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On Characterizing Sanskrit Gemination

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Abstract

In Sanskrit, various intervocalic biconsonantal clusters are affected by gemination, which is typically summarized by phonetic treatises as follows. First, postvocalic consonants followed by another consonant is geminated as in *sapta-* 'seven' > *sappta-* and *cakra-* 'wheel' > *cakkra-*. Second, consonants that follow *r* or *h* is geminated, as in *artʰa-* 'purpose' > *arttʰa-* and *jihma-* 'oblique' > *jihmma-*. In addition to these two major rules, there are subsidiary processes and different dialects show different variations. Given that Sanskrit gemination affects consonant clusters, earlier studies have analyzed the process in terms of syllable structure, but there are counterexamples that indicate that the syllable-only approaches are inadequate.

This paper reexamines the conditioning factors and restrictions of Sanskrit gemination and concludes that the following three tendencies, which are independent and partly overlap or contradict, interact to produce the observed extensiveness and variations. First, as some of the earlier syllable-based approaches claim, syllable-initial and especially word-initial consonant is geminated. Second, consonants with an oral gesture, especially an oral closure, are preferred targets over those without one, which is in accordance with the cross-linguistic tendency of gemination. Third, the first consonant of the cluster tends to be geminated, which is attributed to the articulatory and perceptual problems associated with preconsonantal consonants.

Keywords: Sanskrit, gemination, consonant clusters, phonotactics, syllable

1. Introduction

Gemination in Sanskrit is prescribed by contemporaneous grammarians and is supported by manuscript and inscriptional evidence, but is also known for dialectal variations, which might cast doubt on its reality (Varma 1929: 63–78, 107–125; Cardona 2013: 51–64). While earlier studies on Sanskrit gemination have presented a uniform syllable-based approach, in this paper I propose that gemination is motivated by phonetic, i.e. articulatory and perceptual, in addition to prosodic factors and suggest the possibility that the phenomenon is a merger of several processes.

In what follows, §2 provides the consonant inventory of Sanskrit, §3 illustrates Sanskrit

gemination and discusses its characteristics and problems, §4 critically examines earlier syllable-based approaches and presents the proposed interpretation of the phenomenon, and §5 supplies conclusions. Instead of presenting variations in individual dialects, I have chosen to discuss the phenomenon as a whole and distinguish the contexts where gemination applies most frequently, where there are variations, and where gemination rarely or never applies. That way, I believe, one can get an entire picture of the phenomenon. Sanskrit examples for gemination are cited mainly from Varma (1929: 63–78, 107–25) and Cardona (2013: 51–64).

2. Consonants in Sanskrit

In (1) is a list of consonants in Sanskrit in the conventional transliteration (Whitney 1889: §75; Macdonell 1910: §4; Cardona 2003: 110; Kobayashi 2004: §11). Consonants in (1a) have a phonemic status and occur in lexical items. Oral stops have five places and four series. Fricatives are asymmetrical in voice contrast: there are three voiceless coronal fricatives and the voiced glottal fricative that historically derived from voiced aspirate stops. Note that the letter *h* represents the voiced glottal fricative while the voiceless glottal fricative in (1b) is represented by an *h* with a dot underneath. Both liquids and glides have syllabic counterparts and thus are categorized as semivowels. A dot under a consonant symbol represents retroflex place in the case of stops and syllabicity in the case of liquids.

(1)   a. Primary consonants

		velar	palatal	retroflex	dental	labial	no oral place
Stops/T							
voiceless	plain	k	c	ṭ	t	p	
	aspirate	k^h	c^h	$ṭ^h$	t^h	p^h	
voiced	plain	g	j	ḍ	d	b	
	aspirate	g^h	j^h	$ḍ^h$	d^h	b^h	
Nasals/N		ṅ	ñ	ṇ	n	m	
Sibilants/S			ś	ṣ	s		
Semivowels/R			y	r	l	v	
(V that alternate with R			i	ṛ	ḷ	u)	
Voiced fricative							h

b. Secondary consonants

Voiceless fricatives	(x)				(ɸ)	ḥ (visarga)
Nasal						ṃ (anusvāra)

Consonants in (1b) arise secondarily from phonological processes and occur only in the coda. The velar and labial fricatives in parentheses are optional allophones of the voiceless glottal fricative called visarga before voiceless velar and labial stops, respectively. Anusvāra, which derives from labial and dental nasals in the coda, lacks a specific place. While it is normally classified as a consonant by modern scholars such as Whitney (1889: §§70, 75), Wackernagel (1896: §223), Macdonell (1910: §4), and Cardona (2003: 109–110), it is realized either as a vowel or as a consonant depending on phonetic treatises (Varma 1929: chapter 9; Cardona 2003: 110, 2013; Suzuki 2013).

Among the consonants in (1), *r*, the voiced glottal fricative in (1a), and those in (1b) do not occur in geminates. These consonants are generally exempt from gemination as will be shown below although there are some exceptions. In addition, a few others in (1a), the retroflex sibilant, the palatal and retroflex nasals, which historically derived from the dental counterpart, do not occur in geminates but can be the target of gemination.

3. Sanskrit gemination

Various phonetic treatises give two rules of gemination (Whitney 1889: §§228–229; Wackernagel 1896: §96–98; Varma 1929: 63–78, 99–125; Hock 1991b: 128–132; Vaux 1992; Kobayashi 2001, 2004: §23; Cardona 2003: 120, 2013: 51–64). According to one of these two, the first consonant of the post-vocalic clusters is geminated with the exception of those that cannot be geminated. The actual application of the rule, however, is more restricted. More specifically, the commonest targets are apparently postvocalic stops preceding another stop, nasal, sibilant or semivowel, in the medial position and in word-initial position preceded by another word as in (2a). Also, a postvocalic sibilant followed by a semivowel is geminated as in (2b). Further, in some cases a semivowel before another is geminated as in (2c).

(2)   a. TC > TTC

   mukta- > *mu**kk**ta-* 'set free'
   sapta- > *sa**pp**ta-* 'seven'
   pāpmanā > *pā**pp**manā* 'with sin'
   agni- > *a**gg**ni-* 'fire'
   adya > *a**dd**ya* 'today'
   cakra- > *ca**kk**ra-* 'wheel'

*putrādinī > pu**ttr**ādinī* 'one who eats her child'

*ak^hyat > a**kk^h**yat* 'looked'

*ā tvā > ā**tt**vā* 'hither you'

*manasā d^hyāyati > manasā**dd^h**yāyati* 'considers with the mind'

*dad^hi atra > da**dd^h**yatra* 'there is yogurt here' cf. *dad^h**yy**atra*

*mad^hu atra > ma**dd^h**vatra* 'there is honey here'

*iṣe tvā > iṣe**tt**vā* 'you for nourishment'

*uru prat^hasva > uru**pp**rat^hassva* 'spread wide'

*rakṣaḥ > ra**kk**ṣaḥ* 'guarding' cf. *kṣīra- > k**ṣṣ**īra-* 'milk'

*cakṣuḥ > ca**kk**ṣuḥ* 'eye'

b. SR > SSR

*viśvataḥ > vi**śś**vataḥ* 'everywhere'

*amuṣya > amu**ṣṣ**ya* 'of that one'

*uru prat^hasva > uru**pp**rat^ha**ss**va* 'spread wide'

c. $R_1R_2 > R_1R_1R_2$

*daivyā > dai**vv**yā* 'divine'

*pṛt^hivyām > pṛt^hi**vv**yām* 'earth'

According to the second rule, the consonant that follows a postvocalic *r* or a voiced glottal fricative is geminated. After *r*, any consonant is geminated as in (3a). However, due to phonotactic constraints, only nasals and semivowels may occur after *h* as in (3b).

(3)　a. *r*C > *r*CC

*arka- > ar**kk**a-* 'ray, sun'

*art^ha- > ar**tt^h**a-* 'purpose'

*ūrd^hvaḥ > ūr**dd^h**vaḥ* 'erect'

*darśapūrṇamāsa > darśapūr**ṇṇ**amāsa* 'new and full moon rites'

*ūrmiṇīḥ mad^humattamāḥ > ūr**mm**iṇīr**mm**ad^humattamāḥ* 'full of flow, most sweet'

*varṣya- > var**ṣṣ**ya-* 'of rain'

*sūryasya > sūr**yy**asya* 'of the sun'

*oṣadīḥ pūrvāḥ > oṣadīφ**pp**ūr**vv**āḥ* 'plants first'

b. *h*C > *h*CC

    jihma- > *jih**mm**a-* 'oblique'

    brahmā > *brah**mm**ā* 'Brahman'

    apahnute > *apah**nn**ute* 'hides, denies'

    bahvīḥ > *bah**vv**īḥ* 'many'

Other cases of gemination of the second consonant are supplied by some phonetic treatises, namely, oral and nasal stops after a fricative as in (4a) and a stop preceded by *l* and a nasal preceded by *v* as in (4b): in both cases the first consonant may geminate instead (Cardona 2013: 53, 57–58).

(4) a. ST/SN (also *ḥ*T) > STT/SNN (~ SST/SSN)

      haste > *has**tt**e* 'in the hand'

      aṣṭābiḥ > *aṣ**ṭṭ**ābiḥ* 'with eight' cf. *a**ṣṣ**ṭābiḥ*

      sparśa- > *s**pp**arśa-* 'touch'

      asmin > *as**mm**in* 'in that one'

      sukṣmā > *sukṣ**mm**ā* 'fine'

      yaḥ kāmayeta > *yaḥ**kk**āmayeta* 'who is to be loved/may be loved'

      manaḥ kṣeme > *manaḥ**kkṣ**eme* 'mind on maintenance'

      viṣṇoḥ kramaḥ > *viṣ**ṇṇ**oḥ**kk**ramaḥ* 'the stride of Viṣṇu'

      vaḥ kāmadʰaraṇam > *vax**kk**āmadʰaraṇam* 'your maintaining desires'

      oṣadīḥ pūrvāḥ > *oṣadīɸ**pp**ūr**vv**āḥ* 'plants first'

  b. *l*T, *v*N > *l*TT, *v*NN (~*ll*T, *vv*N)

      kalpān juhoti > *kal**pp**āñjuhoti* 'offers with the kalpa mantras' cf. *kal**l**pāñjuhoti*

      hiraṇyaśalkān > *hiraṇyaśal**kk**ān* 'pieces of gold'

      pragalbʰaḥ > *pragal**bb**ʰaḥ* 'adept, capable'

      vibʰudāvne > *vibʰudāv**nn**e* 'who grants power' cf. *vibʰudā**vv**ne*

There are also a number of restrictions on gemination supplied in phonetic treatises, which are again subject to dialectal variations (Varma 1929: 110–116; Cardona 2013: 51–64). In terms of targets, as in (5ai), *r*, the voiced and voiceless glottal fricatives, and anusvāra do not undergo gemination; these are the consonants that do not occur in geminates in the first

place.

(5) a. Targets: NOT

(i) *r*, *h*, visarga, and anusvāra; but see (6) below;

(ii) sibilants in any position or sibilants followed by a vowel:

ādarśa- 'mirror', *karṣati* 'draws', *varṣati* 'it rains', but *kṣṣīra-* 'milk';

(iii) geminates and homorganic nasal-stop clusters;

(iv) stop clusters: but *mukkta-*, *sappta-* in (2a).

b. Environments: NOT

(i) intervocalic consonants

(ii) after long vowels: *dātra-* 'sickle', *sūtra-* 'thread, sūtra', but *pāppmanā*,
ūrdd^{h}vaḥ in (2a), *oṣadīϕppūrvvāḥ* in (4a);

(iii) clusters of more than two consonants: *indra-* 'Indra', *rāṣṭra-* 'kingdom',
kārtsnya- 'totality', but *ūrdd^{h}vaḥ* in (2a), *varṣṣya-* in (3a);

(iv) before syllabic liquids: *vismṛta-* 'forgotten', *aniṣkṛtaḥ* 'not defeated, harmed',
ṛdd^{h}iḥkl̥ptam 'thriving';

(v) consonants before yama: *rukk̃mam* (< *rukmam*) 'jewel', but also *rukkk̃mam*;

(vi) after pause:

but fricatives in *hvayāmi* > **hh***vayāmi* 'I call', *ścotanti* > **śś***cotanti* 'drip';

(vii) word-final or pre-pausal position: *ūrk* 'strength' (before pause)
cf. *ūrk ca* > *ūrkkca* 'strength and';

(viii) a consonant that triggers gemination of another: *sukṣ***mm***ā* in (4a).

However, there are some examples of the geminated voiced glottal fricative as shown in (6), that is, initial *h* before *v* or *r* in the first two examples, *h* after *r* or anusvāra in the next three (Varma 1929: 115–116; Cardona 2013: 58).

(6) Gemination of *h*

hvayāmi > **hh***vayāmi* 'I call'
hriyate > **hh***riyate* 'is taken away'
barha- > *bar***hh***a-* 'tail-feather'
siṁha- > *siṁ***hh***a-* 'lion'

*etarhi agniḥ > etar**hh**yagniḥ* 'now Agni'

Also, in (5aii), depending on the dialects, sibilants in any position or prevocalic sibilants are not geminated. In (5aiii), geminates and homorganic nasal-stop clusters are not geminated, but homorganic stop-nasal clusters are affected by gemination. This is because both geminates and homorganic nasal-stop clusters have one single oral closure of a longer duration, which is not further lengthened by gemination, in contrast to stop-nasal clusters with two discontinuous oral closures, e.g., *pāpmanā > pā**pp**manā* in (2a). In this respect homorganic nasal-stop clusters but not stop-nasal clusters are comparable to geminates, the former of which Kirchner (2001: 111) characterizes as "partial geminates". In (5aiv), in a certain tradition, stop clusters are prohibited from undergoing gemination, but there are examples where the first stop is geminated: *mukta- > mu**kk**ta-* and *sapta- > sa**pp**ta-* in (2a) above.

In terms of environments, shown in (5b), gemination generally does not affect intervocalic consonants as in (5bi) and this is a curious restriction because, cross-linguistically, geminates are most common in the intervocalic position (see below this section). According to some, gemination does not occur after long vowels as given in (5bii) or, according to a certain grammarian, in consonant clusters of more than two consonants as given in (5biii), both of which are restrictions on syllable length. Exclusion of consonant clusters before syllabic liquids in (5biv) is to be attributed, as Varma (1929: 111) suggests, to the ambivalent nature of syllabic liquids; for the purpose of gemination, syllabic liquids may also function as consonants, which add an additional consonant to the preceding cluster, and that is excluded by (5biii). In (5bv), gemination does not apply to consonants before yama, literally meaning "twin", which is a partially nasalized stop that arises between a stop and a nasal. Gemination does not apply because the stop together with the following yama is comparable to a geminate, which is exempt from gemination by (5aiii). In (5bvi, vii), consonants after or before a pause are generally not geminated, and, depending on dialects, this prohibition may extend to word-final position. In (5bviii), a consonant does not trigger gemination of two adjacent consonants; for example, in *sukṣ**mm**ā*, the sibilant *ṣ* triggers gemination of the following *m* and thus not simultaneously that of the preceding *k*.

Table 1 summarizes the outcomes of biconsonantal clusters, that is, whether the cluster is affected by gemination and, if so, which consonant is geminated. T, N, and S in the table stand for oral stops, nasal stops, and sibilants, respectively, as in (1). An m-dash "—" denotes impossible consonant clusters due to phonotactic constraints (or accidental gaps); presence or

absence of consonant clusters draws on Turner and Turner (1971) except that vN is supplied based on Varma (1929) and Cardona (2013). A question mark "?" indicates that relevant examples of the predicted outcomes are not found in Varma (1929: 63–78, 107–25) and Cardona (2013: 51–64). The predicted outcomes follow from the following three rules already discussed: (i) the first consonant of the cluster is geminated except for those that cannot be geminated, cf. (2); (ii) the consonant after r or h is geminated, cf. (3a, b); (iii) prevocalic sibilants are not geminated, cf. (5aii). Anusvāra $\dot{m}$ is not included in the table due to its ambivalent nature; there seems to be no strong evidence that anusvāra triggers gemination of the following consonant. NT-clusters are homorganic and SS-clusters are all geminates, both of which are exempt from gemination by (5aiii). Variations are indicated by a slash with the less dominant variant in parentheses.

Table 1: Gemination of biconsonantal clusters C_1C_2

C_2 / C_1	T	N	S	l	v	y	r	h
T	$T_1T_1T_2$	TTN	TTS/(TSS)	?TTl	TTv	TTy	TTr	—
N	NT	?$N_1N_1N_2$	—	?NNl	?NNv	?NNy	?NNr	—
S	STT/(SST)	SNN/(SSN)	SS	?SSl	SSv	SSy	?SSr	—
l	lTT/(llT)	?llN	—	ll	?llv	?lly	—	?llh
v	—	vNN/(vvN)	—	—	vv	vvy	?vvr	—
y	—	—	—	—	—	yy	—	—
r	rTT	rNN	rS	?rll	rvv	ryy	—	rh/(rhh)
h	—	hNN	—	?hll	hvv	?hyy	hr/(hhr)	—
$ḥ$	$ḥ$TT	—	?$ḥ$S	—	—	—	—	—

Sanskrit gemination is, in some respects, typologically unique. As has been shown by earlier cross-linguistic studies including Thurgood (1993), Kirchner (2001: chapter 5), and Kraehenmann (2011), geminates are most common in the intervocalic position, but Sanskrit gemination normally does not affect intervocalic single consonants (Varma 1929: 63). Other languages do have gemination that affects consonant clusters, but it is typically more restrictive. For example, in Proto- and West Germanic only the consonants preceding glides and liquids are geminated: OE *bi**dd**an*, OS *bi**dd**ian*, OHG *bi**tt**en* as opposed to Go. *bidjan*, ON *biþia* (Prokosch 1939: §30; Hock 1974: 245–246; Vennemann 1988: 42–50; Hogg 1992: 57, 71–72).

As for the motivation of gemination, of the seven "general pathways of geminate evolution" in Blevins (2004: 170–171), two concern gemination: lengthening under stress (including expressive lengthening) and boundary lengthening. While gemination is common after a stressed vowel, Sanskrit gemination is not conditioned by accent. The geminated consonant either precedes or follows an accented vowel and it occurs both in an accented and in an unacceted syllable: e.g., *ártt^{h}a-* 'purpose', *jih**mm**á-* 'oblique', ***aggn***í- 'fire', *vax**kk**āmad^{h}áraṇam* 'your maintaining desires' (Wackernagel 1896: §98a; Cardona 2013: 51–64). Lengthening under stress is apparently associated with stress accent. However, Sanskrit accent is "musical" or of pitch-type (Whitney 1889: §80; Wackernagel 1896: §244a; Macdonell 1910: §83), which is not likely to lead to lengthening. Also, Sanskrit gemination is obviously not expressive gemination. The second type of gemination of Blevins is boundary lengthening in the phrase-final position, but this is an environment where Sanskrit gemination typically does not occur (cf. (5bvii)). The motivation behind Sanskrit gemination is apparently not of the common types, which would leave the question as to what motivates Sanskrit gemination.

In terms of targets, consonants with an oral closure are preferred over those without one irrespective of the consonant order. In (7) is the hierarchy of consonants in terms of susceptibility to gemination.

(7)   Susceptibility to Sanskrit gemination:
       oral stops > nasal stops > sibilants > *l, v, y* > *r, h, ḥ, ṁ*

Oral stops are the most frequent target (Varma 1929: 63–64), which geminate either as the first member of a cluster preceding any consonant or the second after any consonant. Next, nasal stops undergo gemination typically as the second member of consonant clusters after sibilants or semivowels, but not after stops. On the other hand, sibilants are geminated typically as the first member before semivowels, and optionally before oral and nasal stops. I have placed nasals between stops and sibilants because in the sequence of a sibilant and a nasal, it is primarily the nasal that gets geminated. Semivowels vary in their susceptibility to gemination (Suzuki 2014). Glides *y* and *v* geminate after *r* and *h*. The liquid *l* optionally geminates before stops. On the other hand, *r* does not geminate. Finally, glottal fricatives and anusvāra, sounds that lack a specific oral gesture, do not geminate as a rule although there are examples as in (6) where the voiced glottal fricative geminates when preceded or followed by certain semivowels.

This hierarchy of susceptibility to gemination is on the whole in accordance with the general tendency of consonant classes to occur as geminates. Thus, based on a survey of 44 languages with gemination, Maddieson (2008: 1928–1929) notes that the following are likely to occur as geminates: stops > nasals > fricatives > liquids > glides > *h* in descending order (also Hock 1974: 244–245; Kirchner 2001: 114–116). There are two differences between the hierarchy in (7) and the cross-linguistic tendency that Maddieson gives. First, Maddieson's survey suggests that liquids are more likely to geminate than glides, but this is not the case in Sanskrit gemination. Further, in Sanskrit, the two liquids show distinctly different behaviors in gemination: *l* may geminate but not *r*.

The asymmetry of the two liquids is cross-linguistically observed (Proctor 2009: 38–45; Proctor and Walker 2012) and in Sanskrit is not restricted to gemination, but is also observed in external sandhi (Whitney 1889: §§202, 206, 213; Wackernagel 1896: §§276, 280, 281, 283; Allen 1962: 80–81, 84, 91–93; Macdonell 1910: §§75–77; Renou 1975: §§33–35; Cardona 2003: 116–117; Kobayashi 2004: §66; Suzuki 2014). While the two liquids generally form a natural class, in Sanskrit *l* and *r* behave in parallel with stops and sibilants, respectively, apparently due to the presence or lack of an oral contact; for discussions and examples, see Suzuki 2014. In addition, both liquids and glides alternate with a syllabic counterpart and together form a class of semivowels in traditional Sanskrit grammar: see above §2. The idiosyncracy observed in the hierarchy in (7), therefore, is not peculiar to gemination, but can be attributed to the consonant system of Sanskrit as a whole.

The next section attempts to account for the extensiveness, variations, and the obscure motivation that apparently result from these two features.

4. Analysis

In the recent literature on theoretical phonology, there are two major approaches, i.e., prosodic or syllable-based and phonetic or phonotactic, to phenomena involving consonant clusters such as assimilation, deletion, epenthesis, and well-formed consonant clusters. On the one hand, prosodic approaches attribute the phenomena observed in consonant clusters to a move towards less marked prosodic structure or improvement of the syllable structure (Parker 2011 and references therein). On the other hand, phonetic approaches find perceptual or articulatory motivations behind the same phenomena such as cue enhancement, misperception, and gesture retiming (Ohala 1981, 1997, 2005; Browman and Goldstein 1989,

1990, 1991, 1992; Côté 2000; Blevins 2004; Wright 2004 among others). For example, Jun (2011: 1103) compares "prosody-based approach" and "cue-based approach" to account for C_2 dominance effect in C_1C_2-clusters and Seo (2011: 1259) resorts to the notion "segment contact" as opposed to "syllable-contact". To account for phonotactics, acoustic/perceptual and articulatory bases have been proposed as an alternative to sonority that supplies the basis of the syllable (e.g. Kawasaki-Fukumori 1992; Ohala and Kawasaki 1997; Henke, Kaisse, and Wright 2012; Proctor and Walker 2012).

While these two approaches tend to be treated as alternatives, they do not always contradict and often yield the same predictions. Moreover, particular phonological processes may operate in multiple dimensions, both prosodic and phonotactic. The approach adopted in this paper thus incorporates both aspects observed in Sanskrit gemination. The idea that a phonological phenomenon reflects different aspects is inspired by the framework of Optimality Theory, according to which the grammar consists of a set of universal constraints whose different rankings yield different outcomes (e.g. Kager 1999; McCarthy 2008b), although the paper does not resort to the apparatuses such as formulated constraints and tableaus for the comparison of different constraint rankings.

4.1. Critique on earlier approaches to gemination

Earlier studies beginning with Varma (1929: 63–64, 70) have analyzed the process in terms of syllable structure, according to which gemination attains a more preferred syllable structure or results from resyllabification (also Hock 1974, 1991a: 138, 1991b; Vennemann 1988: 33–35; Vaux 1992; Cho 1999: 153–167; Kobayashi 2001: 96–97, 2004: 31–32; Calabrese 2009). Whatever the motivation of the exact course of development, these analyses presuppose that the resultant sequence has the syllable boundary between two components of the geminate, i.e. either VC_1-C_1C_2V or VC_1C_2-C_2V, depending on which consonant is geminated.

In fact, some of the restrictions on gemination pertain to syllable length, namely, prohibition of gemination after a long vowel in (5bi) and gemination in clusters of more than two consonants in (5bii), which suggests that Sanskrit gemination is motivated or at least conditioned by syllable structure. In addition, in many cases, gemination appears to affect the onset-initial consonant (Cho 1999; Calabrese 2009). That is, TR > TTR such as *cakra-* > *cakkra-* and SR > SSR such as *amuṣya* > *amuṣṣya* in (2) follow from syllabification of both consonants of the input cluster into the onset. On the other hand, in *r*C > *r*CC such as *art^ha-* > *artt^ha-* and *h*C > *h*CC such as *jihma-* > *jih**mma**-* in (3), the two consonants in

the cluster are heterosyllabic and thus only the second is in the onset. Variations such as ST > STT ~ SST, e.g., *aṣṭābiḥ > aṣṭṭābiḥ ~ aṣṣṭābiḥ*, may be attributed to two possible ways of syllabification, in which either of the two consonants may be onset-initial. Strengthening in the onset is a common phenomenon cross-linguistically (Hock 1991a: 83; Spencer 1996; Kirchner 2001; McCarthy 2008a; Jun 2011; Yu 2011) and thus is a plausible assumption for Sanskrit gemination. It is also a plausible account for the exceptional gemination of a fricative after pause in (5bvi) and of *h* in (6): *hvayāmi > **hh**vayāmi, ścotanti > **śś**cotanti, barha- > barhha-*.

However, the interpretation of gemination as strengthening of the onset-initial consonant cannot be extended to all cases of gemination because coda consonants, which are typically subject to weakening, are also geminated: $T_1T_2 > T_1T_1T_2$ as with *sapta- > sa**pp**ta-* in (2a) and $lT > llT$ as with *kalpān juhoti > ka**ll**pāñjuhoti* in (4b). Examples such as these do not support the assumption of Cho (1999) and Calabrese (2009) that gemination affects the syllable-initial consonant. Therefore, approaches based on the position are descriptively inadequate, at least in part.

The last set of examples is also problematical for the assumption that the geminated consonants strand over two syllables, which is presupposed by all the syllable-based approaches. More specifically, the clusters of two distinct stops, as exemplified at the beginning of (2a), e.g., *mukta- > mu**kk**ta-* and *sapta- > sa**pp**ta-*, cannot be analyzed straightforwardly in syllable-based approaches because gemination yields an onset of two stops, i.e., $VT_1\text{-}T_1T_2V$, which is a change towards a highly marked structure that Sanskrit originally lacked. Also problematical is the alternate development of $lT > llT$, *kalpān juhoti > kallpāñjuhoti* in (4b), which would yield the onset cluster of lT. Syllabification of geminates to two successive syllables is not necessarily supported by the phonetic treatises, either, which give variable syllabification such as *ā tvā* 'hither you' *> ātt-vā ~ āt-tvā*, *agnim* 'fire' *> agg-nim ~ ag-gnim*, *pārṣṇyā* 'with the heel' *> pārṣṣ-ṇyā ~ pār-ṣṣṇyā, pārṣṣṇ-ṇyā*, *rukmam* 'jewel' *> rukkk̃-mam ~ rukk-k̃mam* (Varma 1929: chapter 2; Cardona 2013: 51–64). While these examples may be extreme cases, syllabification *sapp-ta* and *mukk-ta*, *kall-pān* with no aberrant onset clusters appear more reasonable than that where geminates are separated into two syllables such as *sap-pta*, which requires justification.

I have discussed here some problematical issues of the syllable-based approaches rather than examining individual analyses in detail; see Suzuki 2012: 195–196 for critical evaluation of various syllable-based approaches. While the observed facts suggest that syllable-based

factors are in fact relevant, the problems just discussed suggest that gemination as a whole resists a uniform analysis based on syllable structure, that change in syllable structure may be at least in part a result rather than the cause, and that motivation for Sanskrit gemination must be sought elsewhere.

A different type of interpretation is presented in de Saussure (1889). He assumes that single and geminate dental stops are not distinguished in the position preceding a sonorant consonant. The hypothesis is supported by Whitney's (1889: §232) observation that preconsonantal geminate stops are written as single stops in manuscripts. However, lack of distinction between single and double consonants does not necessarily motivate gemination and much less extensive gemination beyond the contexts that de Saussure assumes (also Hock 1974: 247). Also, lack of distinction between single and double consonants in manuscripts does not necessarily imply lack of distinction in actual speech. Thus, while it may not have been de Saussure's intention to pursue the motivations behind all cases of Sanskrit gemination, his hypothesis is untenable as a single factor to encompass various types of gemination in Sanskrit.

4.2. Phonotactic factors in gemination and gemination as a composite phenomenon

To recapitulate the discussions in §3, there are three features observed in Sanskrit gemination: (i) gemination affects various types of consonant clusters and not intervocalic single consonants; (ii) the preferred targets are stops rather than consonants without an oral closure or, more broadly, an oral gesture; (iii) with the exceptions of *r*, *h*, visarga, and anusvāra, the target tends to be the first or postvocalic consonant of the clusters.

The first feature has led to the interpretation that gemination is conditioned by the syllable structure, but §4.1 has shown that the syllable-only approach cannot be supported. Another possible interpretation of this feature is that gemination results from phonetic effects of consonant sequences. That is, in articulation, gemination resolves the difficulty of articulating consonant sequences (Fourqué 1927; Suzuki 2012). In perception, preconsonantal consonants are more difficult to perceive than prevocalic consonants and may require remedy in some way. The phonetic interpretation predicts that the first consonant is more liable to be affected, which is the third feature discussed below. On the other hand, intervocalic single consonants pose no comparable difficulties.

The second feature concerning the preferred targets is in accordance with the cross-linguistic tendency and thus requires no further explanation. As already discussed,

consonants with an oral closure are more easily lengthened than those with a stricture (Kirchner 2001; Maddieson 2008). The susceptibility hierarchy in (7) above is independent from the order of the affected consonants in the consonant clusters and this is one aspect of Sanskrit gemination that partly contradicts with the third feature concerning the order of the target consonants. In this respect the process is characterized as a lengthening of the oral gesture, especially closure (Suzuki 2012).

As the third feature, the first consonant of the cluster has a prominent tendency to become the target of gemination with the exceptions of those that cannot be geminated: here the second feature overrides the third. However, the order determines the affected consonant when the two consonants that form a cluster are equally susceptible to gemination. This applies to the clusters of two distinct stops, where both consonants have an oral closure, e.g., *mukta-* > *mukkta-* and *sapta-* > *sappta-*. There are also variable outcomes where the second and the third features interact such as alternates of sibilant-stop clusters, the *l*-stop clusters, and the *v*-nasal clusters, e.g., *aṣṭābiḥ* > *aṣṭṭābiḥ* ~ *aṣṣṭābiḥ*, *kalpān juhoti* > *kalppāñjuhoti* ~ *kallpāñjuhoti*, *vibʰudāvne* > *vibʰudāvnne* ~ *vibʰudāvvne* in (4), where the first and the second variants follow from the second condition on consonant classes and the third condition on the order, respectively. The third feature may also be responsible for the exceptional gemination of the voiced glottal fricative such as *hvayāmi* > **hh***vayāmi*.

I have already stated in §3 and §4.1 above that there are apparently length restrictions that constrain gemination. In addition, part of the environments where gemination occurs is the strong positions such as syllable-initial and word-initial positions, where fortition typically occurs cross-linguistically. Thus, as shown above, word-initial consonants can be the targets for gemination while word-final consonants typically do not undergo gemination; in fact, the word-final position is normally affected by lenition, in Sanskrit by external sandhis or assimilation to the following consonant. I propose, therefore, that Sanskrit gemination is a composite phenomenon that results from articulatory, perceptual, and syllabic factors.

Finally, given the fact that a single factor cannot encompass the entire phenomenon, Sanskrit gemination is likely to have resulted from several processes with restricted targets and contexts such as lengthening of fricatives in phrase-initial position in addition to the two major rules by Indian grammarians. Or, due to the amount of variations, these two rules might in turn consist of several processes, for example, lengthening of stops before *r*, fortition of glides after *r* and *h*, and lengthening of stops before stops. This seems to be the only reasonable way to account for the variation, extensiveness, and heterogeneity of the

phenomenon.

5. Conclusions

I have attempted to show that, in identifying tendencies observed in numerous variations, Sanskrit gemination is phonotactically motivated and not just prosodically as earlier analyses suggest. The lengthening of the oral gesture, especially closure, the lengthening of the first consonant, fortition in syllable-initial position, and restriction on syllable length, interact to produce the observed outcomes. These independent but interacting factors partly overlap but may contradict, in which case there arise variaions.

Sanskrit gemination is prescribed by Pānini and various Prātiśākhyas, and these treatises are dated to the late Old Indo-Aryan and early Middle Indo-Aryan stages. It is apparently a change in progress, which has been considered to have led to Middle Indo-Aryan assimilation by a number of scholars beginning with Jacobi (1881) (Varma 1929; Murray 1982; Vaux 1992; Cho 1999; Suzuki 2012). It is likely to be a testimony of the beginning stages of vast assimilation and cluster reduction that affected most of the consonant clusters in later stages.

While my interpretation of the phenomenon still requires further elaboration and justification, based on the observed facts, I believe it is in the right direction. Variations and extensiveness observed in Sanskrit gemination arise from the interaction of more than one factor and the merger of more than one process. While we typically know only the inputs and outputs of historical changes, without evidence of how the changes proceeded, variations of Sanskrit gemination suggest that they resulted from interactions of different aspects that form phonetic realization.

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