). On the other hand, when the feature [coronal] spreads onto the place node of the *Constriction* plane, the palato-alveolar affricate [tʃ] results, replacing the consonant's original place feature by virtue of deletion as displayed in (1b).

Hume does not discuss the processes of k → c and k → tɕ, but there could be only one way left in spreading the vocoid's coronal feature; the coronal feature spreads to the *Constriction* place of the velar consonant while maintaining the primary velar feature as illustrated in (2). However, this procedure does not seem to end up with either the palatal stop /c/ or the alveo-palatal affricate /tɕ/. As long as the feature 'velar' is sustained under the *Constriction* place, either cannot be produced, because /c/ should be specified as [palatal] and /tɕ/ as [coronal] and [-ant] under the *Cons* place. Therefore, the palatalization processes from velar to palatal and to alveo-palatal consonants cannot be attributable to assimilatory spreading according to Hume's treatment of coronal spreading.

(2)



While Hume provides successful descriptive analyses of k → k^j and k → tʃ, such patterns as k → c and k → tɕ would be incorrectly derived according to the coronal spreading. In other words, all the attested patterns of velar palatalization are not satisfactorily analyzed in Hume's framework.

2.2. Ohala (1993)

In this section, I discuss Ohala's (1993) analysis of velar to palato-alveolar palatalization (k → tʃ) and its insufficiencies. Opposing to the generative formalists, Ohala examines velar palatalization on the basis of more empirically grounded phonetic factors, but he solely focuses on a single attribute to the natural assimilatory process.

Ohala ascribes the velar to palato-alveolar assimilation to a listener's confusion due to the acoustic similarities of the two consonants. In other words, listener's role and responsibility are merely considered in his analyses, and speaker's articulation is completely disregarded though articulatory mechanisms and principles play a significant role in palatalization.

Ohala discusses, specifically, the pattern of palatalization of the velar stop /k/ to the palato-alveolar affricate /tʃ/. He asserts that the change of /ki/ to /tʃi/ is motivated by perceptual similarity of the stop and affricate, given that the spectra of their bursts are very similar except for a sharp peak near 3KHz in the case of the velar stop. Furthermore, since it is more likely that listeners would miss the detail in the burst spectra than that they would spuriously imagine it in the spectrum of the /ti/, the most probable direction of confusion is from /ki/ to /ti/ rather than the reverse (p. 158).

Ohala's argument, however, does not seem to provide a straightforward explanation of the palatalization of /k/ to /tʃ/ because /tʃi/ is far more different from /ti/. Acoustically, /tʃi/ entails frication noise, and the transition frequency is much higher than in /ti/. In other words, the lack of the velar burst peak near 3KHz might not be perceptually directly associated with /tʃ/ (moreover, Ohala does not explain why a listener might miss the velar burst peak at 3KHs). In addition, Ohalas explanation might make an incorrect prediction; /t^j/ should be a more plausible output of the palatalization of /k/ because /t^ji/ is acoustically more similar to /ti/ than to /tʃi/. However, such a pattern is not attested in phonology. Therefore, a perceptual or acoustic account may not provide sufficient evidence for the palatalization of /k/ to /tʃ/.

2.3 Flemming (1995)

Flemming (1997) functionally interprets the assimilation as the enhancement of a vowel's auditorily or perceptually contrastive feature. He claims that palatalization is a consequence of enhancing the (high) front vowels auditory feature which is high F2. For example, among the outputs of the palatalization of /k/, /tʃ/ involves a greater enhancement of the vowel’s F2 contrast in the transition than do the palatal stop /c/ and the palatalized velar stop /k^j/. This is because the palato-alveolar affricate involves a stronger stridency and a longer F2 transition than the palatal stop and the palatalized velar stop do.

Flemming’s analysis, however, poses two problems. First, he does not provide a reasonable motivation for why enhancing a vowel’s feature is more important than maintaining a consonant’s feature. The enhancement of a vowel’s contrastive feature will sometimes suppress the contrastiveness of a consonant. In other words, the assimilatory neutralization of a consonant induced by a vowel should be tolerated to enhance vowel’s contrastive features. Therefore, it is not clearly discussed how and why consonant to vowel assimilation such as palatalization is more likely to occur than the reverse case.

Second, it is not satisfactorily clarified how the stridency itself is correlated with the enhancement of the vowel's high F2 feature in the change of /k/ to [tʃ]. It seems to be plausible that the output, the palatalized velar stop /k^j/, involves the perceptually enhanced F2 feature of a high front vowel in the transition such as a higher F2 frequency and longer duration. It might be true that /k^j/ is motivated in order to enhance the vowel's F2 feature for a listener. However, it does not seem to be clearly discussed that the stridency of the alveo-palatal affricate /tʃ/ is indicative of a perceptual enhancement of the high F2 feature. Supposedly, stridency is perceptually salient, but this salience does not appear to involve a perceptual association with the high F2 feature of a vowel. Moreover, the frication noise of the affricate /tʃ/ would not be part of the vowel transition; therefore, it might be misleading to say that stridency is a further enhancement of the vowel's high F2 feature.

3. Articulatory bases for velar palatalization

In this section, I argue that coarticulatory mechanisms serve as a substantial basis for the velar palatalization, attributing the pattern variety to different degrees of coarticulation between a velar stop and a palatal vocoid.[2] Based on my instrumental result that palatalization stems from phonetic coarticulation (Lee 1999), I present the details of coarticulatory processes, in which a velar consonant is distinctively modified according to the magnitude of coarticulation with the following palatal vocoid.

As generally assumed, coarticulation is a process to minimize the articulatory cost, where two target constrictions are distant enough to require much energy consumption (Browman and Goldstein 1990; Lindblom 1983; Ohala 1993; Farentani 1997 and many others). Although Lindblom does not present specific examples and articulatory details, he demonstrates his intuitive thoughts as follows:

> An assimilation—whether phonological (a historical fact or a grammatically significant pronunciation rule), or phonetic (a grammatically nonsignificant attribute of an individual utterance)-invariably implies shortened movement (glottal or supraglottal).... we see that assimilation, defined as reduced distance between two sequentially timed articulatory targets, implies less work per unit time.

What follows from his statement is that the articulatory cost may proportionally decrease as the degree of coarticulation increases. That is,

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[2] In this paper, I primarily deal with a velar stop in the discussion of the coarticulatory mechanisms, though a velar fricative is also a frequent target in velar palatalization.

the more two target gestures coarticulate, the less the articulatory energy is taken in the production of a sequence of two sounds. Furthermore, as discussed in Browman and Goldstein (1990), the magnitude of coarticulation, “gestural overlap” in their term, is different depending on languages. This is consistent with Farentani (1997) that language-specific parameters specify the dynamics of gestures and their overlap, which suggests that the different gestural set-up in phonetics may bring up a variety in the phonological patterns. Based on such empirical claims, I provide the manners, in detail, of how a velar stop coarticulates with a palatal vocoid and of how the coarticulatory configurations differ depending on the degree of coarticulation in the remainder of this section.

It is broadly assumed that consonants intrinsically differ from vowels in terms of coarticulatory strength. According to Recasens (1991), vowels are less vulnerable to coarticulation because they are produced by means of global vocal tract shapes which require articulatory control upon the entire tongue body configuration. On the other hand, consonants involve only local constrictions which leave other articulatory regions free to coarticulate. In other words, vowels involve greater coarticulatory strength, being less likely to be interfered by an adjacent consonant gesture, but consonants, entailing less coarticulation resistance, are more readily coarticulated by a vocalic gesture. We would expect a greater effect of a vowel on an adjacent consonant than the reverse.

Due to the fact that a velar consonant and a palatal vocoid share the same gesture, which is the tongue body, the velar consonant is presumably affected by the anticipation of the vocoid gesture to a significant extent.[3] Based on this assumption, I investigate the blending mechanism of the tongue body gesture and its influence on the modification of a velar stop.

It should be clarified that palatalization outputs will be phonologically categorical even if phonetic coarticulation gradually increases/decreases. That is, the gradual articulatory modification only perceptually significant to a listener can be promoted to a phonological pattern. Therefore, I do not discuss a gradual change in the degree of phonetic coarticulation in detail, but deal with its relevance to phonologically categorical outputs. As shown in Figure 1, the tongue body, more specifically the back of the tongue body, has a constriction at the back of the vocal tract (e) in the articulation of a velar stop, and the tongue body, more specifically the front of the tongue body, has a contact at the palatal region (c) in the

[3] As mentioned in Browman and Goldstein (1989) and Fowler and Salzman (1993), two gestures, when they do not share articulators, involve minimal spatial perturbation in each other's target tracking. For example, when a vowel and a labial consonant coarticulate, although the lip gesture of the labial consonant is temporally completely anticipated by the tongue body gesture of the vowel, the lip constriction will not be interfered because they do not have the competing articulatory demand. On the contrary, when two gestures share the same articulator, for instance, a velar consonant and a vowel, they are significantly blended, resulting in a gestural conflict.

articulation of a palatal vocoid. When a minimal degree of coarticulation is involved between the velar stop and a palatal vocoid, the back constriction of the velar stop is not satisfactorily achieved due to its gestural conflict with the palatal vocoid. The velar constriction is perturbed by the palatal constriction of the front tongue body, resulting in an attraction toward the hard palate. Consequently, the tongue body moves forward and, the modified constriction will be made at the region of (d), producing [k^j] with a slightly extended laminal contact. This is also instrumentally evidenced by Heffner (1950), Ladefoged (1975), and Keating (1993).

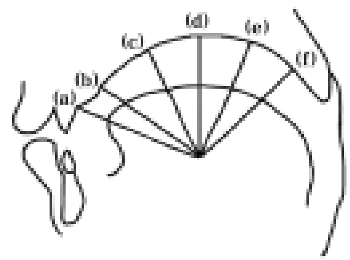

Figure 1 Schematic display of articulatory points along the vocal tract: (a) alveolar, (b) palato-alveolar, (c) alveo-palatal, (d) palatal, (e) palatalized velar, and (f) velar.

What happens if the degree of coarticulation between a velar stop and a palatal vocoid is greater than in the case of [k^j]? The tongue body constriction at the back will be more significantly interfered by the palatal constriction because of a stronger gestural blending. The front tongue of the palatal vocoid attracts the velar constriction much closer to the hard palate than in [k^j], and phonologically, this complicated place of articulation develops to a categorical segment which is the palatal stop [c]. Gradual increases in the degree of coarticulation can possibly produce more phonetic scales between the velar and palatal constrictions, but as mentioned before, I assume that the gradual details induced by speaker's articulation may be categorically perceived by a listener.

The attested phonological outputs of velar palatalization, [k^j] and [c], can be readily explained in terms of varying degrees of coarticulation. In languages where a velar stop is palatalized to [k^j], the degree of coarticulation is not as extended as in languages where a velar stop changes to [c].[4] This is consistent with Browman and Goldstein (1990) and Farentani (1997). Here, let's consider what Farentani claims as follows:

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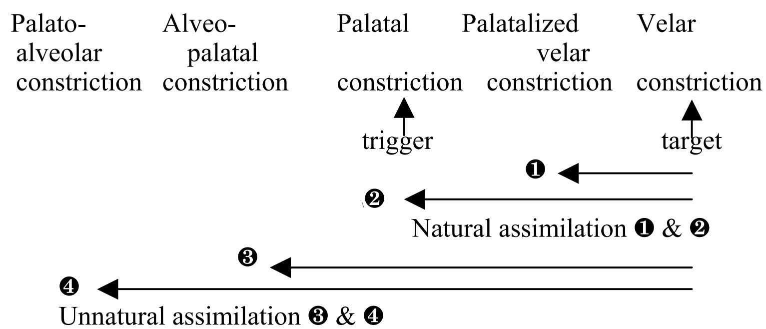
[4] To the best of my knowledge, there is no attested language in which a velar stop is *phonologically* palatalized to both the palatalized velar stop [k^j] and the palatal stop [c] in the same, phonological or morphological, environment within a language.

> Language may differ in degree of coarticulation in relation to their inventories, but these differences are consequences of the different gestural set-up, i.e., the parameters that specify the dynamics of gestures and their overlap, which are learned by speakers of different languages during speech development (p. 396).

That is, individual language may have its own distinctive degree of coarticulation in consonant and vowel sequences, giving rise to the various outputs of palatalization cross-linguistically.

4. Perceptual factors in velar palatalization

Recall that a velar stop involves more palatalization outputs which have not been dealt with: *k → tɕ* and *k → tʃ*. The coronal outputs, however, do not appear to be articulatorily natural. In the linear illustration of the oral articulation points of Figure 1 in (3), the velar stop should not be able to move forward, beyond the place where the coarticulation attractor is articulated, to the coronal area because the palatal vocoid is merely produced at the palatal region. That is, the palatal attractor does not seem to be a sufficient condition to cause the coarticulation of a velar to the coronal place. In other words, assimilation processes ❶ and ❷, in which the velar target constriction changes close to and merely up to the palatal trigger constriction, seem to be coarticulatorily natural and have been explained in terms of varying degrees of coarticulation in the previous section. On the other hand, assimilation processes ❸ and ❹, in which the target constriction moves forward beyond the trigger constriction, seem to be coarticulatorily and physically unnatural if all conditions being equal.

(3)


As mentioned in section 3, an extensive degree of coarticulation gives rise to a considerable modification of the velar constriction to the palate, manifesting the palatal stop [c]. Here consider the articulation of [c] in detail. Keating (1988) describes that the palatal constriction is made at the highest region along the vocal tract; therefore, the palatal contact of [c] is very extensive, covering the whole palatal region. Therefore, the tongue body, especially the front part of the tongue body, might exert a most articulatory effort to reach the long and high palatal contact. If the effort is presumably defined with respect to the articulatory distance to the contact and its extent. As shown in Figure 2, the palatal stop involves a longer movement up to the hard palate and a relatively more extensive contact, utilizing the front tongue body.

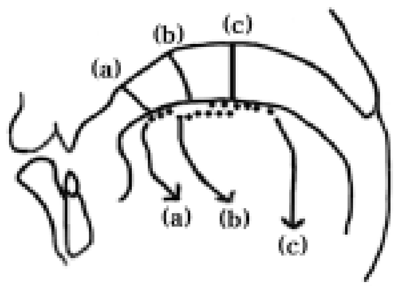


Figure 2. Schematic display of articulatory effort for the palato-alveolar affricate (a & a'), the alveo-palatal affricate (b & b'), and the palatal stop (c & c'). The thick lines indicate the articulatory distance to the target constriction and the number of dots indicates the extent of the contact.

Given that coarticulation is a natural process to decrease articulatory efforts (Lindblom 1983), the articulatory economy induced by coarticulation might be cancelled out by the effortful articulation of the palatal stop. Therefore, the output [c], though a natural output of coarticulation, might be plausibly avoided to decrease articulatory effort. In this process, the palatal stop [c] could be replaced with a consonant which is less effortfully articulated but perceptually similar to [c]. In this way, the contrastive features of [c] are minimally deteriorated, and a communication can be still effectively achieved. Both the palato-alveolar affricate [tʃ] and the alveo-palatal affricate [tç] are perceptually very similar to the palatal stop [c] because both entail palatal frication.[5] However, it is my contention that [tʃ] is preferred because its constriction is simply made with the tongue blade whereas [tç] requires almost the same articulatory efforts as [c]. As Keating (1988) points out, the alveo-palatal consonants are basically produced in the same manner as the palatal in that the alveo-palatal affricate [tç] is articulated with the back part of the blade and the front tongue body and that the front tongue body is more extensively involved in the articulation of the palatal stop [c]. As shown in Figure 2, the alveo-palatal affricate [tç] involves almost the same extent of

[5] The palatal stop [c] is slightly affricated due to the constriction made with the front of the tongue body (Ladefoged 1975).

the contact as the palatal stop although the articulatory distance up to the constriction seems to be somewhat shorter. In real, the palatal stop [c] and the alveo-palatal affricate [tɕ] are relatively limited in prevalence, as shown in the Appendix. They are significantly outnumbered by the palato-alveolar affricate [tʃ] in the patterns of velar palatalization, and this asymmetry can be readily explained in terms of the articulatory principle of speech production: articulatory economy.

I claim, then, that the palatalization changes of *k* → *tɕ* and *k* → *tʃ* necessarily arise from coarticulation prior to a perceptual factor playing its significant role. Although such outputs emerge due to their acoustic/ perceptual similarities to the palatal stop [c], they also considerably decrease the articulatory cost which would be otherwise maximally required because of the extreme articulation of [c]. Therefore, I contend that both articulatory and perceptual principles govern the palatalization patterns of *k* → *tɕ* and *k* → *tʃ*.

5. Conclusion

Various patterns of velar palatalization are appropriately characterized in terms of different degrees of coarticulation, and moreover, a listener's perceptual factor also plays a prominent role in determining some patterns. This suggests that phonological patterns and processes can be satisfactorily understood on the basis of substantive phonetic nature. Both speech production and perception may be significant contributes to phonological patterning.

Appendix

Examples and languages in velar palatalization

Pattern	Languages	Examples
$k \rightarrow k^j$	Bulgarian (Foley, 1973)	vipusk[k^j]i (before front vowels)
	Cheyenne (Davis, 1962)	wohk[k^j]eso 'fox' (cf, hahk[k]ot 'grass hopper')
	Chiricahua Apache (Hoijer, 1946)	diʃg[g^j]is 'I am lazy', dig[g^j]e 'he swoops down' (cf, g[g]o 'snake', g[g]ah 'rabbit', si-k[kx^j]e 'my shoes' k[kx]a 'disease'
	Greek (Foley, 1973)	k[k^j]ino
	Icelandic (Gussman, 1986)	ekk[k^j]i 'not' g[g^j]ifta 'to marry]', g[g^j]egen 'against'
	Kirundi (Swift, 1965)	gukh[kx^j]enera 'to need'
	Polish (Rubach, 1981)	k[k^j]ino 'cinema', bɨok[k^j] # jest 'the clouds is'

	Proto-Algonquian (Kaye, 1978)	reported, but no examples.
	Proto-Athapaskan (Cook, 1978)	reported, but no examples.
	Russian (Jones & Ward, 1969)	g[g]ot ‘year,’ g[g]udok ‘hooter’ vs. nʌg[g^j]I ‘foot,’ g[g^j]eni ‘genius,’ x[x]atə ‘hut’ vs. x[x^j]er^{j}is
	Tupi-Gruarani (Firestone, 1965)	g[g^j]ira ‘eagle’, seag[g^j]irv ‘whose hat’
	Turkish (Underhill, 1986)	k[k^j]ere ‘time (cf. k[k]ara ‘black’)
k→c	Akan (Boadi, 1988)	k[c]im ‘ideophone’ (cf., k[k]um), g[ɟ]i ‘receive’ (more fricated palatal stops [cç] and [ɟʑ])
	Kinyarwanda (Kimenye, 1979)	a-rek-e [arece] ‘he should stop’, a-rog-e [aroɟe] ‘he should poison’, ku-kaang-iisa [gukaaŋɟiisa] ‘to frighten with’
	Lamba (Doke, 1938; Kenstowicz & Kisseberth 1979)	fuk+ika [fucika] ‘creep (pass.)’, (cf., fuk+a [fuka] ‘creep (past)’), kak+ika [kacika] ‘tie (pass)’, (cf., kak+a [kaka] ‘tie (past)’)
	Margi (Hoffman, 1963)	tək+ia [təcia/təca] ‘to measure’ (from təku ‘to measure’) ntək+ia [ntəcia/ntəca] ‘to divide’ (from ‘ntəku ‘to divide’)
	Modern Icelandic (Arnason, 1978)	kemur [cɛ:myr] ‘comes (cf., koma [kɔ:ma] ‘come’), geta [ɟɛ:ta] ‘be able to’ (cf., gat [ga:t] ‘could’)
	Ogoni (Brosnahan, 1964)	reported, but no examples.
k→tʃ	Acadian French (Lucci 1972; Flikeid 1988)	[ki] ~ [tʃi] ‘who’, [ke] ~ [tʃe] ‘quay’, [gɛte] ~ [dʒɛte] ‘to watch for’
	Italian (Maiden 1995)	*kena > tʃena ‘dinner’, *kiŋkwe > tʃiŋkwe ‘five’, di:k+i [ditʃi] ‘you say’, lɛgg+e [lɛddʒe] ‘he reads’.
	Kannada (Murthy, 1984)	kivi > tʃivi ‘ear’ vs. kaalu >

		kaalu ‘leg’
	Kirundi (Broselow & Niyondaraga, 1990)	iki+eera [i tʃeera] ‘white ones’, iki+oobo [i tʃoobo] ‘pit’, (cf., iki+raato [ikiraato] ‘shoe’
	Polish (Rubach, 1981)	drobjazg+ek [drobjaʒdʒek] ‘detail (dim.)’, mjazg+i+tɕ [mjaʒdʒitɕ] ‘squash’
	Rumanian (Ruhlen, 1972)	fak+i [fatʃ] ‘you do’, fak+e [fatʃe] ‘he does’, merg+i [merdʒ] ‘you go’, merg+e [merdʒe] ‘he goes’
	Russian (Hamilton, 1980)	plak+j+u [platʃu] (cf., plak+atj [plakatj]), dorog+je [dorodʒe] (cf., dorog+oj [dorogoj]).
	Slovak (Rubach, 1993)	tʃlovek+ik [tʃlovetʃik] ‘man (dim.)’, strig+i [stridʒi] ‘witch (adj.)’
	Qizil Qujas (Wurm, 1947)	k[tʃ]eldim ‘I came’
	Vote (Collinder, 1957)	kjaappa > tʃaappa ‘burial mound’
k→tɕ	Chinese (Chen, 1972)	kiai > tɕ ‘to continue,’ giau > tɕiau ‘palanquin’

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Byuksan Apt. #108-606
Shiheung2-Dong, Keumcheon-Gu
Seoul, 153-032, Korea
Jookyeong@hotmail.com