Gestural Motor Programs and the Nature of Phonotactic Restrictions: Evidence from Loanword Phonology

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1. Introduction – differential repair of loanwords

Languages are known to make an important distinction with respect to the ways in which they treat words borrowed from other languages, or loanwords. Differential repair of loanwords allows us to segregate phonotactic restrictions in a given language into two classes:

(1) A phonotactic restriction is violated in loanwords.

(2) A phonotactic restriction is upheld in loanwords.[1]

This paper addresses the following questions: Is there anything systematic about the distinction between restrictions falling into classes (1) and (2), and if so, how can we explain it?

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1. Much of the literature on loanword phenomena (e.g., Hyman 1970; Holden 1972; Danesi 1985 among many others) focuses on type (2) as an important language-specific issue. However, from a more global point of view, the distinction between classes (1) and (2) becomes more interesting. Recent work exploring theoretical mechanisms recognizing this distinction includes, among others, Ito and Mester (1994; 1995), and Fukazawa, Kitahara, and Ota (1998).

 WCCFL 22 Proceedings, ed. M. Tsujimura and G. Garding, pp. 505-518. Somerville, MA: Cascadilla Press.

2. Initial data and an approach to explaining the split

As a brief introduction to the kind of data we are interested in, consider the following contrasting sets of data in (3) and (4).

(3) Final devoicing tends to be enforced in loans (German and Turkish)

Source pronunciation	*German loanword*	*Gloss*
[hɑt dɔg]	[hɑt dɔk]	'hot dog'
[hɑliwʊd]	[hɑliwʊt]	'Hollywood'
[daʊnloʊd]	[daʊnlot]	'download'
[klʌb]	[klɑp]	'club'
[kɑɹd]	[kɑːt]	'card'

Source pronunciation	*Turkish loanword*	*Gloss*
[stɑd]	[sɯtɑt]	'stadium'
[kyb]	[kyp]	'cube'
[tyb]	[typ]	'tube'
[bɹɪd͡ʒ]	[biɹɪt͡ʃ]	'bridge (the card game)'

(4) Vowel harmony can often be violated in loans (Turkish and Koromfe[2])

Source pronunciation	*Turkish loanword*	*Violation*	*Gloss*
[ɑktɥɛl]	[ɑktyɛl]	Back	'current'
[klinik]	[kɯlinik]	Back	'clinic'
[kɑ̃piŋ]	[kɑmpiŋ]	Back	'camping place'
[beɪsbɑl]	[besbol]	Back	'baseball'
[komik]	[komik]	Back	'comical'
[limon]	[limon]	Back	'lemon'
[ʒyre]	[ʒyri]	Round	'jury'
[ynite]	[ynite]	Round	'unity'
[zigurat]	[zigurat]	Round/Back	'ziggurat'

2. Koromfe is a Niger-Congo language in the Gur family which exhibits obligatory ATR harmony within native roots (Rennison 1997). Koromfe is spoken in northern Burkina Faso. All data cited are from Rennison (1997, p.c.). [+ATR] vowels are underlined.

Source pronunciation	*Koromfe loanword*	*Violation*	*Gloss*
[ʁɑdjo]	[ragjo̲:]	ATR	'radio'
(Arabic, uncertain)	[ajawo̲o̲di̲]	ATR	'good lord!'
[tomɑt]	[to̲mattɛ]	ATR	'tomato'
[ʒønɔm]	[ze̲nɔm]	ATR	'young man'
[butik]	[bu̲ti̲ki]	Round	'boutique'
[velo]	[ve̲lo̲]	Round	'bicycle'
[ʁejɔ̃]	[rɪjɔ̃]	Round	'spoke of wheel'

The impressionistic trend evident from these and other data is that the larger the distance over which a phonotactic restriction applies, the more likely it is to be violable in loans. Our proposal is that a more deeply explanatory account of this distinction can be found in the higher-order organization of speech gestures.

3. Motor programs and articulatory gestural molecules

Research on the execution of complex motor sequences suggests that with repetition, a motor sequence becomes consolidated into a motor program characterized by higher-level organization of the component gestures, resulting in more accurate and rapid subsequent execution (Wolpert et al. 1995; Shadmehr and Holcomb 1997; Willingham 1998).

Likewise in articulation, practiced sequences of atomic gestural units have been shown cohere in what have been termed *gestural molecules*. (Browman and Goldstein 1986; 1989 et seq.; Byrd and Saltzman 2002; Byrd 2003; inter alia). Consistent with this finding, the execution of articulatory gestural sequences has been shown to become more efficient with practice, indicative of development of higher-order organization (Sparrow and Newell 1998).

Motor theory therefore makes several predictions concerning the acquisition and subsequent deployment of speech gestures. First, during acquisition, all groupings of consistently correlated/overlapped gestures will tend to become organized into gestural molecules, i.e., motor programs. Second, speakers will subsequently assemble utterances from practiced gestural molecules, not from their component gestural atoms (Browman and Goldstein 1988; 1989; Levelt 1993; Levelt and Wheeldon 1994; Byrd 1996a).

These predictions have the following implication that will be seen to bear on the issue of differential loanword repair. While there is no principled upper bound on the size of individual gestural molecules acquired by a speaker, there are lower bounds defined by the minimal set of gestural groupings required to reproduce surface forms in the target language (Ussishkin and Wedel 2003). Sequences of overlapping gestures that are not required for reproduction of the target language will not be

represented in gestural molecules acquired by a speaker of that language. Additionally, a novel utterance will be more difficult the more novel the atomic gestures required, and/or the more novel the organization of pre-existing atomic gestures. Based on this, we hypothesize that under the assumption that utterances are preferentially assembled from practiced gestural molecules, violation of a phonotactic restriction in novel forms is likely only when other legal utterances in the borrowing language provide gestural molecules enabling that violation.

This can be illustrated with several examples from English. To begin, in English, [ŋ] never surfaces without preceding vocalic gestures. Therefore, English speakers acquire gestural molecules including e.g., laryngeal gestures overlapping following [ŋ] gestures, but no gestural molecules that are initiated with [ŋ] gestures alone.[3] English speakers do not readily reproduce utterances beginning with [.ŋ-] when prompted by acoustic example or orthography, as for example in pronunciations of the Vietnamese surname 'Nguyen' [ŋwɛn], variously pronounced by English speakers as [nəgujən] or [nujɛn].

A second example concerns a different type of restriction, in this case involving a word-bounded domain. English contains no words of the form [sC_1VC_2], where C_1 and C_2 are homorganic non-coronal consonants (Davis 1990, cited in Byrd 1996b:236). However, gestures for tautosyllabic onset and coda sequences are not consistently coupled in English (Browman and Goldstein 1988; Byrd 1995), indicating that they can correspond to independent gestural molecules. In this case, an English speaker should be able to assemble any [sC_1VC_2] sequence using existing [.sC_1-] and [-C_2.] gestural molecules. Indeed, English speakers can readily produce violating forms such as [smɪp], [skʌg], etc., and have accepted the historically recent form [spæm].

Although both restrictions (*[.ŋ] on the one hand vs. *[sC_1VC_2] on the other) have the theoretical status of morpheme structure constraints, current theory provides no explanation for the discrepancy in their violability. In contrast, research on gestural phasing in conjunction with distributional considerations allows us to make predictions about the kinds of gestural molecules used to produce English speech. Reference to these predicted gestural molecules in English can explain why speakers readily violate *[sC_1VC_2] but not *[.ŋ].

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3. A more articulated model of an utterance-initial gestural molecule would include non-tract π gestures (variables related to control of timing; Byrd and Saltzman 2003). Accordingly, we might say that English speakers lack gestural molecules initiated by [ŋ] phased with the relevant non-tract variables (D. Byrd p.c.).

4. The range of patterns in loanword adaptation

Before beginning, several structuring assumptions will be made explicit. First, studies of gestural organization in English indicate that the gestures of VCCV sequences are organized (coupled) distinctly when the consonants are syllabified as onset, coda or heterosyllabic sequences (Browman and Goldstein 1988; Byrd 1995; 1996b; Turk and Shattuck-Hufnagel 2000). In contrast, there is no evidence that VC.CV sequences are distinct from VC#CV sequences with respect to timing/pairing of component gestures (Turk and Shattuck-Hufnagel 2000; Dani Byrd p.c.). We take this as evidence that onset, coda and heterosyllabic CC sequences are produced by distinct (sets of) gestural molecules in English. In contrast, heterosyllabic CC sequences, whether or not in the same word (i.e., [C.C] vs. [C.#C]), may not require distinct gestural molecules for their production. In this paper, we will be making the initial assumption that these properties hold in other languages as well.

In the next section, we present a series of case studies of loan repair driven by a range of phonotactic restrictions classes, arranged for expositional purposes on an informal scale of decreasing 'locality.' Our purpose will be to show that indeed, there appears to be some correlation between the size of the domain over which a restriction applies and its likelihood of violation in loans; however, we will go on to show that this correlation can be grounded through reference to the probable inventory of gestural molecules available to speakers of the borrowing language.

4.1. Outright inventory restrictions

Outright inventory restrictions – that is, a borrowing language borrowing a loanword containing a segment that does not exist in the borrowing language – tend to be enforced in loanwords. Such examples are widespread throughout the literature; some of these include no interdentals in French, German, no [ʃ] in Puluwat (Elbert 1970), and no pharyngeals in English. These restrictions have important consequences for the inventory of gestural molecules available in a borrowing language. If a unique segment corresponds to a unique gestural score, the absence of that segment in a language's inventory necessarily results in the absence of a gestural molecule reproducing that segment. Under this view, the lack of faithfulness in loanwords that violate inventory restrictions is straightforwardly explained through a speaker's lack of a corresponding gestural molecule. In fact, this issue has fueled much research in loanword phonology adaptation patterns, with much attention paid to determining how to assess the "closest native sound" or "phonetic approximation" (e.g., Stene 1940; Holden 1972; Hyman 1970; Danesi 1985; Paradis 1996; Steriade 2001). Non-native sounds are of course occasionally preserved in

loan vocabulary, which, under this view, would require the acquisition of a novel gestural molecule. We will not discuss this issue further here, except to note that for adult speakers, some novel gestural molecules should be easier to acquire than others, depending in part on whether they require learning of a new component gestural atom, or can be constructed by rearrangements of pre-existing gestural scores. For example, we might expect that acquisition of a word-initial [ʒ] might be easier for a native English speaker than a pharyngeal, even abstracting away from some measure of absolute difficulty, because the native English speaker already possesses the molecule for medial-onset [ʒ], as well as word-initial [ʃ], which differs from word-initial [ʒ] only in voicing. In contrast a native English speaker cannot produce a pharyngeal through recombination of existing gestural scores.

4.2. Positional restrictions on single segments

Like inventory restrictions, positional restrictions on single segments also tend to be upheld in loanwords. An example that falls into this category is one we've already examined: the lack of onset [ŋ] in English. In loanwords, onset [ŋ] tends to be resolved by epenthesis or substitution. The examples involving German and Turkish final devoicing seen in (3) fall into this category as well. Another example comes from Tongan, which has no coda consonants. In loanwords, codas are resolved via epenthesis (Schütz 1970) as seen in the following data:

(5) Tongan resolves loanword codas via epenthesis

Source pronunciation	*Tongan loanword*	*Gloss*
[kɑːd]	[kɑːti]	'card'
[tuzdeɪ]	[tuːsite]	'Tuesday'
[mæp]	[mɑpe]	'map'

Single segment positional restrictions have important consequences for the inventory of gestural molecules available in a borrowing language. There are two lines of evidence suggesting that the syllable affiliation of a given segment affects its internal gestural organization and gestural environment.

The first of these concerns the presence of intersegmental transitions. An onset is necessarily followed by some overlapping gesture(s), while a coda is necessarily preceded by some overlapping gesture(s). Therefore, the gestures associated with a given segment in utterance-initial onset position differ from those associated with the same segment in utterance-final coda position (e.g., Browman and Goldstein 1988; 1989).

The second concerns the relative phasing of intrasegmental gestures. Browman and Goldstein (1988 et seq.; see also Byrd 1995; 1996b) have shown that the gestures for a segment in onset versus coda position are distinctly timed with respect to each other and surrounding vowels, suggesting that syllable position not only influences a segment's external gestural context, but also affects that segment's internal gestural organization.

In general then, [.C-] ("a consonant in onset position") is likely to correspond to a distinct set of gestural molecules relative to [-C.] ("the same consonant in coda position"). As a consequence, production of a segment in onset position when it only natively occurs in coda position would require on-the-fly articulation of a novel gestural grouping.

As a consequence, while a particular [.C-] and its [-C.] counterpart may have a unitary identity at some phonological level, this work supports the view that they differ at some level of gestural organization and inventory.

The next case to be considered involves loanwords that contain adjacent consonants.

4.3. Syllable margin cluster restrictions

As in the previous two cases, syllable margin cluster restrictions tend to be upheld in loans. A first example comes from Puluwat, in which loanwords with complex onsets are borrowed with epenthesis between the consonants:

(6) Puluwat resolves complex onsets via epenthesis (Elbert 1970)

Source pronunciation	*Puluwat loanword*	*Gloss*
[pleɪ]	[peleej]	'play'
[glæs]	[kilɑs]	'glass'
[flæg]	[filajik]	'flag'
[bɹæs]	[biræs]	'brass'
[stoʊv]	[sitof]	'stove'

A similar case exists in Turkish:

(7) Turkish resolves complex onsets via epenthesis

Source pronunciation	*Turkish loanword*	*Gloss*
[tʁɛ̃]	[tiren]	'train'
[gɹup]	[gurup]	'group'
[spɔʁ]	[sʊpor]	'sport, sports'

The consequences of these syllable margin cluster restrictions on the inventory of gestural molecules are as follows. CC sequences exist independently in Puluwat across word boundaries, as word final codas are tolerated. Likewise, CC sequences exist independently in Turkish, for example, across syllable and word boundaries (e.g., [.tit.re.mek.] 'to tremble'). The appropriate question to ask, then, is whether gestural molecules corresponding to these heterosyllabic sequences could be pressed into service for the production of onset clusters.

As in the previous cases, evidence suggests that the relative timing and overlap of heterosyllabic consonant sequences are distinct from those of either onset- or coda-consonant sequences (Browman and Goldstein 1988; Byrd 1996b). Further, given that a gestural molecule corresponding to a consonant includes the transition (or lack thereof) into neighboring segments, [.CC-] and [-CC.] sequences require unique gestural scores relative to [-C.C-]. Generally then, the existence of $[V_1C_2.C_3V_4]$ sequences in a language may not imply that $[\#C_2C_3V_4]$ or $[V_1C_2C_3\#]$ sequences are likely to surface without modification in loanwords.

4.4. Heterosyllabic consonant sequence restrictions

In contrast to inventory and intrasyllabic positional restrictions (sections 4.1 – 4.3), restrictions that span a syllable boundary are more often violated in loans. For instance, although no morpheme-internal consonant sequences are found in Puluwat, loanwords tolerate such sequences (Elbert 1970) as seen below:

(8) Puluwat loanwords tolerate medial consonant sequences

Source pronunciation	*Puluwat loanword*	*Gloss*
[kæpsaɪz]	[kɑpsɑjis]	'capsize'
[əɹɪθmətɪk]	[jɑritmetik]	'arithmetic'
[wɑʃbeɪsən]	[wɑspesin]	'wash basin'
[pɹɑtəstənt]	[porostɑn]	'Protestant'
[kæləndəˑ]	[kilɑnder]	'calendar'
[kaʊnsəl]	[konsel]	'council'
[ælfəbɛt]	[jelfɑbet]	'alphabet'

As evident from this interesting behavior, heterosyllabic consonant sequence restrictions have intriguing consequences on the inventory of gestural molecules. Although Puluwat does not permit morpheme-internal consonant sequences, because word-final codas are permitted, [-C.#C-] sequences do exist. In contrast to the cases detailed above for inventory

restrictions, positional restrictions, and syllable margin cluster restrictions, timing differences between syllable- and word-edges have not been found, at least for English (Turk and Shattuck-Hufnagel 2000), suggesting that they may be mutually substitutable. If gestural molecules corresponding to [-C_1.#C_2-] sequences are sufficiently similar to those required for production of [-C_1.C_2-] sequences, the existence of [-C_1.#C_2-] sequences should allow [-C_1.C_2-] sequences to surface without modification in loanwords.

For an interesting contrast, reconsider the case of Tongan. Tongan is similar to Puluwat, but in addition disallows morpheme-final codas, with the result that there are no [CC] sequences of any sort in surface utterances. In Tongan, no medial CC clusters are tolerated in loanwords (data from Schütz 1970).

(9) Tongan loanwords do not tolerate medial consonant sequences

Source pronunciation	*Tongan loanword*	*Gloss*
[plæstɪk]	[pɑlɑsitiki]	'plastic'
[blækbɔɹd]	[pelekipoːti]	'blackboard'
[kæktəs]	[kɑkɑtisi]	'cactus'
[bɑlsəm]	[polosomo]	'balsam'

The violability of the proscription against morpheme internal CC clusters is correlated with the existence of surface [C.#C] sequences, consistent with the argument that such surface sequences result in acquisition of gestural molecules for coda sequences in general.

4.5. Restrictions across intervening segments

Turning now to the final cases, the following data illustrate that restrictions that hold across intervening segments are more often violated in loanwords. Turkish and Koromfe vowel harmony systems, for instance, are not enforced in loanwords as seen in (4) above. Another restriction that holds across intervening segments is the Obligatory Contour Principle (OCP) on consonant cooccurrence restrictions, which in Arabic prohibits identical first and second consonants within a root. This OCP restriction is violated by loanwords:

(10) Arabic loanwords violate the OCP

Source pronunciation	*Arabic loanword*	*Gloss*
[sɪstəm]	[sistɛm]	'system'

Similarly, OCP restrictions in Javanese, which prohibit homorganic first and second consonants within a root (Uhlenbeck 1949; Mester 1986), may be violated in loanwords[4] as seen below:

(11) Javanese loanwords violate the OCP against homorganic C1 and C2

Source pronunciation	*Javanese loanword*	*Gloss*
[penənmɛs]	[pemes]	'pen-knife'
[vɑpən]	[bɑpəm]	'weapon'
[bʏfet]	[bipet]	'buffet'
[tonel]	[tonil]	'stage'
[təny]	[tənen]	'clothes, uniform'
[wɑpɑt]	[wɑpɑt]	'pass away'
[dinɑr]	[dinɑr]	'gold coin'
[d͡ʒɑsɑd]	[d͡ʒɑsɑd]	'body'
[d͡ʒisim]	[d͡ʒisim]	'corpse
[mɑsd͡ʒid]	[səd͡ʒid]	'mosque'

A distinct prohibition against identical C2 and C3 within a root in Javanese is also violated in loanwords:

(12) Javanese loanwords violate the OCP against identical C2 and C3

Source pronunciation	*Javanese loanword*	*Gloss*
[sʌʊsɛɪs]	[sosis]	'sausage'
[stɑːt]	[sətɑt]	'state'
[stoːt]	[sətut]	'push'
[təny]	[tənen]	'clothes, uniform'
[kisɑs]	[kisɑs]	'death'
[nusus]	[nusus]	'tensed up'
[wɑsis]	[wɑsis]	'comfortable'
[kɑnɑn]	[kɑnɑn]	'right'
[tənun]	[tənun]	'to weave'
[gɑmɑm]	[gɑmɑm]	'to feel unsure'

The consequences of these restrictions across intervening segments on the inventory of gestural molecules are quite different from the first three cases examined, though they resemble those for the most recent case. Cross-segment restrictions are domain-bounded, resulting in surface

4. These loanwords come from a variety of sources: Dutch, Arabic, and Malay.

'violations' of such restrictions across adjacent domains. In Turkish, vowel harmony is word bounded, such that a [-back]-harmonic word may be followed by a [+back]-harmonic word and vice versa (e.g., [ekmek#pɑrɑsɯ] 'bread money, daily monetary allowance'). Likewise, rounding harmony is word-bounded, as for example in the compound [ip+ud͡ʒu] 'string-end, clue' (where '+' represents a morpheme boundary). In Arabic, a prefixal consonant may be identical to a stem-initial consonant ([mu-maassa] 'contact,' [ma-msuus] 'touched, insane'). In Javanese, multimorphemic words reveal that consonantal restrictions are root-bounded; C1 and C2 may be homorganic if C1 is prefixal ([pɑmɑn] (=/pɑ-ɑmɑ-ɑn/) 'younger brother of mother or father'); likewise, C2 and C3 may be identical if C3 is a suffix ([pɑnen] (=/pɑ-əni-ɑn/) 'harvest').

The fact that in Turkish, [V_1-V_2] sequences violating vowel harmony surface without modification in loanwords suggests that gestural molecules corresponding to disharmonic [V_1-#-V_2] sequences may be identical, or sufficiently similar to those required for production of disharmonic [V_1-V_2] sequences, allowing native speakers to accurately reproduce disharmonic sequences without adding to their palette of gestural molecules. Likewise, the violation of the OCP in loans in Arabic and Javanese suggests that gestural molecules corresponding to 'OCP-violating' [C_iV+C_i-] sequences may be similar to those corresponding to OCP-violating [C_iV.C_i-] sequences (where '+' represents a morpheme boundary).

5. Conclusion: Gestural organization and adaptation patterns

Loanword adaptation patterns provide support for the proposal that availability of corresponding gestural molecules influences the violability of phonotactic restrictions. The data presented here support the long-standing impressionistic observation that 'short-range' phonotactic restrictions are cross-linguistically more likely to be upheld in potentially violating loanwords than 'longer range' restrictions. However, this line of research takes the position that rather than locality *per se*, the factor responsible for this general pattern is the influence of a phonotactic restriction on the range of gestural molecules extant in the borrowing language. The larger the span over which a restriction applies, the more likely it is that the sequence within the span may potentially be assembled from multiple independently practiced gestural molecules. The smaller the domain over which a restriction applies, the more likely it is that this restriction will result in a gap in the inventory of independently practiced gestural molecules, requiring the speaker to construct a novel gestural score on the fly if he or she attempts to violate the restriction.

Therefore, phonotactic restrictions that limit *combinations* of gestural molecules are more easily violated than those that limit the *content* of gestural molecules. Because the range of gestural molecules in a language

depends on the total set of surface patterns, whether a given restriction falls into one or the other class will depend on the interplay of all restrictions exhibited by a language.

These results have interesting implications for language change as well. The proposal that speech is assembled from practiced gestural molecules rather than atomic gestural units suggests that on the one hand, the deformation of one molecule into another existing molecule may constitute a common pathway for phonological change. Blevins (2003) has recently shown that the diachronic development of syncope alternations appears to be limited to languages that already possess codas in other contexts. On the other hand, exceptions to phonotactic restrictions in native vocabulary are likely to exist only when violation does not require the existence of an exceptional gestural molecule. Under the approach advocated in this paper, German and Turkish lack gestural molecules for final, voiced stops. Consistent with this absence, there are no exceptional words in German or Turkish that surface with coda-voiced stops among monolinguals. In contrast, restrictions spanning multiple segments are less likely to result in gaps in the inventory of acquired gestural molecules. Consistent with this presence, there are often exceptions to vowel-harmony and OCP restrictions in native vocabularies, especially in high-frequency words.

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