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A prosodic account of consonant gemination in Japanese loanwords

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1 Introduction

The distribution of geminate consonants in Japanese loanwords is notoriously complex. On the one hand, there are intrinsic factors. Some consonants, in particular obstruents (called *sokuon* when geminated), are more prone to gemination than sonorants. Segmental features lead to further distinctions: Voiceless obstruents geminate more easily than voiced obstruents (1a), and some types of fricatives geminate more easily than others (1b) (dots indicate syllable boundaries, with initial and final syllable boundaries usually not marked, and an accent mark after a vowel indicates that it is accented).

(1) Segmental factors

a. Voicing type: voiceless vs. voiced obstruents

	Gemination		No Gemination
cap	kya'p.pu	*cab*	kya'.bu
lock	ro'k.ku	*log*	ro'.gu

b. Fricative type: [ʃ] vs. [s], [x] vs. [f]

	Gemination		No Gemination
bush	bu'ʃ.ʃu	*bus*	ba'.su
Bach	ba'h.ha	*puff*	pa'.fu

On the other hand, one and the same consonant is more likely to geminate in some phonological contexts than in others (2).

(2) Positional factors

		Gemination		No Gemination
p	*cap*	kya'p.pu	*captain*	kya'.pu.ten
p	*apple*	a'p.pu.ru	*chapel*	t͡ʃa'.pe.ru
p	*happy*	ha'p.pii	*happiness*	ha'.pi.ne.su
t	*market*	ma'a.ket.to	*marketing*	ma'a.ke.tin.gu
k	*pack*	pa'k.ku	*park*	pa'a.ku
k	*tax*	ta'k.ku.su	*tact*	ta'.ku.to
g	*frog*	fu.ro'g.gu	*log*	ro'.gu
s	*listen*	ri's.sun	*listener*	ri'.su.naa
s	*message*	me's.see.d͡ʒi	*mess*	me'.su

This paper discusses how the distribution of geminates as opposed to singletons (e.g., /pp/, /dd/, /mm/ vs. /p/, /d/, /m/) is determined in loanword adaptations in Japanese, a language whose native system employs consonant length contrastively. We propose an output-oriented analysis to account for both new and previously-established generalizations in the framework of Optimality Theory (OT, Prince and Smolensky 1993) and demonstrate that consonant gemination in Japanese loanwords is caused by two different factors, one of them involving prosodic faithfulness, the other prosodic markedness. Analyses that champion only one of these, as we will show, remain incomplete.

First, prosodic faithfulness to the source word is involved when gemination is a way of preserving word-final codahood, or moraicity, in the English source words (see Lovins 1975; there is a significant literature in recent decades, we will return to details later).

The second factor is prosodic markedness. Significant higher-level prosodic factors that are part of the native system are also at work and result in gemination. For example, we will see the workings of the INITIALFOOT constraint, demanding prosodic words to start out with a bimoraic foot, not with an unfooted syllable.

The paper is organized as follows. We will first sketch the basic structure of modern Tokyo Japanese, with a main focus on geminate consonants in its native phonology (section 2). We will then present our basic claim and analysis about consonant gemination in Japanese loanwords (section 3). We demonstrate in this section how our prosodic analysis is different from previous analyses based solely on input-output correspondences. Sections 4 and 5 are the core part of this paper where our output-oriented analysis is illustrated for each and every basic fact regarding gemination and non-gemination. Segmental conditions on gemination are discussed in section 4 and prosodic conditions, in section 5. Previous studies on consonant gemination in Japanese loanwords are also critically discussed throughout the paper. The final section gives a summary of our analysis and future agenda.

2 Basic structures of native Japanese phonology

2.1 Segmental length

As is well known, consonant length as well as vowel length is distinctive in Japanese phonology (Shibatani 1990; Kawahara 2015; Kawagoe 2015). Thus, there are many minimal pairs including those in (3) that contrast a single consonant (singleton) with a geminated consonant (geminate). Geminates appear only word-medially.

(3) Singleton and geminate segmental minimal pairs:

Singleton		*Geminate*	
ki.ta	'north'	ki't.ta	'cut (past)'
ʃu.t͡ʃoo	'assertion'	ʃut.t͡ʃoo	'business trip'
sa.ki	'point, edge'	sa'k.ki	'a short time ago'
ka'.ʃa	'freight car'	kaʃ.ʃa	'pulley'
ka.sen	‘underline’	kas.sen	‘battle’

Phonetic studies have shown that, other things being equal, consonant length is signaled primarily by consonant duration (Fujisaki and Sugito 1977; Han 1994). Thus, the closure duration of [t] is much longer in /ki'tta/ 'cut (past)' than in /kita/ 'north'. Geminate fricatives have a much longer frication duration than singletons: e.g., [s] is considerably longer in /kassen/ 'battle' than in /kasen/ 'underline'.

While consonant length is contrastive in Japanese, not all consonants have a geminate counterpart. First, no voiced obstruent (b, d, g) can be geminated in the native (Yamato and Sino-Japanese) phonology.[1] This is illustrated, for example, by the fact that in the course of history /tada/ 'only' turned into /tatta/, not /tadda/, when geminated for emphasis. It follows from this and other facts that the native phonology of Japanese is subject to the constraint in (4), which has a well-known aerodynamic basis (Kawahara 2015:53-56) and cross-linguistic support. The presence of voiced obstruent geminates always implies the presence of voiceless obstruent geminates: No language bans just voiceless obstruent geminates while allowing voiced obstruent geminates (Maddieson 1984).

[1] Nasals have geminated counterparts (/kammuri/ ‘crown', /kannon/ ‘goddess of mercy') where the coda portion is considered a moraic nasal. Glides following moraic nasals are best understood as geminate glides with an initial nasalized portion (fuɴwari → fuw̃wari ‘floating' boɴyari →boỹyari ‘unfocused', see Mester and Ito 1989:275; Vance 2008:96).

(4) NOGEMINATEVOICEDOBSTRUENT (NOGEMVOIOBS)
Voiced obstruent geminates are prohibited.

We will return to the details later, when we show that further differentiation between segment types might be warranted for Japanese. Second, voiceless fricatives fall into two types: Those that can be geminated ([s] and [ʃ]) as shown in (5), and those that cannot ([h]).

(5) ka.sen 'underline' vs. kas.sen 'battle'
ka.ʃa 'freight car' vs. kaʃ.ʃa 'pulley'

Note that /h/ can be geminated in several independent contexts in the native phonology, but when geminated, it alternates with [pp] rather than [hh], for historical reasons.[2] This is true irrespective of the following vowel, which determines the phonetic quality of /h/ ([ç], [ɸ] or [h]) in Yamato and Sino-Japanese words. Some examples are given in (5), and we return to the more recent loanwords such as /bah.ha/ 'Bach' in section 4.4.

(5) a.	ha 'leaf'	~ hap.pa 'leaf'
b.	ni.hon 'Japan'	~ nip.pon 'Japan'
c.	a.ho 'fool'	~ ap.po 'fool (colloquial)'
d.	/it/ 'one' + hu [ɸu] 'husband'	→ ip.pu 'one husband'
e.	/it/ 'one' + hi [çi] 'day'	→ ip.pi 'first day of the month'

2.2 Syllable structure constraints

As in many languages, only a single consonant can fill the onset and coda position in a well-formed Japanese syllable. We state this unviolated constraint as NOCOMPLEX in (6) (after (Prince and Smolensky 1993), combining NOCOMPLEXONSET and NOCOMPLEXCODA.

(6) NO COMPLEX SYLLABLE MARGINS (NOCOMPLEX): No more than a single consonant can fill the onset or the coda position in a syllable.

NOCOMPLEX is responsible for triggering epenthesis in the adaptation of many loanwords (such as *plan* → p*u*ran). Besides this complexity restriction, there is another condition on the type of allowed codas (see Ito and Mester 2015:370-371 and work cited there).

[2] Modern Japanese /h/ derives from old Japanese /p/ (Frellesvig 2010). In the native vocabulary of Japanese, /h/ has three allophones: [ç] and [ɸ] appear before /i/ and /u/, respectively, while [h] appears before other vowels. [pp] occurs in reduplication (5a), in emphatic forms (5b-c), and in compound-medial positions via regressive place assimilation (5d-e).

(7) CODACONDITION (CODACOND): The coda can only be the first part of a geminate or a moraic nasal.[3]

The effects of CODACOND can be seen in the verbal inflectional paradigm, where it is responsible for both gemination (/kir-ta/ 'cut-past'→ *kitta*) and place assimilation (/kam-ta/ 'chew-past' → *kanda*).

Finally, there is an important size restriction on the syllable, which can be gleaned from the fact that geminate consonants cannot occur after a long vowel or diphthong. Thus, in the native phonology, *toki*, *tokki*, and *tooki* are all legal forms, but **tookki* is not (8).

(8)

	Singleton		*Geminate*	
Short V___	to.ki	'time'	tok.ki	'projection'
Long V___	too.ki	'pottery'	*took.ki	

Kubozono (1999) attributes this distributional restriction to a constraint on the optimal size of the syllable, which permits light (monomoraic) and heavy (bimoraic) syllables, but not superheavy (trimoraic) ones. In Japanese, as in other languages, long vowels and diphthongs count as two moras, while the moraic nasal as well as the first half of geminate consonants counts as one mora.

(9) NOSUPERHEAVYSYLLABLES (NOSUPERHEAVY): Trimoraic syllables ($\sigma_{\mu\mu\mu}$) are banned.

The same constraint accounts for the seemingly peculiar loanword adaptation process known as 'pre-nasal vowel shortening' (Lovins 1975). This process, illustrated in (10), shortens long vowels and diphthongs before a moraic nasal, thus creating bimoraic syllables out of a string that would otherwise result in trimoraic syllables (see Kubozono 1999; 2015 for more evidence for the trimoraic syllable ban in Japanese).

(10) Pre-nasal vowel shortening[4]

Source	Loan	
foundation	*fan*.dee.ʃon	**faun*.dee.ʃon
stainless	su.*ten*.re.su	*su.*tein*.re.su
Cambridge	*ken*.bu.rid.d͡ʒi	**kein*.bu.rid.d͡ʒi
corned beef	*kon*.bii.fu	**koon*.bii.fu

[3] In final position, the moraic nasal realized as a dorso-uvular [ɴ] with weak constriction, elsewhere it assimilates to the place of articulation of the following segment, with details depending on the type of segment involved, see Vance 2008:93-101.
[4] As a reviewer correctly points out, there are sporadic exceptions to trimoraic shortening involving the /aw/ diphthong such as /raun.d͡ʒi/ 'lounge' and /maundo/ 'mound' from English.

2.3 Prosodic form

Native phonology exhibits a striking tendency to favor Heavy-Light (HL) and Heavy-Heavy (HH) sequences, and to disfavor Light-Heavy (LH) sequences in word-final position. This tendency is observed in various independent phenomena in Japanese, one of which is the *zuuzya-go* formation discussed in depth by Ito, Kitagawa and Mester 1996. *Zuuzya-go* (ZG) is a jazz musicians' secret language involving metathesis: e.g., /ma.nee.d͡ʒaa/ → /d͡ʒaa.ma.ne/ 'manager'. The input to this process can be any word with any prosodic structure, but its output is severely constrained in prosodic terms. This is illustrated with monosyllabic and disyllabic input forms in (11) below.

(11) ZG formations

Input form	Word	ZG output form	ZG-word	
L	me	HL	ee.me	*eye*
H	kii	HL	ii.ki	*key*
LL	me.ʃi	HL	ʃii.me	*rice*
LH	go.han	HL	han.go	*meal, rice*
HL	tan.go	HL	gon.ta	*tango*
HH	too.kyoo	HH	kyoo.too	*Tokyo*
	ron.don		don.ron	*London*

In these examples, the input forms vary from a monomoraic monosyllable (L) to a disyllabic word consisting of two heavy syllables (HH). This variability in the input contrasts with uniformity in the output, where only HL or HH structures are permitted. For example, the input *me* (L) gives rise to *ee.me* (HL). More striking is the fact that both HL and LH inputs yield HL outputs: *go.han* and *tan.go* turn into *han.go* and *gon.ta*, respectively.[5] All in all, *ZG*-formation exhibits a strong tendency towards HL and HH outputs and against LH outputs. *ZG* is not isolated in exhibiting such a tendency. Baby words display a remarkable preference for HL and HH rather than LH and other prosodic forms (Kubozono 2003). In (12), inputs and outputs represent adult and baby forms, respectively.

[5] This output neutralization in prosodic structure results here from a special method of reversal that HL inputs undergo, by which input mora strings are entirely reversed: /ta-n-go/ → /go-n-ta/, */go.tan/.

(12) Baby words

a.	LL → HL	ba.ba	→ baa.ba, *ba.baa	'grandma'
		d͡ʒi.d͡ʒi	→ d͡ʒii.d͡ʒi, *d͡ʒi.d͡ʒii	'grandpa'
		ku.t͡su	→ kuk.ku	'shoes'
		da.ku	→ dak.ko	'to hold up'
		ne.ru	→ nen.ne	'to sleep'
		o.bu.u	→ on.bu	'to carry a baby piggyback'
b.	LL → HH	ha.u	→ hai.hai	'to crawl'
		bu.bu	→ buu.buu	'car, pig'

The interesting asymmetry between HL and LH in the output is also observed in the process of loanword truncation. Crucially, HL forms are perfectly acceptable in the output, whereas LH forms are strictly prohibited (Ito 1990; Kubozono 2003).

(13) Loanword truncations

a.	HLX→ HL	roo.tee.ʃon	→ roo.te	*rotation*
		pan.fu.ret.to	→ pan.fu	*pamphlet*
		ʃin.po.d͡ʒi.u.mu	→ ʃin.po	*symposium*
b.	LHX→ LL	ro.kee.ʃon	→ ro.ke, *ro.kee	*location*
		de.mon.su.to.ree.ʃon	→ de.mo, *de.mon	*demonstration*

There are several other independent processes that display a bias towards HL and HH, and against LH outputs in Japanese (see Kubozono 2003 for more evidence).

Rather than a prosodic form constraint directly banning LH sequences in word-final position (adopted in Kubozono, Ito and Mester 2008), our proposal here is that the real generalization can be found at a prosodic level higher than the syllable, namely, the foot level. Given the standard assumption that Japanese has bimoraic foot structure (see Poser 1990 for evidence), sequences of syllables are maximally parsed as either (LL) or (H), with leftover light syllables remaining unparsed. Thus, the relevant forms in question are parsed as in (14), where ($_f$) and [$_ω$] demarcate feet and prosodic words, respectively.

(14) a. [$_ω$ ($_f$ H) ($_f$ H)]

b. [$_ω$ ($_f$ H) L]

c. *[$_ω$ **L** ($_f$ H)]

Viewed in terms of footing, we see immediately what the problem is with (14c): It violates the constraint INITIALFOOT, which requires prosodic words to begin with a foot left-aligned with the prosodic word (Ito and Mester 1992:31).

(15) INITIALFOOT (INITFT):[6] A prosodic word begins with a foot.

This constraint is violated by prosodic words with an initial unfooted syllable, and can be understood as an instance of a more general STRONGSTART requirement (Selkirk 2011:470). It is satisfied in (14a,b) but violated in (14c), causing the HL~*LH asymmetry in the patterns discussed above in (11)-(13). As we will see, INITIALFOOT, together with other constraints, is also responsible for consonant gemination in loanwords.

2.4 Accent structure

In the light of more recent work, (Tokyo) Japanese also exhibits a certain bias with respect to accent structure. It permits two major accent patterns: accented and unaccented (McCawley 1968, Kubozono 1988). Putting aside the unaccented pattern, there is a striking tendency to put the accent on the third or fourth mora from the end of the word if it is a noun (Martin 1952:33). Seen conversely, accents on the penultimate or final mora of a word are avoided.

In the Yamato and Sino-Japanese lexicon, words with an accent on the antepenultimate mora, such as *i'not͡ʃi* 'life', overwhelm those with an accent on the penultimate or final mora, such as *koko'ro* 'heart' or *otoko'* 'man' (Kubozono 2006; Kubozono, Ito and Mester 2008). This is true of loanwords, as well, as shown by typical examples as in (16), where the accent is on the antepenultimate mora irrespective of its location in the source words.

(16)	source:	*banána*	*potáto*	*cámera*	*currículum*	*Galápagos*
	loan:	ba'.na.na	po'.te.to	ka'.me.ra	ka.ri.kyu'.ra.mu	garapa'gosu

In accordance with classical metrical theory, antepenultimate accent can be understood as the result of a bimoraic trochaic foot placed at the end of the word modulo NONFINALITY, i.e., with an extrametrical final syllable separating it from the end of the word (e.g., [(*ba*'.*na*)*na*]. The relevant constraint is given in (17), where "head foot" denotes the foot carrying the antepenultimate accent.

(17) NONFINALITY: The head foot (Ft') is not final in a prosodic word.

This constraint is clearly violable in Japanese since many bimoraic native nouns such as *ne'ko* 'cat', have accent on the penultimate mora, and this penultimate pattern is by far the most common in bimoraic SJ nouns (e.g., *e'ki* 'station', *to'syo* 'book'), as well as in bimoraic loanwords (e.g., *ba'su*, 'bus', *pi'ru*, pill, *kya'bu* 'cab'). In fact, we will see in section 5.2 that it is convenient to have, besides the general NONFINALITY constraint (17), a separate version for non-minimal words larger than a single foot.

[6] We present this and other related constraints in lieu of the cover constraint ‘Prosodic Form' in our earlier analysis (Kubozono, Ito and Mester 2008).

In this context, it is worth considering the peculiar behavior of /ru/, /su/ and /fu/ (=[ɸu]) in Japanese phonology. In loanword adaptations, word-final /CVru/, /CVsu/ and /CVfu/ sequences behave in many ways as if they were a single heavy syllable. One possibility, pursued in earlier work (Kubozono, Ito and Mester 2008), is that the final (usually epenthetic) vowel ⟨u⟩ is indeed extraprosodic here, so these sequences count as heavy syllables: *.CVr.⟨u⟩*, *.CVs.⟨u⟩*, and *.CVf.⟨u⟩*. The accentuation pattern of words consisting of four moras shows that word-final LL sequences of the form *CVru, CVsu,* and *CVfu* pattern with word-final H. While loanwords generally show a remarkable bias towards the accented (vs. unaccented) pattern in Tokyo Japanese (Shibata 1994; Kubozono 2006), they tend to be unaccented if they are four moras long and end in a sequence of two light syllables (see also Ito and Mester 2015). Thus LL-final (*a.me*)(*ri.ka*) and (*mon*)(*ba.sa*) (place names) are unaccented, whereas H-final (*ro'n*)(*don*) 'London', (*sa'i*)(*daa*) 'cider', and (*bu'.ru*)(*zon*) 'blouson' are accented. However, LL-final cases with *ru/su/fu* are accented and behave as if they were H-final: (*ko'n*)(*do.ru*) 'condor', (*i'n*)(*da.su*) 'the Indus River', and (*mo'.ro*)(*zo.fu*) 'Morozoff' (Kubozono 1996; Giriko 2008). Here again, if final /u/ after /rsf/ is extraprosodic, these words are indeed H-final: (*ko'n*)(*dor.*)<*u*>, (*i'n*)(*das.*)<*u*>, (*mo'.ro*)(*zof.*)<*u*>, and their accented status would be expected. In this line of analysis, monosyllabic loanwords like *bell, bus,* and *rough* ending in /ru, su, fu/ in Japanese would be parsed as bimoraic feet consisting of a single H syllable (*ber*.)<*u*>, (*bas*.)<*u*>, (*raf.*)<*u*>, rather than as the otherwise straightforward (LL) feet (*be.ru*), (*ba.su*), (*ra.fu*). The extraprosodicity analysis might then also account for why gemination does not occur in these examples, since the geminating candidate would conceivably violate NoSuperheavySyllable (*(*bass.*)<*u*>).

Although this unifying explanation is quite attractive, it is best implemented within an analysis with abstract stages of the derivation. In our output-based analysis couched in classical parallel OT (vs. Stratal OT, e.g., as in Kiparsky 's (2003) analysis of Ancient Greek accent), there are several unresolved problems, both in analysis and description.

Descriptively, the generalization that such final /u/'s are treated as extraprosodic appears to be limited in scope, holding only for words of exactly two or four moras (e.g., *be'ru, ko'ndoru*). For words of other lengths, the expected antepenultimate accent arises, as following from bimoraic footing and NonFinality, as in (*pa'ru*)*su* 'pulse', (*pi'ru*)*su* 'Pilsener', *kuri*(*su'ma*)*su* 'Christmas', *asupa*(*ra'ga*)*su* 'asparagus', (*go'ru*)*fu* 'golf', (*d͡ʒi'ra*)*fu* 'giraffe', *pori*(*gu'ra*)*fu* 'polygraph', *ofiro*(*gu'ra*)*fu*, (*pa'zu*)*ru* 'puzzle', (*ke'to*)*ru* 'kettle', or *tore*(*a'do*)*ru* 'toreadór'. If the final /u/ were extraprosodic here, we would incorrectly expect a penultimate mora accent in **pa*(*ru's.*)<*u*> and **pi*(*ru's.*)<*u*>: NonFinality is not violated, due to the presence of the extraprosodic final /u/, so the predictions are different from *ba'ree* 'ballet' and *pu'rin* 'pudding', where **bare'e* and **puri'n* violate NonFinality. In 5μ-words such as *asupara'gasu* 'asparagus' (or even longer words), extraprosodic final /u/ wrongly predicts either **asu*(*pa'ra*)*gas.*<*u*> with pre-antepenultimate accent or **asupara*(*ga's.*)<*u*> with penult accent, not the correct *asupa*(*ra'ga*)*su* with antepenult accent. Even among 4μ-words of the forms /LLLL/ and /HLL/ ending in /-ru/, which clearly go against the general trend for LL-final 4μ-words in being accented, there is also a significant number of unaccented words which have no accented variant (according to the NHK accent dictionary), such as *kaasoru* 'cursor', *t͡ʃanneru* 'channel', or *teeburu* 'table'.

Analytically, the parsing of /CVrV/ as CVr.V violates the universal ONSET constraint, whereby /VCV/ is required to be parsed as V.CV, with the medial C as an onset. This might arguably be circumvented by the final V being extraprosodic, but another more serious problem is the resulting surface syllable structure .CVr., .CVs., and .CVf., violating CODACOND (7), which restricts codas to moraic nasals or the first parts of geminates. Since /r,s,f/ are singleton coda consonants, this would be the only instance in the entire Japanese phonology where the otherwise unviolated CODACOND would be violated in surface representations. It is beyond the scope of this paper to pursue the ramifications which such CODACOND violations in output forms would entail, and leave this interesting issue for future investigation.

3 Gemination vs. non-gemination

Most previous studies assume, either explicitly or implicitly, that consonant gemination in Japanese loanwords is triggered exclusively by a force to preserve the coda status of the consonant—or equivalently, the closed character of the syllable—in the source words (see Kunihiro 1963; Ohye 1967; Ohso 1971; Lovins 1975; Kawagoe 1995; Tsuchida 1995; Katayama 1996, 1998; Kitahara 1997; Shirai 2001; Kawagoe and Arai 2002, among others). For example, the English word *hit* is supposed to undergo coda gemination together with vowel epenthesis, *hit* → [hitto], despite the fact that the ungeminated form, [hito] 'man', is perfectly well-informed in the language. The crucial difference between the two output candidates, [hitto] and [hito], is that the coda consonant in the input is preserved as a coda in the former, but not in the latter.

In this paper we question the idea that this kind of prosodic faithfulness between source word and loanword output is the sole factor responsible for gemination. In addition, we claim, many cases of gemination in loanwords are instead due to output-oriented optimization, driven by the imperative to achieve a better prosodic structure. There is of course no contradiction between these two factors, which jointly account for the intricate gemination patterns found in the data. Our analysis starts by tackling the mystery that consonant gemination is a highly productive process in Japanese loanwords, while it creates a structure that is marked cross-linguistically. That geminate consonants are more marked than their single counterparts can be seen from the fact that all languages have single consonants but only some of them permit geminate consonants (Maddieson 1984). Geminates are thus marked in the classical sense that the existence of geminates implies the existence of singletons, but not vice versa. This is stated as a general markedness constraint against geminate consonants.[7]

(18) NOGEMINATE (NOGEM): Geminate consonants are disallowed.

The productivity of gemination in Japanese loanword phonology, on the other hand, can be illustrated by the fact that it occurs in almost all monosyllabic English words ending in a voiceless obstruent, such as *toppu* 'top', *hitto* 'hit' and *bukku* 'book'. The first question that faces us is why gemination occurs so productively in loanword phonology.

As mentioned above, it cannot be attributed to a phonotactic constraint of the recipient language. The ungeminated output form [hito], for example, is perfectly well-formed in the language, where it means 'man'. Similarly, there is nothing inherently wrong with the form [buku].

Previous analyses have assumed, in one way or another, that consonant gemination in loanwords only occurs to preserve the coda consonant in the source words as a coda in the output. We state here the constraint explicitly as in (19), and illustrate the OT-interaction with some of constraints already discussed in tableau (20).

(19) FAITHCODA: A consonant that is a coda in the source word is a coda in the output.

We will see in section 5.1 that a more specific version that focuses on the word-final position is actually at play in the grammar of Japanese.

(20)

			CODACOND	FAITHCODA	NOGEM
hit	☞	[(hi't)to]			*
		[(hi'to)]		*!	
		[(hi't)]	*!		

In [(*hi't*)*to*], the coda *t* in the source word *hit* is faithfully preserved as the coda in the output (as the first half of a geminate), while in the ungeminated [(*hi'to*)] the source coda *t* is unfaithfully parsed as an onset. The fully faithful candidate [(*hit*)] does not violate FAITHCODA, but without a final epenthetic vowel, it has a fatal CODACOND violation.[8]

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[7] We have already seen the more specific NOGEM-VOIOBS constraint (4) at work in the native phonology. We will see later that in addition to (18), more specific constraints are needed that refer to specific types of consonants, reflecting fundamental differences in geminability. Cf. also Kawahara (2007) universal markedness hierarchy on geminates, where geminate markedness correlates with sonorancy: *GG (glide) >> *LL (lateral) >> *NN (nasal) >> *OO (obstruent). A reviewer points out that a language like Ponapean, with geminate sonorants but without geminate obstruents, might be a counterexample to the proposed universal hierarchy.

8 Instead of appealing to FAITHCODA, we might also consider the alternative possibility that the constraint already discussed in connection with the general antepenultimate accent, namely, NONFINALITY(Ft') (17) is responsible for the gemination. Substituting NONFINALITY(Ft') for FAITHCODA in the tableau (20), we see that

Another case of non-gemination that straightforwardly follows from the constraints already discussed is the fact that gemination does not occur after a tense (long) vowel or diphthong. This is because gemination here creates violations of the constraint against superheavy syllables in (9), which is high-ranking in Japanese.

(21)

				NoSuperheavy	CodaCond	FaithCoda	NoGem
a.	*mitt*	☞	(mit)to				*
	/mɪt/		(mito)			*!	
			(mit)		*!		
b.	*meat*	☞	(mii)to			*	
	/miːt/		(miit)to	*!			*
			(miit)	*!	*		

In (21b), the winner *mii.to* violates FaithCoda, but the alternative candidate *miit.to* violates the even higher-ranking NoSuperheavy.

In what follows, we demonstrate that the seemingly complex gemination and non-gemination patterns, including those presented in the introduction, can be accounted for by the interaction of several violable optimality-theoretic constraints, as improvements of both markedness and faithfulness.

4 Segmental conditions on gemination

In this section, we present the main generalizations regarding which segments are more prone to gemination, and the constraints responsible for the difference. The factors involved concern the major phonological type distinctions in voicing (4.1), sonorancy (4.2), place (4.3), and manner (4.4). In order to not be sidetracked by nonsegmental factors, we consider only source words that are monosyllabic CVC, with simple (including null) onset and simple coda. Since Japanese does not allow complex onsets or codas, other monosyllabic inputs like CCVC (*drop*), CVCC (*duct*) or CCVCC (*tract*) emerge with multiple epenthetic vowels, affecting the overall prosodic profile. As we will see in section 5, this in turn means that some prosodic structure constraints enter the picture. For CVC-inputs, however, high-ranking CodaCond will mean that the two relevant outputs are disyllabic, either the geminating CVC.CV or the non-geminating CV.CV. The former fulfills FaithCoda, but violates NoGem, the latter violates FaithCoda, but fulfills NoGem. Which of these is the preferred outcome is determined by the segmental type of the input coda consonant (henceforth marked as [C]).

---

the winner [(*hi'*t)*to*] has the head foot (accented and bimoraic) in non-final position, while in the ungeminated [(*hi'to*)], the head foot does not have a buffer final syllable. As we will see later, besides the fact that the general NonFinality constraint (17) is ranked too low to fulfill this function, there are cases of gemination that do not involve the head foot and need an account based on faithfulness.

4.1 Voicing

The major generalization that has been noted in all previous work is that voiceless stops are more prone to gemination than voiced ones. This is unsurprising, given that the native phonology of Japanese allows gemination of voiceless obstruents /p, t, k/, but not gemination of voiced obstruents /b, d, g/. As we saw in (3) above, *sa.ki* 'point, edge' turns into *sakki* 'a short time ago' as the physical notion expands to a temporal one, but *tada* 'just' underwent consonant devoicing as well when geminated for emphasis in *tatta*, **tadda* . This constraint on voiced geminates (22) (repeated from (4) above) is also active in loanword phonology, where voiced stops are much less likely to undergo gemination than their voiceless counterparts.

(22) NOGEMINATE-VOICEDOBSTRUENT (NOGEM-VOIOBS): Voiced obstruent geminates are prohibited.

Given FAITHCODA (19), gemination is expected whenever the source word contains a coda, but previous work has shown that gemination is found most regularly only with voiceless codas.

(23) a. Voiceless stop gemination:	kyap.pu	'cap'	bak.ku	'back'
b. Voiced stop non-gemination:	kya.bu	'cab'	ba.gu	'(computer) bug'

We had already established that the general NOGEM (18) is ranked below FAITHCODA (19) (see tableau (20)), but the contrast in (23) shows that the more specific NOGEM-VOIOBS (22) is ranked above FAITHCODA. The OT tableau with FAITHCODA sandwiched between the two NOGEM-constraints shows the correct winning candidates being chosen.[9]

(24) Voicing difference

			NOGEM-VOIOBS	FAITHCODA	NOGEM
Voiceless [C]: *ra[ck]*	☞	(rak)ku			*
		(ra'ku)		*!	
Voiced [C]: *ru[g]*	☞	(ragu)		*	
		(rag)gu	*!		*

[9] While voiceless final obstruent virtually always geminate in CVC-words, voiced obstruents mostly do not, but the details depend on place of articulation, and there are some instances of gemination: *heddo* 'head', *baggu* 'bag' vs. *bagu* 'bug', *nobbu~nobu* 'knob'. We return to this point in section 4.3.

4.2 Sonorancy

Sonorant consonants (nasals, liquids, and glides) also behave like voiced obstruents in not geminating in this CV[C]-situation (25).

(25) Sonorant coda inputs – no gemination

a.	ha'mu	*ham.mu	*ham*
b.	e'nu[10]	*en.nu	*the letter N*
c.	be'ru	*ber.ru	*bell*

We formulate the relevant constraint in (26), and illustrate the point in (27).

(26) NOGEMINATE-SONORANT (NOGEM-SON): Sonorant geminates are prohibited.

(27)

			NOGEM-SON	FAITHCODA	NOGEM
Sonorant [C]: *ha[m]*	☞	(ha'.mu)		*	
		(ha'm.)mu	*!		*

Since sonorant consonants are also voiced, one might consider combining NOGEM-VOIOBS and NOGEM-SON into one constraint NOGEM-VOI. Although such a merged constraint would be unproblematic for the simple CV[C] cases analyzed so far, there are good reasons to keep the voiced obstruent and the sonorant versions separate. First, the two constraints, NOGEM-VOIOBS and NOGEM-SON, must be separate in the native phonology, where voiced obstruents and approximants (the rhotic /r/ and the glides /w/ and /y/) are not geminated, but nasals regularly are. We find native items like *tomma* ‘silly' (see also footnote 1 above for other examples of geminated sonorants in the native vocabulary), but the name *Tom* is ungeminated *to'mu*, and not **to'mmu*. Second, as we will see in section 5, voiced obstruents do geminate under certain prosodic conditions (*dora'ggu* ‘drug', **do'ragu*, while sonorants do not (*do'ramu* ‘drum', **dora'mmu*). The crosslinguistic facts point in the same direction: Taylor 1985 showed in a typological survey that the presence of a sonorant geminate in a language generally implies the presence of at least one obstruent geminate, but not vice versa, and Kawahara, Pangilinan and Garvey 2011 provide several arguments supporting the distinction between voiced obstruents geminates and sonorant geminates. In addition, there are processes turning sonorant geminates into obstruent geminates, but no processes going in the other direction. Examples are the occlusivization of geminate approximants in Berber and LuGanda. Finally, there are processes degeminating only the most sonorant types of geminates: For

[10] Coda /n/ usually appears as moraic nasal, e.g., paN 'bread', but can also appear with the epenthetic vowel as in CNN *ʃii enu enu*. Crucially, it does not geminate (**ennu*), except in borrowings from French such as *kannu* ‘Cannes' or *ʒannu* 'Jeanne', where the final nasal is released.

example, in Sanskrit glides and rhotics were degeminated, but not lateral, nasal, and obstruent geminates.

4.3 Place of articulation

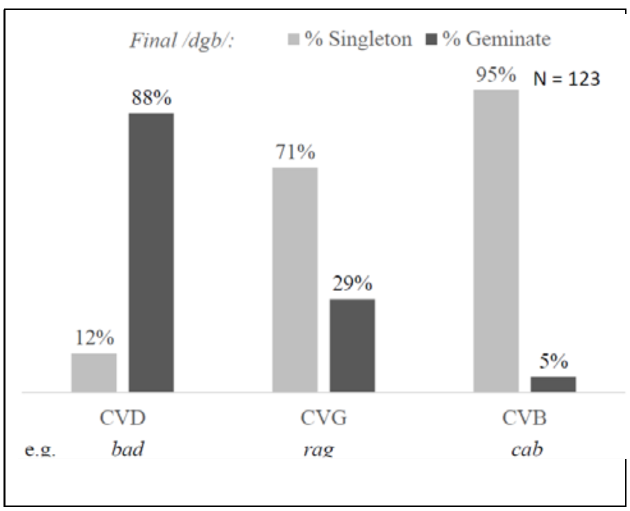
A closer survey at the gemination pattern reveals that place of articulation affects the geminability of C. Kawagoe 2015 (see also references cited there) notes that coda stops in the input are almost invariably geminated if they are voiceless (except in consonant clusters such as *ask* → *asuku* and *tact* → *takuto*). As (28) shows, this holds for all places of articulation, labial, coronal, and dorsal, in fulfillment of FAITHCODA. But among voiced stops, only the coronals geminate on a regular basis (e.g. *paddo* 'pad').

(28)

	Labial	Coronal	Dorsal
Voiceless stop:	/pp/ *map.pu* 'map'	/tt/ *mat.to* 'mat'	/kk/ *mak.ku* 'mac'
Voiced stop:	/b/ *pa.bu* 'pub'	/dd/ *pad.do* 'pad'	/g/ *ma.gu* 'mug'

Our own survey data show the distribution in (29).

(29)



Among the voiced obstruent stops, the gemination constraints therefore need to distinguish between places of articulation, e.g., NOGEM-B >> NOGEM-G >> NOGEM-D. For our purposes, it is sufficient to distinguish consonants with peripheral (labial and dorsal) places of articulation from consonants with central (coronal) place, with the resulting constraint ranking in (30). An illustrative tableau appears in (31).

(30) NOGEMVOIOBS[BG] >> FAITHCODA >> NOGEMVOIOBS[D]

(31)			NoGem-VoiObs[bg]	FaithCoda	NoGem-VoiObs[d]
pub	☞	pa.bu		*	
		pab.bu	*!		
pad	☞	pad.do			*
		pa.do		*!	
mug	☞	ma.gu		*	
		mag.gu	*!		

It is of some interest that the preference scale that emerges in (29)—DD>GG>BB, where ">" stands for "less marked than"—is at variance with the articulation-based scale BB>DD>GG, which reflects the aerodynamics of voicing and is well supported by typological data (see Hayes and Steriade 2004:7-12, who even use this case as a textbook example of a markedness ranking with a clear phonetic basis). Questions of detail aside, the smaller the cavity behind the constriction, the more difficult it is to maintain voicing in a geminate stop (Ohala and Riordan 1979). However, in the Japanese loanword data, two of three articulatory preference relations are reversed. There might be no incompatibility here since the scale that is at work in the loanword data is perhaps not based on aerodynamic difficulty, but on duration. It stands in full agreement with the different duration ratios determined by Homma (1981) for geminate vs. singleton stops at the three places of articulation: DD:D=4.11, GG:G=3.27, BB:B=2.89.[11]

4.4 Manner of articulation

Finally, among the segments involving frication (32), we find non-gemination for the segments in the highlighted box, the anterior fricatives—[−sonorant, +continuant, +anterior],[12] i.e., *f*[ɸ], *s*, and *z*, even though we expect gemination given our constraints (voicelessness and/or coronality).

[11] It is still true, though, that even 2.89 is a ratio that should guarantee a robust contrast. Another factor that might play a role is the fact that the epenthetic vowel inserted after /t,d/ in Japanese is not the default /u/, but /o/ (in order to avoid the otherwise unavoidable allophonic change of /t,d/ to [ts, (d)z] before /u/): *ta'kuto* 'tact', not **ta'kutsu*. As epenthetic segments /u/ and /o/ are not fully equal—for example, the so-called "perceptual illusion" effects associated with /u/ for Japanese listeners (Dupoux, Kakehi, Hirose, Pallier and Mehler 1999) do not hold of /o/ (Mohanan, Takahashi, Nakao and Idsardi 2008), i.e., in some sense /o/ is perceived more as a 'normal' vowel than /u/. One could therefore speculate that gemination of /d/ before /o/ (*he'ddo* 'head' rather than *he'do*) might serve to highlight the epenthetic character of /o/ here.

[12] I.e., as defined in Chomsky and Halle (1968:304): "sounds produced with an obstruction that is located in front of the palate-alveolar region of the mouth".

(32)

	[+continuant]		[−continuant]	
[+anterior]	f [ɸ]	*ta.fu* 'tough'	tt͡s	*nat.tsu* 'nuts'
	s	*ba.su* 'bus'	dd͡z	*gud.dzu* 'goods'
	z	*ba.zu* 'buzz'		
[−anterior]	ʃʃ	raʃ.ʃu 'rush'	tt͡ʃ	tat.tʃi 'touch'
	hh	mah.ha 'Mach'	dd͡ʒ	bad.dʒi 'badge'
		goh.ho 'Gough'		

We subsume the voiced fricative /z/ under the constraint banning gemination of voiced stops (30), which we now restate as in (33).

(33) NOGEM-VOIOBS[BGZ]: Gemination of voiced obstruents (peripheral or continuant) is prohibited.

The complication in the statement of (33) stems from the fact that /d/ needs to be excluded. This is perhaps an artifice—the ultimate analysis might involve a general constraint against geminating voiced obstruents, as in (4) above, interacting with a constraint exempting /d/ from this ban, as discussed at the end of the previous section. The remaining segments in (32), the voiceless anterior fricatives, require a gemination constraint (34) of their own. An illustrative tableau appears in (35).

(34) NOGEM-VOICELESSANTERIORFRICATIVE/_]$_{WD}$ (NOGEM-ANTFRIC/_]$_{WD}$): Gemination of voiceless anterior fricatives (/s/, /f/) that are final in the source word is prohibited.[13]

[13] In Kubozono, Ito and Mester 2008, this case was analyzed as extraprosodicity of the final epenthetic vowel, see the discussion above in section 2.4.

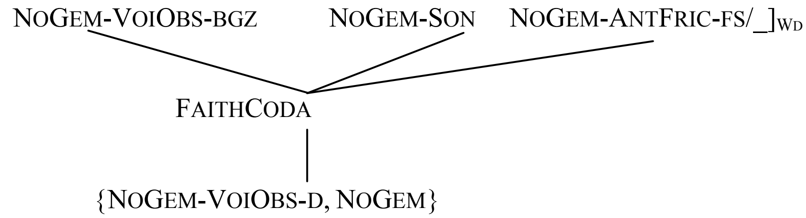
(35)			NOGEM-ANTFRIC/_]$_{Wd}$	FAITHCODA	NOGEM
tough	☞	ta.fu		*	
		taf.fu	*!		
bus	☞	ba.su		*	
		bas.su	*!		
rush	☞	raʃ.ʃu			*
		ra.ʃu		*!	
Mach	☞	mah.ha			*
		ma.ha		*!	

The NOGEM-ANTFRIC/_]$_{Wd}$ constraint (34) is different from the other NOGEM constraints in that it is positionally restricted to word-final position (*re'su* 'less', *ba'su* 'bus', *ha'pinesu* 'happiness', *o'fu* 'off', *ta'fu* 'tough', *gu'rafu* 'graph', *ka'adifu* 'Cardiff', etc.). Medially, /s/ and /f/ occur geminated in certain prosodically motivated configurations (e.g., *ri'ssun* 'listen', *e'ssee*, 'essay', *ha'ssuru* 'hustle', *massa'ad͡ʒi* 'massage', *ba'ffaa* 'buffer', *ʃa'ffuru* 'shuffle') to be discussed in section 5. This is also the reason for not including /z/ in (34): The avoidance of gemination in this case is not limited to word-final position but holds across the word (e.g., *pa'zuru* 'puzzle' and *no'zuru* 'nozzle', not **pa'zzuru*, **no'zzuru*), requiring a more general constraint, as in (33).

Recent work has raised the possibility that (34) is grounded in perceptual facts. Matsui 2012:67 presents experimental evidence showing that word-final [−anterior] /ʃu/ and [+anterior] /su/ are perceived in different ways by Japanese listeners: In the case of the (geminating) /ʃu/, a formant transition is observed between /ʃ/ and /u/, serving as a perceptual cue to gemination by marking the end of frication. In the case of the (non-geminating) /su/, no such formant transition is observed.

Summarizing so far, the five different gemination constraints are ranked with respect to FAITHCODA in the way depicted in (36). In the following sections, we show that more specific versions of FAITHCODA (19) and NONFINALITY (17) are needed, and that INITIALFOOT (15) plays a crucial role in explaining cases of gemination different from those seen so far. Since NOGEM-VOIOBS-D and the general NOGEM are both ranked at the bottom of the hierarchy, we will henceforth regard the case of /d/ as being adequately included in the general constraint.

(36)



5 Prosodic conditions on gemination

5.1 Prosodic faithfulness I: word-final vs. word-internal codas

In the preceding section, we considered only monosyllabic CVC inputs, in order to focus on the difference in geminability between segment types (voicing, place, and manner). We found gemination of C with /p, t, t͡s, t͡ʃ, k/ (voiceless stops), /ʃ, h/ (non-anterior fricatives), and /d, d͡z, d͡ʒ/ (voiced coronal stops). No gemination in C position was found with /b, g, z/ (peripheral voiced stops and voiced fricative), /s, f/ (voiceless anterior fricatives), and /m, n, r/ (sonorants). For CVC-inputs, there is only one coda, which is also the word-final coda.

In polysyllabic words, we find a fundamental distinction between two different kinds of coda positions: Word-final codas are geminated, but not word-internal codas. This is illustrated in (37), where we find word-final codas geminated whatever the length of the word, but word-internal codas ungeminated.

(37)				
	Word-final coda: geminated		Word-internal coda: ungeminated	
p	kya'p.pu	*cap*	kya.pu.ten	*captain*
	a'p.pu	*up*	o.pu.ʃon	*option*
	go.ʃi'p.pu	*gossip*	kya.pu.ʃon	*caption*
k	do'k.ku	*dock*	.do'.ku.taa.	*doctor*
	pik.ku	*pick*	.pi'.ku.nik.ku.	*picnic*
	kuraʃi'k.ku	*classic*	.se'.ku.ʃon.	*section*
t	a't.to	*at, @*	.a'.to.ra.su.	*atlas*
	ba.ge't.to	*baguette*	.ba.to.raa.	*butler*
	ma'a.ket.to	*market*	.ri'.to.ma.su.	*litmus*
d	kyu'u.pid.do	*cupid*	.fi.do.raa.	*fiddler*
	wa'n.ted.do	*wanted*	.me'.do.ree.	*medley*
	.ba'd.do.	*bad*	ba.do.mi'n.ton	*badminton*
ʃ	haʃ.ʃu	*hash*	.a'.ʃu.ree.	*Ashley*
h[ç]	dii.to.rih.hi.	*Dietrich*	.ri.hi.taa.	*Richter*
t͡s	nat.t͡su	*nuts*	.na.t͡su.me.gu.	*nutmeg*

This means that the FAITHCODA constraint (19) appealed to so far is too sweeping, and what we saw at work in section 4 was in fact a more restricted version of prosodic faithfulness targeting only word-final codas, as in (38).

(38) FAITHCODA/_]$_{WD}$: If a consonant in the input source word is a coda in word-final position, its correspondent in the loan output is also a coda.

Tableau (39) shows that, different from FAITHCODA/_]$_{WD}$, the general FAITHCODA constraint ranks below general NOGEM and cannot command its violation.

(39)			FAITHCODA/_]$_{WD}$	NOGEM	FAITHCODA
dock	☞	dok.ku		*	
		do.ku	*!		*
doctor	☞	do.ku.taa			*
		dok.ku.taa		*!	
cupid	☞	kyuu.pid.do		*	
		kyuu.pi.do.	*!		*
butler	☞	.ba.to.raa.			*
		.bat.to.raa		*!	

This prosodic faithfulness analysis singling out the word-final coda received further support in work by Kubozono, Takeyasu and Giriko 2013, who not only replicate the final/medial coda contrast in (37) with nonce words, but show in addition that what Japanese listeners are sensitive to is not position per se, but phonetic differences in the English source words relating to duration and pitch that are associated with word-final vs. word-medial position. One way of interpreting this is to take the constraint (38) to be sensitive to significant phonetic detail.

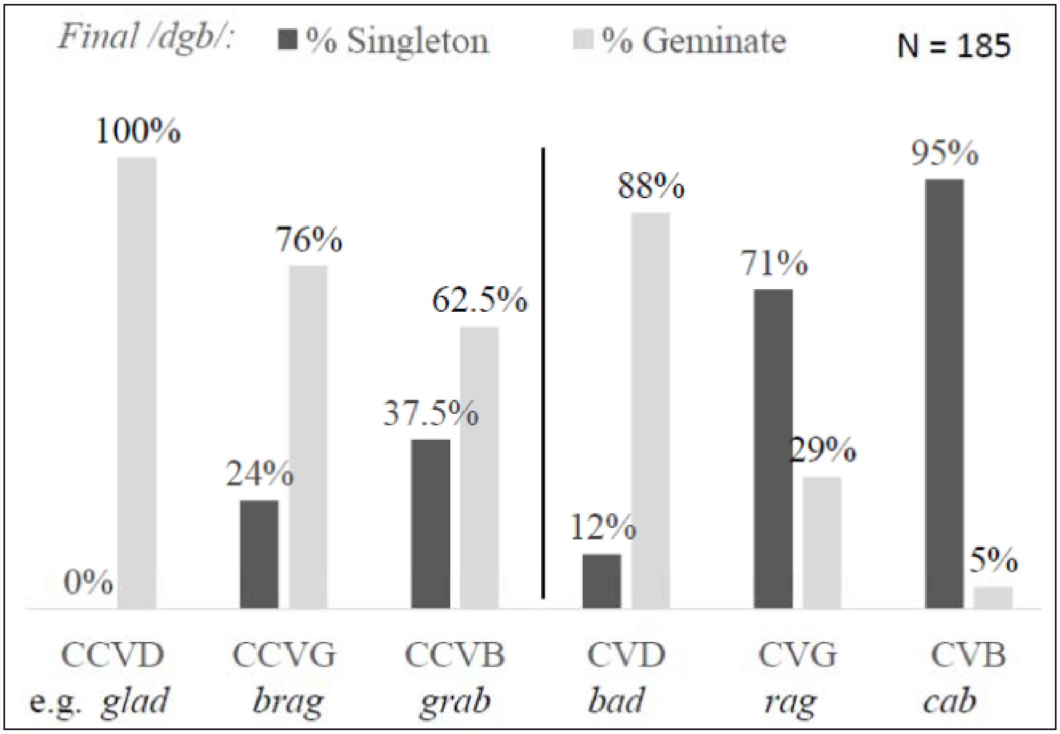
5.2 Prosodic markedness I: NonFinality

We had seen in section 4 that three types of consonants do not geminate word-finally for CVC inputs: /b,g,z/ (NoGem-VoiObs[bgz]), /r,m,n/ (NoGem-Son), and /s,f/ (NoGem-AntFric[sf]). It comes as a surprise, then, that word-final /b,g,z/ (40abc) usually do geminate when the source syllable is CCVC, with a complex onset. /d/ also geminates (*bureddo* 'bread', etc.) here, which comes as no surprise since it also geminates in CVC, just like /p,t,k,ʃ,h/ (*suto'ppu* 'stop', *fura'tto* 'flat', *buro'kku* 'block', *fureffu* 'fresh', *buro'hho* 'Bloch' (name of German philosopher)).

(40)	a.	ra'gu	*rug*	dora'ggu	*drug*
		ra'gu	*lag*	fura'ggu	*flag*
		ro'gu	*log*	furo'ggu	*frog*
		ta'gu	*tag*	suna'ggu	*snag*
	b.	no'bu	*knob*	suno'bbu	*snob*
		ta'bu	*tab*	suta'bbu	*stab*
		ra'bu	*rub*	gura'bbu	*grab*
		ri'bu	*rib*	kuri'bbu	*crib*
	c.	ri'zu	*Liz*	furi'zzu	*frizz*

The pattern here is not exceptionless, there are cases of non-gemination of /b,g/ in CCVC, such as *su'ragu* 'slag' and *ku'rabu* 'club', but the majority pattern to be captured is clearly gemination, as in *suno'bbu* 'snob' and *furo'ggu* 'frog', see (41) for summary statistics. Even for /b/, the most gemination-averse (only 5% gemination in CVC), we find 62.5% gemination in CCVC.

(41)



One of the reasons, we claim, is that the avoidance of a word-final head foot is much stronger in non-minimal words than in strictly minimal words (i.e., consisting of exactly one foot). We acknowledge this by stating a separate and higher-ranking constraint NONFINALITYXFT' for non-minimal words.[14]

(42) NONFINALITY-XFT' (NONFIN-XFT'): The head foot (Ft') is not final in a non-minimal prosodic word.

The general NONFINALITY constraint given earlier in (17) covering all words, including minimal ones, ranks rather low, subordinate even to the general NOGEM constraint, and plays little role in the analysis. Effects of NONFINALITY-XFT' are shown in (43).

(43)	(po'te)to	*po(te'to)	*potato*
	(te're)bi	*te(re'bi)	*television*

Tableau (44) shows the crucial interaction (epenthetic vowels are marked by capitalization): NONFIN-XFT' dominates NOGEM-VOIOBS and commands its violation in *fu*(*ro'g*)*gu* (44c), which is superior to **fu*(*ro'gu*) (44e). The minimal word (*ro'gu*), however, violates only bottom-ranked general NONFIN, hence no violation of NOGEM-VOIOBS is called for, and

[14] It is conceivable that the effects of NONFIN-XFT' can be obtained by the combined action of general NONFIN together with other constraints, but we leave this issue for future exploration.

ro'gu (44a) emerges as the winner. FaithCoda/_]$_{\text{Wd}}$, also ranked below NoGem-VoiObs, is also unable to demand gemination.

(44)

			NonFin-XFt'	NoGem-VoiObs	FaithCoda/_]$_{\text{Wd}}$	NoGem	NonFin
log	☞a.	(ro'gU)			*		*
	b.	(ro'g)gU		*!		*	
frog	☞c.	fU(ro'g)gU		*		*	
	d.	fU(ro'gU)	*!		*		*

A second difference between CVC-inputs and CCVC-inputs is that the latter receive an epenthetic vowel between the first two consonants (*frog* → *furo'ggu*). An alternative output (*fU'ro*)*gU* (see (47j) below) shows retraction of the head foot, and hence the accent, to the antepenult with its epenthetic /u/. However, this option runs afoul of HeadDep (45) (after Alderete 1995), also outranking NoGem-VoiObs.

(45) HeadDep: Segments in a prosodic head in the output have correspondents in the input.

The constraint is violated when an epenthetic vowel carries the accent. Word-final codas /r,m,n/ (subject to NoGem-Son), and /s,f/ (subject to NoGem-AntFric) continue to be singletons in comparable forms (46).[15]

(46)

NoGem-Son	ra'mu	*rum*	do'ramu	*drum*	su'ramu	*slum, slam*
	pi'ru	*pill*	su'riru	*thrill*	gu'riru	*grill*
NoGem-AntFric	ra'fu	*rough*	gu'rafu	*graph*	ku'rifu	*cliff*
	ba'su	*bus*	pu'rasu	*plus*	bu'rasu	*brass*

These non-geminating cases show that HeadDep ranks below the two high-ranking NoGem constraints but above NoGem-VoiObs, as in (47).

15 The frequent word *suta'ffu* 'staff, stuff' is an isolated exception.

(47)

			NoGem-Son	NonFin-XFt'	NoGem-AntFricC/_]$_{Wd}$	HeadDep	NoGem-VoiObs	FaithCoda/_]$_{Wd}$	NoGem
lamb	☞a.	(ra'mU)						*	
	b.	(ra'm)mU	*!						*
gram	☞c.	(gU'ra)mU				*		*	
	d.	gU(ra'm)mU	*!						*
	e.	gU(ra'mU)		*!				*	
plus	☞f.	(pU'ra)sU				*		*	
	g.	pU(ra's)sU			*!				*
	h.	pU(ra'sU)		*!				*	
frog	☞i.	fU(ro'g)gU					*		*
	j.	(fU'ro)gU				*!		*	
	k.	fU(ro'gU)		*!				*	

Taking *fu*(*ro'g*)*gu* (47i) as an example, it is better to violate NoGem-VoiObs than to violate HeadDep, but *gu'ramu* (47c) shows that for NoGem-Son, the opposite holds.[16]

Turning next to complex word-final codas, we find no gemination, neither of the first nor of the second consonant.

(48) /lt/	ka'ruto	*cult*	/sk/	ma'suku	*mask*
/t͡s/ → /lt͡s/[17]	he'rut͡su	*Hertz (G)*	/sp/	wa'supu	*wasp*
/lp/	he'rupu	*help*	/st/	kya'suto	*Cast*
/lb/	barubu	*bulb*	/kt/	da'kuto	*Duct*
/lk/	mi'ruku	*milk*	/pt/	a'puto	*Apt*

Such CVCC-inputs have (LL)L output profiles (cvcU)cU, with two epenthetic vowels (after each coda C).[18] It is revealing to compare the adaptation of inputs with complex codas such as *bulb*, with that of inputs with complex onsets such as *snob* (49d).

[16] Another candidate which fulfills HeadDep is the unaccented (*gura*)*mu*. It loses to (*gu'ra*)*mu* because WordAccent, which demands an accent, dominates HeadDep. A different outcome results with an input like *skull*, which turns into *su̥*(*ka'ru*): Here a constraint barring accent on voiceless vowels prevents *(*su̥'ka*)*ru*, and high-ranking NoGem-Son, which dominates NonFin, prefers *su̥*(*ka'ru*) to **su̥*(*ka'r*)*ru*. NoGem-AntFric also dominates NonFin, resulting in *spiff (up)*→*su̥*(*pi'fu*), but this ranking seems to be variable, like some of the rankings in our analysis, and *su̥*(*pi'f*)*fu* is also found.

[17] /t͡s/ is interpreted as the allophone [t͡s] of /t/ occurring before /u/. German coda /r/ is rendered as /r/, not as vowel length, as in *Berlin* → *beruri'n* and *Merkel* → *me'rukeru*.

(49)

			NoGem-Son	NonFin-XFt'	HeadDep	NoGem-VoiObs	FaithCoda/_]$_{\mathrm{WD}}$	NoGem
bulb	☞a.	(ba'rU)bU					*	
	b.	ba(rU'b)bU			*!	*		*
	c.	ba(rU'bU)		*!	*		*	
snob	☞d.	sU(no'b)bU				*		*
	e.	(sU'no)bU			*!		*	
	f.	sU(no'bU)		*!			*	

The crucial difference here is the location of the epenthetic vowels, which is avoided as bearer of the antepenultimate mora accent, a HEADDEP effect (45). In the complex coda case, the penultimate and the final mora have epenthetic vowels, so the accent can fall on the antepenult without violating HEADDEP or NONFIN, resulting in (*ba'bU*)*rU*) (49a). But in the complex onset case, the antepenultimate and the final mora are epenthetic, so a parallel assignment of accent in *(*sU'no*)*bU*) (49d) violates HEADDEP, and accenting the nonepenthetic penultimate vowel, as in **sU*(*no'bU*) (49f), violates NONFIN. This leaves *sU*(*no'b*)*bU* (49e), where gemination has the effect of moving the accent foot away from the end of the word. This geminating candidate also fulfills prosodic faithfulness (to the word-final coda), but the corresponding constraint FAITHCODA/_]$_{\mathrm{WD}}$ is ranked too low to be able to overcome the objections of NOGEM-VOIOBS by itself.

Finally, we compare *duct* and *pocket*, where the vowel between /k/ and /t/ is epenthetic in the former but underlying in the latter. As background, we first discuss a third example without any epenthesis, *potato*. Here the faithful candidate (*po'te*)*to* (50a) violates none of the constraints under discussion and is not defeatable by some candidate with gemination, in particular not by **pote'tto* (50c), which shows pointless gemination of a consonant which is an onset in the input, not a word-final coda.

[18] Coda clusters of the form /rC/ and /NC/ make heavy syllables: /r/ becomes vocalic (e.g., *ba'aku* 'bark'), and nasals become moraic nasal codas (e.g., *ba'nku* 'bank' or *ra'mpu* 'lamp'). Both result in the prosodic profile [(H')L]. There is one other type of coda cluster, /ks, ps/, which behaves as if the final /s/ is syllabic. We take these cases up in section 5.4 below.

(50)

			NoGem-Son	NonFin-XFt'	HeadDep	NoGem-VoiObs	FaithCoda/_]$_{\text{Wd}}$	NoGem
potato	☞a.	(po'te)to						
	b.	(po't)(teto)						*!
	c.	po(te't)to						*!
	d.	po(te'to)		*!				
duct	☞e.	(da'kU)tO					*	
	f.	(da'k)(kUtO)					*	*!
	g.	da(kU't)tO			*!			*
	h.	da(kU'tO)		*!	*		*	
pocket	☞i.	po(ke't)tO						*
	j.	(po'k)(ketO)					*!	*
	k.	(po'ke)tO					*!	
	l.	po(ke'tO)	*!	*			*	

For the input *duct*, the winning candidate (*da'kU*)*tO* (50e) violates FaithCoda/_]$_{\text{Wd}}$, but its main competitor, *da*(*kU't*)*tO* (50g), with a faithfully geminated word-final coda, suffers from a fatal HeadDep violation. The outcome is different when the second and third consonant are separated by an underlying vowel, as in *pocket*: Here the candidate faithfully geminating the word-final consonant, *poke'tto* (50i), has an underlying vowel in its accented penultimate syllable, which does not violate HeadDep and avoids a violation of NonFin-XFt.

5.3 Prosodic markedness II: InitialFoot

So far, we have only looked at word-final gemination, triggered by both faithfulness (FaithCoda/_]Wd) and markedness (NonFin-XFt'). In this section we turn to word-internal gemination, which comes in several varieties. On the one hand, there are cases of gemination which can only be attributed to orthography,[19] being triggered by doubled consonants, such as *hi'ttaito* 'Hittite', *kappado'kia* 'Cappadocia', or *buryu'sseru* 'Brussels'. Orthographic gemination can also affect consonants which otherwise avoid gemination, such as the sonorants in *d͡ʒire'mma* 'dilemma', *kaperri'ini* 'capellini', or *berri'ini* 'Bellini'.[20] There are also cases of gemination which are morpheme-final and not word-final, such as *kya'ppu+resu*

[19] See Smith 2006 for other cases of orthographic influence on loanwords.
[20] The last two are loans from Italian, where faithfulness to geminates in the source word enters as an additional factor (Tanaka 2007). Morimoto 2015 has shown that even in this vocabulary the prosodic structure of Japanese plays a decisive role in determining gemination and non-gemination.

'cap+less', *attattʃi+me'nto* 'attachment', or *kurokku+wa'izu* ‘clockwise’ (Lovins 1975:93). These can be understood as being due to analogy with their bases, where the consonants in question are in fact word-final, and can be captured by means of Output-Output constraints. What demands our attention here is a third kind of word-internal gemination, which has a definite prosodic base: Word-internal gemination can be triggered by another prosodic markedness constraint, INITIALFOOT. In section 2.3 above, we saw various effects of the INITIALFOOT constraint (51) in reversing language games, baby talk, and loanword truncations.

(51) (=(15)) INITIALFOOT (INITFT): A prosodic word begins with a foot.

INITIALFOOT is violated by word-initial LH sequences because the initial L is prosodically trapped and remains unfooted, since the following H is footed on its own as a bimoraic foot [L(H)…]. This is the constraint responsible for word-internal gemination in cases such as *ku'kkii, *ku'kii* 'cookie or *ha'ppii* **ha'pii* 'happy', illustrated first with a simple minimal tableau below.

(52)

			INITIALFOOT	NOGEM
cookie	☞a.	(ku'k)(kii)		*
	b.	ku'(kii)	*!	

Gemination creates the initially-footed (H)(H) structure, while non-gemination leads to an LH output that violates INITIALFOOT. This is a case of prosodic markedness at work rather than prosodic faithfulness (FAITHCODA), since there are no codas in the source words *cookie* and *happy*. Gemination in words with medial intervocalic voiceless obstruents like *cookie* is the majority pattern that needs to be captured by our analysis. As Kawagoe 2015:114 points out, there is also a minority pattern represented by words like *puppy*→*pa'pii*. This variation can be captured by assuming that this group of words is marked for a variant ranking with NOGEM >> INITIALFOOT.

Further confirmation of the effect of INITIALFOOT can be found in the contrasts between derivationally related words in (53), where the initial trapping effect, and hence gemination, is found only in one case. Gemination in *happy*–type words can in general not be attributed to spelling since double consonants in orthography often do not geminate (e.g., *happiness*), and orthographic singletons, as in *cookie*, do geminate.

(53)	Geminated			Not geminated		
	happy	(ha'p)(pii)	*ha'(pii)	*happiness*	(ha'pi)(nesu)	*(ha'p)pi(nesu)
	happen	(ha'p)(pun)	*ha'(pun)	*happening*	(hapu)(ni'n)gu	*(hap)pu(ni'n)gu
	listen	(ri's)(sun)	*ri'(sun)	*listener*	(ri'su)(naa)	*(ri's)su(naa)

A tableau for contrasts of this type appears in (54) (we henceforth do not mark epenthetic vowels with capitalization, since they are easily identifiable, and not the focus of discussion).

(54)				INITIALFOOT	NOGEM
	happen	☞a.	(ha'p)(pun)		*
		b.	ha'(pun)	*!	
	happening	☞c.	(ha'pu)(nin)gu		
		d.	(ha'p)pu(nin)gu		*!

The geminated (54d) fulfills INITIALFOOT with its initial H (*ha'p*), but so does the ungeminated (54c), where the initial syllable forms a bimoraic foot with the next syllable (*ha'pu*), and is the winner because it does not have a NOGEM violation.

We return here to an observation briefly made in section 4.4 above: The constraint NOGEM-ANTFRIC/_]WD (34) against geminate /s/ and /f/ only holds strictly in word-final position. Candidate (*re'su*) (55a) wins because (*re's*)*su* (55b), which observes coda faithfulness, violates NOGEM-ANTFRIC/_]WD. But once removed from the end of the word, /s/ is free to geminate to fulfill INITIALFOOT, as in (*re's*)(*sun*) (55c). A parallel case with /f/ is *pa'fu* 'puff' vs. *ba'ffaa* 'buffer'. When the end of the word is not involved and neither word-final coda faithfulness nor the ban against word-final geminate /s,f/ is at play, the gemination patterns are regulated by the prosodic markedness constraint INITIALFOOT, as shown by the contrast between *ri'ssun* (55e) and *ri'sunaa* (55h).

(55)

			NoGem-AntFric/_]Wd	FaithCoda/_]Wd	InitialFoot	NoGem
less	☞a.	(re'su)		*		
	b.	(re's)su	*!			*
lesson	☞c.	(re's)(sun)				*
	d.	re'(sun)			*!	
listen	☞e.	(ri's)(sun)				*
	f.	ri'(sun)			*!	
listener	☞g.	(ri'su)(naa)				
	h.	(ri's)su(na'a)				*!

The length of the word by itself is not the responsible factor for gemination, and we find gemination in longer LH-initial words, as in (56).

(56)	*massage*	*ma(saa)d͡ʒi	(mas)(saa)d͡ʒi
	passenger	*pa(sen)(d͡ʒaa)	(pas)(sen)(d͡ʒaa)
	Buckingham	*ba(kin)(gamu)	(bak)(kin)(gamu)
cf.	*pessimist*	(peʃi)(mi'su)to	*(peʃ)ʃi(mi'su)to

Consonants obeying the higher-ranked NoGem constraints (NoGem-VoiObs, NoGem-Son) do not geminate in this [L(H)-configuration, as expected (57).

(57)	*cover*	ka'baa	*ka'bbaa	cf.	*copper*	ko'ppaa	*ko'paa
	cubby	ka'bii	*ka'bbii		*happy*	ha'ppii	*ha'pii
	buggy	ba'gii	*ba'ggii		*lucky*	ra'kkii	*ra'kii
	bazaar	ba'zaa	*ba'zzaa		*essay*	e'ssee	*e'see
	bunny	banii	*bannii		*kitchen*	ki'tt͡ʃin	*ki't͡ʃin
	berry	berii	*berrii		*fashion*	fa'ʃʃon	*fa'son

What comes as a surprise is the fact that the otherwise very gemination-prone /t, d/ remain single in this intervocalic configuration (58).

(58) kitty kitii *kittii cf. kit ki'tto

(58) kitty	kitii	*kittii	cf.	kit	ki'tto
city	ʃitii	*ʃittii			
butter	bataa	*battaa			
bitter	bitaa	*bittaa			
buddy	budii	*baddii	cf.	bad	ba'ddo
body	bodii	*boddii			

Note, however, that this is exactly the context where /t, d/ are flapped (or tapped) in American (also Australian and New Zealand) English. Flaps are extra short segments, very close to the pronunciation of /ɾ/ in Japanese, which also does not geminate (apart from some emphasized or emotional words such as *hirroi* 'very big', as Donna Erickson points out, as well as some loanwords from Italian, see earlier in this section). We take the failure of /t,d/ to geminate in (58) to be a faithfulness effect preserving the extra shortness of the consonant in the input.[21]

(59) FAITHFLAP-LENGTH: Flaps in the source word correspond to singletons in the output.

Tableau (60) shows the interaction between FAITHFLAP and INITIALFOOT.

(60)			FAITHFLAP	INITIALFOOT
city	☞a.	ʃi'(tii)		*
	b.	(ʃi't)(tii)	*!	
body	☞c.	bo'(dii)		*
	d.	(bo'd)(dii)	*!	

A summary tableau with all constraints discussed so far appears in (61).

(61)			FAITHFLAP	NOGEM-ANTFRIC/_]WD	NOGEM-SON	NONFIN-XFT'	HEADDEP	NOGEM-VOIOBS	FAITHCODA/_]WD	INITIALFOOT	NOGEM
bus	☞a.	(ba'su)							*		
	b.	(ba's)su		*!							*
essay	☞c.	(e's)(see)									*

[21] A reviewer suggests that since word-medial flaps as in 'city' and 'body' are nongeminating in Japanese loanwords, word-final /t/ and /d/ geminate (as in [kyatto] 'cat' and [heddo] 'head) so as to avoid being interpreted as flaps (see also discussion in footnote 9).

(61)

			FaithFlap	NoGem-AntFric/_]Wd	NoGem-Son	NonFin-XFt'	HeadDep	NoGem-VoiObs	FaithCoda/_]Wd	InitialFoot	NoGem
	d.	e'(see)								*!	
lucky	☞e.	(ra'k)(kii)									*
	f.	ra'(kii)								*!	
buggy	☞g.	ba'(gii)								*	
	h.	(ba'g)(gii)						*!			*
bunny	☞i.	ba'(nii)								*	
	j.	(ba'n)(nii)			*!						*
city	☞k.	ʃi'(tii)								*	
	l.	(ʃi't)(tii)	*!								*
kit	☞n.	(ki't)to									*
	m.	(ki'to)							*!		

The derivation *bus*→(*ba'su*) (61a) vs. *essay*→(*e's*)(*see*) (61c) shows that NoGem-AntFric prevents prosodic faithfulness from commanding gemination of word-final /s/, but has nothing to say about the gemination of word-medial /s/ to fulfill InitialFoot. *lucky*→ (*ra'k*)(*kii*). (61e) shows that InitialFoot dominates the general antigemination constraint NoGem, but since it is itself dominated by the more specific NoGem-VoiObs and NoGem-Son, we find no gemination, and an initially trapped syllable, in *buggy*→*ba'*(*gii*) (61g) and *bunny*→*ba'*(*nii*) (61i). In *city*→*ʃi'*(*tii*) (61k), FaithFlap prevents turning the flapped /t/ of the American English source word into a geminate to fulfill InitialFoot, but in *kit*→(*ki't*)*to* (61m) prosodic faithfulness demands gemination of the word-final stop to preserve its coda status, violating bottom-ranked NoGem.

Even when they fulfill the segmental conditions on geminability, not all initially trapped L syllables become H by gemination, due to other higher-ranking constraints. An example appears in tableau (62).

(62)

			OCP-GEM	HEADDEP	FAITHCODA/_]WD	INITIALFOOT	NOGEM
gossip	☞a.	go(ʃi'p)pu				*	*
	b.	(go'ʃi)pu			*!		
	c.	(go'ʃ)(ʃipu)			*!		*
	d.	(goʃ)(ʃi'p)pu	*!				**
black	☞e.	bu(ra'k)ku				*	*
	f.	(bu'ra)ku		*!	*		

Here candidate *(goʃ)(ʃi'p)pu* (62d), which fulfills both FAITHCODA/_]WD and INITIALFOOT by geminating both /p/ and /ʃ/, loses against *go(ʃi'p)pu* (62a), which does not geminate /ʃ/ and violates INITIALFOOT. This is due to the force of dominant OCP-GEM, which prohibits geminates in successive syllables (see Tsuchida 1995:158-159 and Ito and Mester 2003:47-52 for the motivation for this kind of constraint).

(63) OCP-GEMINATE (OCP-GEM): Geminates in successive syllables are prohibited.

Candidates (62b, c) manage to fulfill INITIALFOOT without violating OCP-GEM, but are out because they violate FAITHCODA/_]$_{WD}$, which dominates INITIALFOOT. The winner *bu(ra'k)ku* (62e), with an initially trapped syllable but with accent on an underlying vowel, is preferred to *(bu'ra)ku* (62f), which begins with a footed syllable but has the accent on an epenthetic vowel. This is due to the dominance of HEADDEP over INITIALFOOT. Returning to examples discussed above in (50), OCP-GEM dominates FAITHCODA/_]$_{WD}$ and is responsible for the selection of *(da'ku)to* (64a) over *(da'k)(kut)to* (64d), which has otherwise only two violations of low-ranking NOGEM.[22] It also dominates INITIALFOOT, which explains why *po(ke't)to* (64e) is preferred to *(pok)(ke't)to* (64h).

[22] Another serious competitor is **da'(kut)to,* which retracts the accent from the epenthetic vowel (avoiding a HEADDEP violation) and also faithfully geminates the word-final coda. It is out because of a constraint against epenthetic vowels in closed syllables, which is never violated in Japanese and dominates FAITHCODA/_]$_{WD}$.

(64)

			OCP-GEM	HEADDEP	FAITHCODA/_]WD	INITIALFOOT	NOGEM
duct	☞a.	(da'ku)to			*		
	b.	da(ku't)to		*!		*	
	c.	(da'k)(kuto)			*		*!
	d.	(da'k)(kut)to	*!				**
pocket	☞e.	po(ke't)to				*	*
	f.	(po'ke)to			*!		
	g.	(po'k)(keto)			*!		*
	h.	(pok)(ke't)to	*!				**

5.4 Prosodic faithfulness II: PROSODICINTEGRITY

The crucial factor that leads to word-internal gemination involves a light syllable prosodically trapped in word-initial position (INITIALFOOT violation) in the configuration [L(H)…]. For bisyllabic words, this configuration arises when the initial open syllable has a short vowel, and the second syllable is heavy (with a long vowel/diphthong, or closed by a nasal consonant).

Because of the strict syllable structure conditions in Japanese—in particular, NOCOMPLEX (6) and CODACOND (7)—, English H-syllables often become (multiple) L- syllables with epenthesis (cf. the oft-cited disyllabic *Christmas* becoming the 5-syllable *kurisu'masu*). Less often mentioned in the loanword literature is the reverse situation where certain (stressless) English L-syllables are adapted as H-syllables in Japanese, namely, (i) stressless word-final /i/ (orthographic -*y* or –*ie*), (ii) rhotacized schwa (orthographic –*er*),[23] and (iii) the syllabic nasal [n̩], which emerge as *ii*, *aa*, and VN, respectively. We have already seen these cases in (52)–(56) above as triggers, namely as H-syllables in second position triggering INITIALFOOT violations. We list some other profiles to show the generality of this mode of adaptation.

[23] Stressed versions of rhotacized vowels are also rendered as /aa/, such as *sa'abisu* 'service' and *pa'asonaru* 'personal'.

(65)

.Ci. →	(.Cii.)	.Cr̥. →	(.Caa.)	.Cn̥. →	(.CVɴ.)
Winnie	wi'nii	*mother*	ma'zaa	*button̥*	bo'tan
Sandy	sa'ndii	*father*	fa'azaa	*mutton̥*	ma'ton
Mickie	mi'kkii	*sister*	ʃi'sutaa	*captain̥*	kya'puten
Henry	he'nrii	*brother*	bura'zaa	*bacon̥*	be'ekon
Barbie	ba'abii	*daughter*	do'otaa	*token̥*	to'okun
movie	mu'ubii	*toaster*	to'osutaa	*aspen̥*	a'supen
dixie	di'kusii	*manager*	mane'ejaa	*mitten̥*	mi'ton
calorie	ka'rorii	*boxer*	bo'kusaa	*passion̥*	pa'ʃʃon
accessory	akuse'sarii	*computer*	kompyu'utaa		
bakery	be'ekarii	*printer*	puri'ntaa		

Both syllabic /r̥/ and /n̥/ are rendered as heavy syllables (hence also as feet), the former by vocalization and the latter by inserting a full nuclear vowel before the coda (moraic) nasal. Other syllabic consonants in English, namely, the lateral /l̥/ and the labial nasal /m̥/, have regular epenthesis and become /ru/ and /mu/, as in (66).

(66)

phantom	fa'nto*mu*	*sample*	sa'mpu*ru*
rhythm	ri'zu*mu*	*trouble*	tora'bu*ru*
prism	puri'zu*mu*	*Google*	gu'ugu*ru*

Of interest is the fact that these syllabic consonants (occurring with regular epenthesis) appear to be footed together with their onsets in the loanword, as shown in (67b).

(67)

	source →	loan	footing	example	
a.	.Cr̥. →	(.Caa.)	(H)	*daughter* [tr̥]	(do'o)(taa)
	.Cn̥. →	(.CVɴ.)		*bacon* [kn̥]	(be'e)(kon)
b.	.Cm̥. →	(.CV.mu.)	(LL)	*phantom* [tm̥]	(fa'n)(tomu)
	.Cl̥. →	(.CV.ru.)		*sample* [pl̥]	(sa'm)(puru)

This can be interpreted as a preservation of prosodic cohesion: Since these coherent units cannot remain tautosyllabic in Japanese, they at least continue to occupy the same foot: *sample* [pl̥]→(*sa'm*)(*puru*).[24] More formally, we are dealing with sequences of rising sonority XY that are maximal (i.e., Y is not followed by a segment of even higher sonority, such as the /i/ in *tree*). Such sequences play a central role in syllabification patterns as in Berber (Dell and Elmedlaoui 1985; Prince and Smolensky 1993), and constitute the essence of "core

[24] This is an output-oriented way of capturing some of what Kubozono, Ito and Mester 2008 conceived of as extraprosodicity (e.g., of final /ru/, see the discussion in section 2.3 above).

syllable formation" in previous theories of syllabification (such as Steriade 1982). We state the relevant prosodic faithfulness constraint in (68).

(68) PROSODIC INTEGRITY: If X and Y form a maximal sequence of rising sonority in the input, they are parsed within the same word-internal prosodic unit (syllable or foot) in the output.

This constraint ensures that syllabic consonants and their onsets are realized as part of a bimoraic foot, either (H) or (LL). Recall that INITIALFOOT violations arise in the configuration [L(H)], leading to gemination. Given the non-initial foot forced by PROSODIC INTEGRITY, we now also expect the same INITIALFOOT violation in [L(LL)]. This is exactly what happens, as in (69), giving an overt cue to the correctness of this kind of prosodic parse: There would otherwise be no motivation for gemination in cases like *hustle* or *muscle*[25]—*(*ha'su*)*ru* and *(*ma'su*)*ru* have otherwise perfect prosody, their only flaw seems to be that they pull /s/ and /r/ apart.

(69)

	NOGEM violation	PROSODIC INTEGRITY violation	INITIALFOOT violation
hustle [sḷ]	(ha's)(suru)	*(ha' *su)ru*	**ha*'(suru)
muscle [sḷ]	(ma's)(suru)	*(ma' *su*)*ru*	**ma*'(suru)
waffle [fḷ]	(wa'f)(furu)	*(wa' <u>*fu)ru*</u>	**wa*'(furu)
apple [pḷ]	(a'p)(puru)	*(a' *pu)ru*	**a*'(puru)
tackle [kḷ]	(ta'k)(kuru)	*(ta' *ku)ru*	**ta*'(kuru)
Beckham [kṃ]	(be'k)(kamu)	*(be' *ka)mu*	**be*'(kamu)
passim [sṃ]	(pa's)(simu)	*(pa' *si)mu*	**pa*'(simu)

Without making the first syllable heavy through gemination, the alternative candidates either violate PROSODICINTEGRITY or INITIALFOOT. As shown in tableau (70), the geminated version emerges as the winner, with violations of low-ranking NOGEM.

[25] Not even orthographic motivation, a very weak factor at best, see (53) above and the surrounding discussion.

(70)

			FaithFlap	NoGem-Son	NonFin-XFt'	HeadDep	NoGem-VoiObs	FaithCoda/_]Wd	InitialFoot	ProsIntegrity	NoGem
apple	☞a.	(a'p)(puru)									*
[pl̩]	b.	(a'pu)ru								*!	
	c.	a'(puru)							*!		
	d.	a(pu'ru)			*!	*			*		
Beckam	☞e.	(be'k)(kamu)									*
[km̩]	f.	(be'ka)mu								*!	
	g.	be'(kamu)							*!		
	h.	be(ka'mu)			*!	*			*		
hustle	☞i.	(ha's)(suru)									*
[sl̩]	j.	(ha'su)ru								*!	
	k.	ha'(suru)							*!		
	l.	ha(su'ru)			*!	*			*		
cf. *best*	☞m.	(be'su)to						*			
[st]	n.	(be's)(suto)						*			*
	o.	be'(suto)						*	*!		
	p.	be(su'to)			*!	*		*	*		

Whereas *hustle* with input /.sl̩./ cannot be realized as *(*ha'su*)*ru* because /s/ and /r/ are not in the same foot (a ProsodicIntegrity violation), there is no such footing requirement in *best,* where the sequence /st/ does not form a prosodic unit. The nongeminating (*be'su*)*to* is therefore the winner, as we have already seen in detail above in (48)–(49).[26] Similar cases are *help* → (*he'ru*)*pu* and *duct* → (*da'ku*)*to*, where the final CC-cluster need not be in the same foot.

Ranked below InitialFoot, ProsodicIntegrity does not cause gemination when the relevant segments are governed by constraints that we already know to be ranked higher than InitialFoot. Relevant examples are given in (71), and an illustrative tableau in (72).

[26] An interesting contrasting pair of a different kind is *apple* vs. *chapel*: Presumably under the influence of orthography, the first is interpreted as having a syllabic consonant (/æpl̩/), but the second as having an underlying vowel (/t͡ʃæpəl/), with non-syllabic /l/. Consequently, we find *apple* → (*a'p*)(*puru*) but *chapel* → (*t͡ʃa'pe*)*ru*, where the difference in vowel quality is independent evidence for the difference in interpretation.

(71) *middle* (mi'do)ru *(mi'd)(doru)
kettle (ke'to)ru *(ke't)(toru)
rhythm (ri'zu)mu *(ri'z)(zumu)

(72)

			FaithFlap	NoGem-Son	NonFin-XFt'	HeadDep	NoGem-VoiObs	FaithCoda/_]Wd	InitialFoot	ProsIntegrity	NoGem
rhythm	☞a.	(ri'zu)mu								*	
	b.	ri'(zumu)							*!		
	c.	ri(zu'mu)			*!	*			*		
	d.	(ri'z)(zumu)					*!				*
kettle	☞e.	(ke'to)ru								*	
	f.	ke'(toru)							*!		
	g.	ke(to'ru)			*!	*			*		
	h.	(ke't)(toru)	*!								*

The losing non-geminating candidates (72b, f) show that InitialFoot outranks Prosodic Integrity, and the losing geminated candidate (72d, h) that NoGem-VoiObs and FaithFlap dominate ProsodicIntegrity, respectively.

Finally, we find a gemination contrast involving word-final obstruent coda clusters with /s/ in (73). Whereas sC]$_{\text{Wd}}$ (73b) behaves like any other CC-coda in final position (see (73d)), we find gemination in Cs]$_{\text{Wd}}$ (73a) analogous to the final syllabic CC̩ (73c) discussed above.

(73)

a. Cs]$_{\text{Wd}}$	*tax*	[ks]	ta'kkusu	b. sC]$_{\text{Wd}}$	*task*	ta'suku
	mix	[ks]	mi'kkusu		*desk*	de'suku
	dachs[27]	[ks]	da'kkusu		*best*	be'suto
	lapse	[ps]	ra'ppusu		*wasp*	wa'supu
c. CC̩]$_{\text{Wd}}$	*hustle*	[sl̩]	ha'ssuru	d. CC]$_{\text{Wd}}$	*pulse*	pa'rusu
	apple	[pl̩]	a'ppuru		*help*	he'rupu
	buckle	[kl̩]	ba'kkuru		*duct*	da'kuto

Most cases here involve orthographic <x> (*fax*→*fa'kkusu*, *Max*→*ma'kkusu*, *six*→*si'kkusu*, *sex*→*se'kkusu*), but the effect here cannot be attributed solely to spelling, since gemination is regularly found only word-finally (cf. *tax* →*ta'kkusu* vs. *taxi*→ *ta'kuʃii*, *mix*→ *mi'kkusu* vs.

[27] As in *dachshund*, a dog breed.

mixer→*mi'kisaa*), and is also found in the few cases where the orthography does not have <x>, such as *dachs*→*da'kkusu.*

What might be the cause of these cases of gemination? The crucial observation here is that a word-final cluster such as /ks/ in *dachs* (vs. /sk/ in *desk*) forms a maximal XY-cluster of rising sonority, and hence falls under PROSODICINTEGRITY. The explanation for gemination, then, follows along the same lines as in (69)–(70). Tableau (74), with contrasting examples featuring Cs]$_{\text{Wd}}$ vs. sC]$_{\text{Wd}}$ clusters, illustrates how the analysis proceeds.

(74)

			FAITHFLAP	NOGEM-SON	NONFIN-XDT'	HEADDEP	NOGEM-VOIOBS	FAITHCODA/_]WD	INITIALFOOT	PROSINTEGRITY	NOGEM
dachs [k*s*]	☞a.	(da'k)(kusu)									*
	b.	(da'ku)su								*!	
	c.	da'(kusu)							*!		
desk [sk]	☞d.	(de'su)ku									
	e.	(de's)(suku)									*
pils [l*s*]	☞f.	(pi'ru)su									
	g.	(pi'r)(rusu)		*!							
muscle [sl̩]	☞h.	(ma's)(suru)									*
	i.	(ma'su)ru								*!	

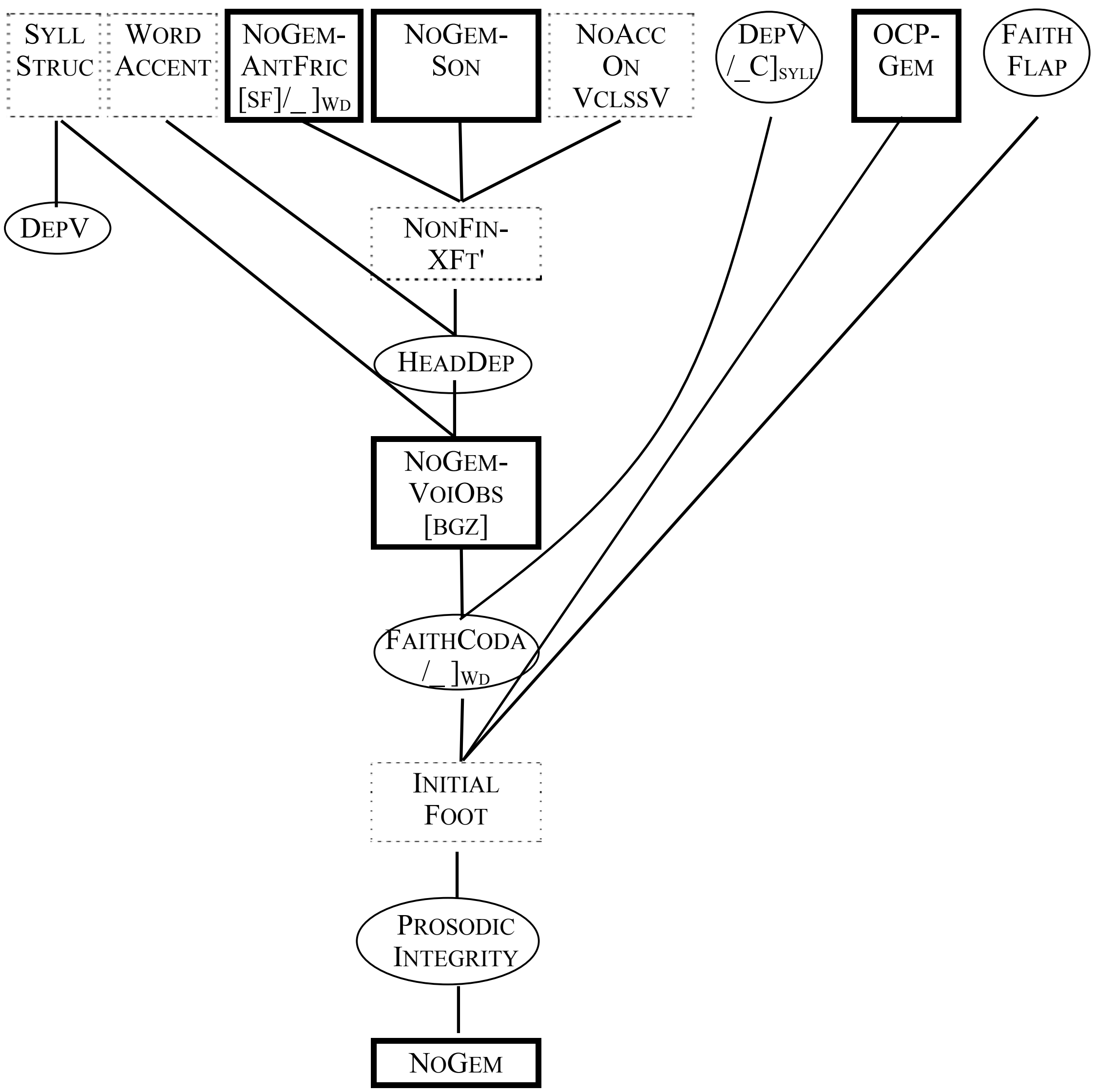
Comparing the relevant forms of the *ks*]$_{\text{Wd}}$- and *sk*]$_{\text{Wd}}$-endings, we see a PROSODICINTEGRITY violation in *(*da'ku*)*su* (74b) and an INITIALFOOT violation in **da'*(*kusu*) (74c), hence geminating (*da'k*)(*kusu*) (74a) emerges as the winner. The output (*de'su*)*ku* (74d), however, violates neither PROSODICINTEGRITY nor NOGEM. For *ls*]$_{\text{Wd}}$- and *sl*]$_{\text{Wd}}$-endings, the winner (*pi'ru*)*su* (74f) violates PROSODICINTEGRITY applying to Cs]$_{\text{Wd}}$ but is still optimal because the geminating (*pi'r*)(*rusu*) (74g)violates higher-ranking NOGEM-SON. On the other hand, the geminating winner (*ma's*)(*suru*) (74h) preserves PROSODICINTEGRITY and violates only bottom-ranked NOGEM.

6 Summary and Conclusion

As a summary of the analysis, we first assemble all constraints that play a role and their ranking. In (75), we reproduce the overall constraint ranking diagram produced by

OTWorkplace (OTW), a software suite developed by Alan Prince, Bruce Tesar, and Naz Merchant that, in the words of its authors, "uses Excel as a platform for interactive research with the analytical tools of modern rigorous OT".[28] In order to bring out the structure of the system, faithfulness constraints have been marked by ovals, and markedness constraints by rectangles. Among the markedness constraints, the special group of segmental anti-gemination constraints have solid borders, whereas the others—all prosodic wellformedness constraints—have broken borders.

(75)



The core data that support these rankings and the analysis, as summarized by OTW in its skeletal basis, appear in (76), adapted to the notations of this paper. The essence of OT's

[28] OTWorkplace_X_83, version of June 27, 2015. The program is open-source and distributed without charge, downloadable from https://``sites.google.com/ site/otworkplace/.

ranking logic is that in each winner-loser pair for a specific input, each constraint favoring the loser must be dominated by some constraint favoring the winner. Being a winner in OT means beating every competitor on the highest-ranking constraint that distinguishes the two. This is most clearly brought out in the comparative tableau format (Prince 2000). In each row representing one such competition, "W" in a constraint column means that the constraint in question favors the winner, "L" that it favors the loser, and no mark that it favors neither. Thus in the first row, "W" in the first column means that the constraint WORDACC requiring words to have accent favors the winner, (*gu*'*ra*)*su*, with accent on an epenthetic vowel, whereas the "L" in the HEADDEP column means that this constraint favors the unaccented winner (*gura*)*su*. The fact that (*gu*'*ra*)*su* is preferred to unaccented (*gura*)*su* supports the ranking WORDACC >> HEADDEP. Another interaction briefly discussed earlier is the preference of *su̥*(*ka*'*ru*) 'skull' over (*su̥*'*ka*)*ru*, which supports the dominance of the constraint militating against accent on a voiceless vowel over the NONFINALITY constraint.[29] "SyllStruc" is a cover constraint combining the three constraints NOCOMPLEX (6), CODACOND (7), and NOSUPERHEAVY (9).

[29] Alternatively, one could interpret the "accent shift" visible here as a switch to iambic foot structure, or even as a strictly phonetic phenomenon.

(76) OTW skeletal basis

Input	Winner	Loser	WordAccent	NoGem-AntFric[sf]/_]Wd	DepV/_C]syll	OCPGem	NoGem-Son	NoAccOnVclssV	SyllStruc	FaithFlap-Length	NonFin	DepV	HeadDep	NoGem-VoiObs[bgz]	FaithCoda / _]Wd	InitialFoot	ProsodicIntegrity	NoGem
glass	(gu'ra)su	(gura)su	W										L					
spiff (up)	su̥(pi'fu)	su̥(pi'f)fu		W							L				L			W
duct	(da'ku)to	da'(kut)to			W										L	W		W
pocket	po(ke't)to	(pok)(ke't)to				W										L		W
skull	su̥(ka'ru)	su̥(ka'r)ru					W				L							W
skull	su̥(ka'ru)	(su̥'ka)ru						W			L					L		
drug	do(ra'g)gu	(dra'gu)							W			L		L	W	L		
bitter	bi'(taa)	(bi't)taa)								W						L		W
class	(ku'ra)su	ku(ra'su)									W		L			W		
drug	do(ra'g)gu	(do'ra)gu											W	L	W	L		L
Bob	(bo'bu)	(bo'b)bu												W	L			W
carat	ka(ra't)to	(ka'ra)to													W	L		L
kettle	(ke'to)ru	ke'(toru)														W	L	
apple	(a'p)puru)	(a'pu)ru															W	L

In conclusion, we would like to highlight three central results of this study. First, as already argued by Kubozono, Ito and Mester 2008, prosodic markedness plays an essential role in the explanation of the gemination and non-gemination patterns in Japanese loanwords. Significant higher-level prosodic factors that are part of the native system are at work and result in gemination. An example is INITIALFOOT, a constraint demanding prosodic words to start out with a bimoraic foot, not with an unfooted syllable, see (Ito & Mester 1992). This is seen in contrasts such as (*.ri's.*)(*sun.*) 'listen' (not **.ri'.*(*sun.*)) vs. (*.ri'.su.*)(*naa.*) 'listener' (not *(*.ri's.*)*su.*(*naa.*)).

Secondly, prosodic faithfulness to the source word also plays a central role. Gemination is a way of preserving word-final codahood in the English source words of consonants geminable in Japanese. The necessity of coda faithfulness in addition to prosodic markedness is clear from examples like the following: The English word *market* exists in two variants, the first with rule-based antepenult mora accent: (*.maa.*)(*ke't.*)*to.*, the second with faithful accent on the first syllable: (*.ma'a.*)(*ket.*)*to.* The gemination of /t/ in the first variant could be explained by NONFINALITY[XFT'], which would be violated in (*.maa.*)(*ke'.to.*)*,* with an accented foot in final position. But NONFINALITY[XFT'] does not explain gemination in (*.ma'a.*)(*ket.*)*to,* which must be due to faithfulness to the coda status of /t/ in English *.mar.ket.* There are many such doublets: *kayákku~káyakku* 'kayak'*, kecháppu~kéchappu* 'ketchup'*, goshíppu~góshippu* 'gossip'*, pokétto~póketto,* 'pocket', etc.

Thirdly, there is not one single constraint against geminate consonants, but rather a whole family of such constraints, ranked at different points within the constraint hierarchy of Japanese grammar (see (75)). Their interleaving with faithfulness constraints and other markedness constraints explains the details of the gemination patterns and crucially requires a system of priority-ranked constraints.

References

Alderete, John D. 1995. 'Faithfulness to prosodic heads'. Rutgers Optimality Archive. ROA-94-0000. http://roa.rutgers.edu/.

Chomsky, Noam, and Halle, Morris. 1968. *The Sound Pattern of English*. New York: Harper & Row.

Dell, François, and Elmedlaoui, Mohamed. 1985. 'Syllabic consonants and syllabification in Imdlawn Tashlhiyt Berber'. *Journal of African Languages and Linguistics* 7:105-130.

Dupoux, Emmanuel, Kakehi, Kazuhiko, Hirose, Yuki, Pallier, Christophe, and Mehler, Jacques. 1999. 'Epenthetic vowels in Japanese: A perceptual illusion?'. *Journal of Experimental Psychology: Human Perception and Performance* 25:1568-1578.

Frellesvig, Bjarke. 2010. *A History of the Japanese Language*. Cambridge, MA: Cambridge University Presss.

Fujisaki, H., and Sugito, M. 1977. 'Sokuon no buturiteki seisitu (Physical properties of geminate obstruents)'. *Iwanami Koza Nihongo* 5:63-98.

Giriko, Mikio. 2008. 'Heibangata akusento seiki zyooken ni taisuru reigai goi ni tuiteno koosatu [remarks on the exceptions to the deaccenting rule in loanwords]'. Handout of talk given at the regular meeting of PAIK (Kobe University, July 5, 2008).

Han, Mieko. 1994. 'Mora timing in Japanese'. *JASA* 96-1:73-82.

Hayes, Bruce, and Steriade, Donca. 2004. 'Introduction: the phonetic bases of phonological markedness'. In *Phonetically Based Phonology*, eds. Bruce Hayes, Robert Kirchner and Donca Steriade. Cambridge, U.K.: Cambridge University Press. 1-33.

Homma, Yayoi. 1981. 'Durational relationship between Japanese stops and vowels'. *Journal of Phonetics* 9:273-281.

Ito, Junko. 1990. 'Prosodic minimality in Japanese'. In *CLS 26: Parasession on the Syllable in Phonetics and Phonology*, eds. Karen Deaton, Manuela Noske and Michael Ziolkowski. Chicago: Chicago Linguistic Society. 213-239.

Ito, Junko, Kitagawa, Yoshihisa, and Mester, Armin. 1996. 'Prosodic faithfulness and correspondence: Evidence from a Japanese Argot'. *Journal of East Asian Linguistics* 5:217-294.

Ito, Junko, and Mester, Armin. 1992. 'Weak layering and word binarity'. Linguistic Research Center Working Paper LRC-92-09, UC Santa Cruz. Published in Takeru Honma, Masao Okazaki, Toshiyuki Tabata and Shin-ichi Tanaka, eds. 2003. A New Century of Phonology and Phonological Theory. A Festschrift for Professor Shosuke Haraguchi on the Occasion of His Sixtieth Birthday. Tokyo: Kaitakusha. 26-65.

Ito, Junko, and Mester, Armin. 2003. *Japanese Morphophonemics: Markedness and Word Structure*. Linguistic Inquiry Monographs, 41. Cambridge, MA, and London, England: MIT Press.

Ito, Junko, and Mester, Armin. 2015. 'Word formation and phonological processes'. In *The Handbook of Japanese Phonetics and Phonology*, ed. Haruo Kubozono. Berlin, Boston, Munich: De Gruyter Mouton. 363-395.

Katayama, Motoko. 1996. 'Gemination in Japanese loanwords'. Ms., University of California, Santa Cruz.

Katayama, Motoko. 1998. *Optimality Theory and Japanese Loanword Phonology*, Department of Linguistics, University of California, Santa Cruz: Doctoral Dissertation.

Kawagoe, Itsue. 1995. 'Shakuyōgo ni miru sokuonka to rizumu shōtotsu [gemination and rhythm clash in loanwords]'. *Gengo Kenkyū [the Study of Language]* 108:46-73.

Kawagoe, Itsue. 2015. 'The phonology of *sokuon*, or geminate obstruents'. In *The Handbook of Japanese Phonetics and Phonology*, ed. Haruo Kubozono. Berlin, Boston, Munich: de Gruyter Mouton. 79-120.

Kawagoe, Itsue, and Arai, Masako. 2002. 'Consonant Gemination in Loanwords'. *Journal of the Phonetic Society of Japan* 6:53-66.

Kawahara, Shigeto. 2015. 'The phonetics of *sokuon*, or geminate obstruents '. In *The Handbook of Japanese Phonetics and Phonology*, ed. Haruo Kubozono. Berlin, Boston, Munich: de Gruyter Mouton. 43-78.

Kawahara, Shigeto, Pangilinan, Melanie, and Garvey, Kelly. 2011. ' Spectral continuity and the perception of duration: Implications for phonological properties of geminates', Ms., Rutgers University. Talk presented at the International Workshop on Geminate Consonants (GemCon 2011). Kobe University, Japan.

Kiparsky, Paul. 2003. 'Accent, syllable structure, and morphology in Ancient Greek'. In *Selected Papers from the 15th International Symposium on Theoretical and Applied Linguistics*, ed. Elizabeth Mela-Athanasopoulou. Thessaloniki. 81-106.

Kitahara, Mafuyu. 1997. ' On'inron to bunpō: Shakuyōgo no sokuon to akusento no bunseki o tsūjite [Phonology and grammar: On the analysis of geminates and accentuation in loanwords]'. In *Bunpō to onsei [Grammar and speech]*, ed. Onsei Bunpō Kenkyūkai. Tokyo: Kurosio. 213-231.

Kubozono, Haruo. 1988. *The Organization of Japanese Prosody*, University of Edinburgh: Doctoral dissertation. Published by Kurosio Publishers, Tokyo, 1993.

Kubozono, Haruo. 1996. 'Syllable and accent in Japanese: evidence from loanword accentuation'. *Bulletin of the Phonetic Society of Japan* 211:71-82.

Kubozono, Haruo. 1999. 'Mora and syllable'. In *The Handbook of Japanese Linguistics*, ed. Natsuko Tsujimura. Oxford: Blackwell. 31-61.

Kubozono, Haruo. 2003. 'The syllable as a unit of prosodic organization in Japanese'. In *The Syllable in Optimality Theory*, eds. Caroline Féry and Ruben van de Vijver. Cambridge: Cambridge University Press. 99-122.

Kubozono, Haruo. 2006. 'Where does loanword prosody come from? A case study of Japanese loanword accent'. *Lingua* 116:1140-1170.

Kubozono, Haruo. 2015. 'Diphthongs and vowel coalescence'. In *The Handbook of Japanese Phonetics and Phonology*, ed. Haruo Kubozono. Berlin, Boston, Munich: De Gruyter Mouton. 215-249.

Kubozono, Haruo, Ito, Junko, and Mester, Armin. 2008. 'Consonant gemination in Japanese loanword phonology '. In *Current Issues in Unity and Diversity of Languages. Collection of the Papers selected from the CIL 18, held at Korea University in Seoul, on July 21-26, 2008*, ed. The Linguistic Society of Korea. Seoul, Korea: The Linguistic Society of Korea. 953-973.

Kubozono, Haruo, Takeyasu, Hajime, and Giriko, Mikio. 2013. 'On the positional asymmetry of consonant gemination in Japanese loanwords'. *Journal of East Asian Linguistics* 22:339-371.

Kunihiro, Tetsuya. 1963. 'Gairaigo hyooki ni tsuite--nichi-ei on'in taikai no hikaku'. In *Nichi-Ei Ruoogo no Hikaku Kenkyuu Jissen Kiroku*. Tokyo: Taishuukan. 27-48.

Lovins, Julie B. 1975. *Loanwords and the Phonological Structure*, University of Chicago: Doctoral dissertation. Distributed by the Indiana University Linguistics Club 1975.

Maddieson, Ian. 1984. *Patterns of Sounds*. Cambridge: Cambridge University Press.

Martin, Samuel E. 1952. *Morphophonemics of Standard Colloquial Japanese*. Language Dissertation No 47. Baltimore: Linguistic Society of America.

Matsui, Michinao F. 2012. ' Shakuyōgo ni okeru sokuon seiki no yokusei yōin [An inhibitory factor of occurrence of voiceless geminate consonants in Japanese loanwords]'. *Theoretical and Applied Linguistics at Kobe Shoin* 15.

McCawley, James D. 1968. *The Phonological Component of a Grammar of Japanese*. The Hague, The Netherlands: Mouton.

Mester, Armin, and Ito, Junko. 1989. 'Feature predictability and underspecification: Palatal prosody in Japanese mimetics'. *Language* 65:258-293.

Mohanan, Philip, Takahashi, Eri, Nakao, Chiziru, and Idsardi, William. 2008. 'Not All Epenthetic Contexts are Equal: Differential Effects in Japanese Illusory Vowel Perception'. In *Proceedings of the 17th Japanese/Korean Linguistics Conference (J/K)*, ed. C. Iwasaki. Stanford, CA: CSLI Publications. 391–405.

Morimoto, Maho. 2015. *Degemination in Japanese Loanwords from Italian*, Department of Linguistics, UC Santa Cruz: M.A. thesis.

Ohala, John J., and Riordan, Carol. 1979. 'Passive vocal tract enlargement during voiced stops'. In *Speech communication papers*, eds. J. J. Wolf and D. H. Klat. New York: Acoustical Society of America. 89-92.

Ohso, Mieko. 1971. *A phonological study of some English loan words in Japanese*, Department of Linguistics, The Ohio State University: M.A. thesis.

Ohye, Saburo. 1967. 'Gairaigochū no sokuon ni kansuru ichi kōsatsu [the mora phoneme /Q/ in English loanwords in Japanese]'. *Onsei no Kenkyū [The Study of Sounds]* 13:111-121.

Poser, William J. 1990. 'Evidence for foot structure in Japanese'. *Language* 66:78-105.

Prince, Alan S. 2000. 'Comparative tableaux'. Rutgers Optimality Archive. ROA-376. http://roa.rutgers.edu/. (Retrieved 8/15/2015).

Prince, Alan S., and Smolensky, Paul. 1993. 'Optimality Theory: Constraint Interaction in Generative Grammar'. RuCCS-TR-2. Ms, Rutgers University and University of Colorado, Boulder, Brunswick, New Jersey, and Boulder, Colorado. [Published 2004, Blackwell. Malden, Mass.].

Selkirk, Elisabeth. 2011. 'The syntax-phonology interface.' In *The Handbook of Phonological Theory.* 2nd edition, eds. John Goldsmith, Jason Riggle and Alan Yu. Oxford: Blackwell Publishing. 435-485.

Shibata, Takeshi. 1994. 'Gairaigo ni okeru akusento kaku no iti [on accent location in loanwords]'. In *Kokugo ronkyuu 4: Gendaigo hougen no kenkyuu [Studies in Japanese 4: Study of Modern Dialects]*, ed. Kiyoji Sato. Tokyo: Meiji Shoin. 388-418.

Shibatani, Masayoshi. 1990. *The Languages of Japan*. Cambridge: Cambridge University Press.

Shirai, Setsuko. 2001. 'Gemination in loans from English to Japanese'. In *Proceedings of the Northwest Linguistics Conference (UBCWPL)*. 155-179.

Smith, Jennifer L. 2006. 'Loan phonology is not all perception: evidence from Japanese loan doublets'. In *Japanese/Korean linguistics 14*, eds. Timothy J. Vance and Kimberly A. Jones. Stanford: CSLI. 63-74.

Steriade, Donca. 1982. *Greek Prosodies and the Nature of Syllabification*, MIT: Doctoral dissertation.

Tanaka, Shin'ichi. 2007. 'Itariago no juushiin to sokuon keisei [Geminate consonants in Italian and sokuon in Japanese]'. In *Proceedings of the 134th Meeting of the Linguistic Society of Japan*. 252-257.

Taylor, Martha. 1985. 'Some patterns of geminate consonants'. In *The University of Chicago Working Papers in Linguistics 1*. 120-129.

Tsuchida, Ayako. 1995. 'English loans in Japanese: constraints in loanword phonology'. In *Working Papers of the Cornell Phonetics Laboratory*. 145-164.

Vance, Timothy J. 2008. *The Sounds of Japanese*. Cambridge, U.K.: Cambridge University Press.