

A Gestural Approach to Gemination and Nasals in Pali

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1. Introduction

Pali is a Middle Indo-Aryan dialect whose mother language is Sanskrit. It is no longer spoken. However, as it is the language used in early Buddhist scriptures, its grammar is still commonly taught. A very rich body of work exists (Whitney, 1889; Gray, 1899; Duroiselle, 1906; Junghare, 1979; Vaux, 1998; Cser, 2000; Suzuki, 2002a,b; Gupta, 2003) on Pali's sound system and how it relates to Sanskrit. A common theme in this research is the phonological process of assimilation. Pali evidences both progressive and regressive assimilation and it is generally the case that a consonant geminate is formed, as evidenced in (1a) and (1b), respectively:

- (1) a. progressive assimilation: Sanskrit: *cakra* 'wheel' → Pali: *cakka*
b. regressive assimilation: Sanskrit: *sapta* 'seven' → Pali: *satta*

At first blush, the direction of the assimilation appears to be dictated by syllable structure (Junghare, 1979: 128); progressive assimilation occurs when the consonant cluster is tautosyllabic (i.e, a complex onset), and regressive assimilation occurs when the cluster is heterosyllabic (i.e, C₁ is in coda position and C₂ is the onset of the following syllable). In the case of (1a), the cluster is a complex onset. The rhotic (C₂) assimilates to the same point of articulation as the previous consonant, a voiceless velar stop in this case, which results in the geminate form in Pali. However, in (1b), the cluster is heterosyllabic. Thus, the voiceless bilabial stop (C₁) assimilates to the same point of articulation as the following consonant, a voiceless dental stop, which also results in the geminate form in Pali.

However, in the case of nasals, cases appear which seem contradictory to an analysis based solely on syllable structure. For example, when the nasal is the second element of the cluster, we find cases of both progressive and regressive assimilation, even though the nasal is in the onset position in both instances, as in (2):

- (2) a. progressive: Sanskrit: *lagna* 'clung' → Pali: *lagga*
b. regressive: Sanskrit: *dharmā* 'righteousness' → Pali: *dhamma*

In the case of progressive assimilation (2a), we evidence the expected gemination, yet it is the (unexpected) onset that assimilates to the previous syllable's coda. Many linguists (Junghare, 1979; Cser, 2000; Suzuki, 2002a,b) have noted the effect of sonority on Pali gemination. The examples in (2) above (and for all consonant clusters, in general) are explained by simply stating that the consonant with greater sonority assimilates to the consonant with lesser sonority. That withstanding, a problem arises when the nasal is the first element of the cluster¹. In consonant clusters in which a nasal is in coda position, gemination is blocked, as in:

¹ Progressive assimilation when a nasal is in coda position is unattested in Pali (Cser, 2000).

(3) Sanskrit: *danta* ‘subdued’ → Pali: *danta*

Given the heterosyllabic context, we would expect the Pali word in (3) to be **datta*, however gemination is blocked and the Pali word maintains the original cluster. In short, Pali evidences gemination of consonant clusters which, in general, seems to be dictated by both syllable structure and sonority.

We have seen above, however, that when a nasal is in coda position, gemination is blocked. The purpose of the current study is to offer a solution to these regressive cases in which it is blocked in articulatory terms. Previous accounts have been very thorough in their treatment in terms of gemination and lack thereof in consonant clusters. Duroiselle (1906) offers a description of nasal assimilation in terms of natural class. Junghare’s (1979) linguistic account uses features, rule-ordering, utosegmental phonology, and segmental features, along with Jespersen’s (1909) sonority scale. Cser (2000) offers an account based on sonority. Suzuki (2002b) analyzes the problem within an OT framework. The current analysis builds from these analyses and is novel in at least three ways: first, it offers an analysis that is based on articulatory constraints, as opposed to simply noting the nasals in regressive assimilation as an exception to the gemination. Second, it analyzes the phenomenon using a theoretical framework that incorporates an articulatory representation in the form of gestural scores, and an abstract representation, in the form of Byrd’s (1994, 1996b) notion of a Phase Window; by doing so, we gain insight into the articulatory conditions that affect nasal assimilation in Pali. Finally, it tests a recent framework on what is considered a ‘dead language’.

The rest of the paper is organized as follows: §2 offers a background of the language and its consonant and vowel inventory. §3 discusses Pali gemination and discusses in further detail previous accounts relating to this issue. §4 offers the current analysis using a gestural approach and finally, §5 concludes.

2. The Pali language

Pali is one of 13 unclassified Middle-Aryan dialects (Gordon, 2005). It is derived from Sanskrit and has remained quite similar to it, which in all likelihood is due to its primarily spoken usage mostly by Buddhist monks, from roughly the 6th Century BC to the 3rd Century BC (Gupta, 2003). Junghare (1979) notes its possible origins in Northeast India (in the modern province of Bihar) and observes it is the possible origin to the language, Magadhi:

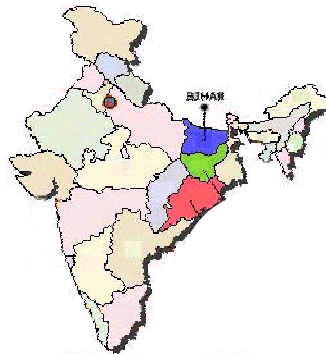


Figure 1: Possible origins of Pali

Pali went from a primarily-spoken language to one known for its written form when it was used to write the Tipitaka, the body of work that comprises the early Buddhist scriptures (1st Century BC). In modern usage, it continues to be the liturgical language of Theravadan Buddhists, which comprise many Southern Asian countries such as India, Sri Lanka, Bhutan, Burma (Myanmar), Thailand, Cambodia, Vietnam. In short, Pali is rather unique in that it was a spoken variety of Sanskrit spoken by few, yet holds the distinction of being the language used to write an astonishingly long text that is the canonical work for one of the World’s main religions.

Pali’s inventory consists of forty-four phones – thirty-six consonants and eight vowels. As in Latin, vowel duration in Pali is phonemically-contrastive. The alphabet is phonetically based, in that every letter represents only one sound. The following offers the consonant inventory:

		Velar	Palatals	Retroflex	Dentals	Labials
voiceless	unaspirate	k	c	t	t	p
	aspirate	k ^h	c ^h	t ^h	t ^h	p ^h
voiced	unaspirate	g	j	ɖ	d	b
	aspirate	g ^h	j ^h	ɖ ^h	d ^h	b ^h
	nasal	ṅ	ñ	ṇ	n	m
	liquid			r, l, l ^h		
	spirant	h				
	sibilant		ś	ṣ	s	
	labiodental					v
	glide		y			

Table 1: The Consonant Inventory for Pali (adapted from Duroiselle, 1906: 6; Suzuki, 2002a: 101)

In Table 1, take note that the dot below the retroflex consonants is at times represented to the left of the consonant (e.g. .l or l) in older texts. Similarly, the tilde (i.e. ~) may either be listed above or to the left (e.g. ñ or ~n). I note one letter, often represented as ‘ṅ’ is not listed above (listed as ‘m’ by Suzuki, 2002a). Duroiselle (1906) notes that this phone ‘has no classification; it is merely a nasal breathing found after short vowels’ (6). He labels it ‘*niggahita*’, whereas Suzuki (2002a) labels it ‘*anusvāra*’.

With regard to the vowel inventory, Pali has eight vowels. Pali maintains phonemic contrast with regard to duration for the front and back vowels, but not for the mid vowels.² The following table offers the vowel inventory:

Place of articulation	Vowels
front	i, ī, u, ū
mid	o
back	a, ā, e

Table 2: The Vowel Inventory for Pali (adapted from Duroiselle, 1906)

² It is worth noting, giving Pali’s phonemic contrast in vowel duration, that Pali is written in the literature as either ‘Pali’, ‘Paali’ or with the macron, ‘Pāli’.

Observe in the above table that ‘e’ is listed as a back vowel. This letter was pronounced like an ‘a’ in the English word, ‘fate’ (Duroiselle, 1906: 6). The written form of the other vowels coincides with their modern phonetic symbols.

3. Pali gemination

3.1. Junghare (1979)

Grammarians (Whitney, 1889; Duroiselle, 1906) first noted both progressive and regressive assimilation in Pali around the beginning of the 20th Century. They noted that both forms of assimilation generally result in gemination. In Junghare’s (1979) book on Pali phonology, she discusses gemination resulting from both types of assimilation in terms of syllable structure and sonority. She goes beyond syllable structure and utilizes Jespersen’s (1909) sonority scale, which I list in the following table:

Category	Sonority Value
Low vowels	1
Mid vowels	2
High vowels	3
Glides	4
Liquids	5
Nasals	6
Voiced fricatives	7
Voiceless fricatives	8
Voiced stops	9
Voiceless stops	10

Table 3: Jespersen’s (1909) sonority scale (adapted from Junghare, 1979: 127)

Crucially for Junghare’s (1979) analysis, regressive assimilation occurs in the heterosyllabic context when the sonority value of the coda is greater (or equal³) compared to that of the following onset. Upon listing the different sequences, a pattern based on sonority emerges:

- (4)
- a. stop + stop: Sanskrit: *bhakta* Pali: *bhatta* ‘rice’
 - b. liquid + stop: Sanskrit: *sarpa* Pali: *sappa* ‘snake’
 - c. liquid + fricative: Sanskrit: *karsaka* Pali: *kassaka* ‘farmer’
 - d. liquid + nasal: Sanskrit: *karna* Pali: *kanna* ‘ear’
 - e. fricative + stop: Sanskrit: *hasta* Pali: *hatta* ‘hand’

In the case of (4a), using Jespersen’s (1909) sonority scale from above, we note the sonority value of the coda stop is equal (10) to that of the following onset. In (4b), the coda liquid has a sonority value of 5, whereas the following onset stop has a sonority value of 10. In (4c), the coda liquid has a sonority value of 5, whereas that of the following onset fricative is 8. In (4d), the coda liquid has a sonority value of 5, whereas that of the following onset nasal is 6. Finally, in

³ I know of no examples in which an equal sonority value produced progressive assimilation.

(4e), the coda fricative has a sonority value of 8, whereas that of the following onset stop is 10. In short, from the examples in (4), we observe that the consonant with the higher sonority value (i.e, the coda) is that which assimilates to the consonant with the lower sonority value (i.e, the onset) to form the geminate. What is pertinent in the discussion is that an analysis based on sonority does not always work when the nasal is in coda position. I repeat the two examples with nasals from above for convenience:

- (5) a. regressive: Sanskrit: *dharma* ‘righteousness’ → Pali: *dhamma*
b. Sanskrit: *danta* ‘subdued’ → Pali: *danta*

When we include the category seen in (5b),⁴ that is, nasal + (voiceless) stop, the sonority relationship is the same as in (5a), with the coda nasal with a sonority value of 6 and the following onset stop with that of 10. What is unexpected, however, is that no gemination occurs. In (5b), given that the onset has a lower sonority value, the result in Pali should be **datta*. Thus, a problem occurs in the analysis when the nasal is in coda position.

As concerns progressive nasal assimilation, Junghare (1979) notes that a nasal consonant preceded by a [+grave]⁵ consonant completely assimilates to it, as in:

- (6) progressive: Sanskrit: *lagna* ‘clung’ → Pali: *lagga*

What is particularly curious about Junghare’s analysis for progressive nasal assimilation is that she does not include reference to the sonority scale. More specifically, on further examination we detect the same notion as in the case of regressive assimilation; the consonant with the lower sonority value is that which spreads its place of articulation to the other consonant. That is, in (6), the coda stop has a sonority value of 9, whereas the following onset has a sonority value of 6. Further examination of progressive assimilation in cases without nasals, however, suggests that sonority might not be the factor that conditions gemination. For example (Duroiselle, 1906:6):

- (7) budh (to know) + ta = *budhta* = *buddha*

In the case of (7), the sonority value of the coda (voiced stop) is 9, but the following onset (voiceless stops) is 10. We would expect the output to be **butta* (or **buthta*); however that does not occur. With so few cases of progressive assimilation in the language, it is difficult to formulate rules; however, cases such as (7) seem to suggest sonority might not play a part. Further research might consider these progressive assimilation cases in which gemination does not occur in Pali in greater detail, as it is not within the parameters of the current study but most certainly of interest.

⁴Duroiselle (1906) lists *danta* ‘subdued’ in Sanskrit as *damta*, which suggests that there was place of articulation assimilation, but not gemination. All other sources researched (e.g, Roca and Johnson, 1999) listed the word as *danta* in Sanskrit. Suzuki (2002) also notes cases of elision in terms of assimilation. I bring this attention to the reader to clarify that the current study only views assimilation in terms of gemination and does not treat these other types.

⁵ A distinctive feature proposed by Jakobson; characterized acoustically by a relative concentration of energy in lower frequencies (Matthews, 1997).

3.2. Recent studies

In Cser's (2000) review of models of sonority, he notes in relation to Pali gemination that "...this highly general change can indeed only be coherently described with reference to sonority, which, of course, also defines permitted syllables in the same language(s). The change itself, however, cannot be captured in terms of syllable structure" (5). In Suzuki's (2002a,b) thorough, two-part treatment of consonant cluster changes in Pali, he argues against an analysis based on sonority and for one on the degree of oral stricture. Among his assumptions in his analysis, he includes his 'consonant strength hierarchy of Pali assimilation', listed below:

(8) Consonant strength hierarchy of Pali assimilation (adapted from Suzuki, 2002b)



In the above hierarchy, 'T' represents stops, 'N' for nasals, 'S' for sibilants, and 'R' for semivowels. The hierarchy is "...based mainly on the degree of oral aperture. In Pali assimilation one of the members of the input cluster is chosen so as to maximize the contrast between the output and the adjacent vowel(s). Thus, consonants with an *oral closure* (my emphasis), i.e, stops and nasals, are preferred to those without one, i.e, sibilants and semivowels" (64). He utilizes Optimality Theory as his framework, offering a series of Preserve (PRES) constraints, following Jun's (1994, 1995) work. The premise of these constraints is to preserve certain feature specifications. In Suzuki's (2002a,b) view, assimilation occurs not in terms of sonority, but rather in terms of consonant strength. In those cases between distinct stops or nasals, the onset would dominate the coda.

His work is quite convincing and rigorous and I agree with him that 'oral closure/stricture plays a central role in Pali assimilation' (78). However, if oral closure/stricture is the central role, a framework based on gestures and their constriction seems more apt to concisely discuss the issue at hand. In the following section, I utilize a gestural approach to discuss Pali gemination and, perhaps more importantly, those cases in which gemination does not occur.

4. Discussion

4.1. Articulatory Phonology

Articulatory Phonology (AP; Browman and Goldstein 1989, 1990, 1991, 1992) is rooted in basic units, called gestures. Browman and Goldstein (1989) define 'gestures' as "...units of action that can be identified by observing the coordinated movements of vocal tract articulators" (202). Browman and Goldstein (1989) note the importance of combining gestures with their temporal patterning by adding, "They characterise the actual observed articulator movements (thus obviating the need for any additional implementation rules), and they also function as units of contrast (and more generally capture aspects of phonological patterning)" (210).

For Browman and Goldstein (1989), 'gestures' are physical articulations that express spatio-temporal articulatory functions. These articulatory functions are performed by major

articulators, which start from the front of the vocal tract and move backwards. In the following figure, we observe the six major articulators in the Articulator Set, with each one accompanied by the minor (i.e, dependent) articulators, listed to the right, involved to perform the constriction:

<u>Articulatory set</u>			<u>Articulators involved</u>
1.	Lips	(LIPS)	upper and lower lips, jaw
2.	Tongue tip	(TT)	tongue tip, body, jaw
3.	Tongue body	(TB)	tongue body, jaw
4.	Tongue root	(TR)	tongue root, jaw
5.	Velum	(VEL)	velum
6.	Glottis	(GLO)	glottis

Table 4: Vocal-tract constriction sites and their respective articulators involved

Each major articulator in the articulator set is analyzed in terms of two factors, constriction degree (CD) and constriction location (CL). Constriction degree measures along a continuum the extent to which a constriction is made within the vocal tract, with the continuum composed of five categories: [closed], [critical], [narrow], [mid], and [wide]. The [closed] constriction degree denotes a tight articulatory closure and is generally used to refer to stops or sonorants; the [critical] constriction degree denotes turbulence and is generally used to refer to fricatives; [narrow], [mid] and [wide] fall under the category of [palatal] and denote vowel quality, with [wide] and [narrow] also used for glottal aperture (as in aspirated or unaspirated stops, for example) (Browman & Goldstein, 1989: 225-226). Constriction location (CL) defines the location in the vocal tract where the major articulator produces a constriction; CL offers ten locations, categorized, like the articulatory set, in a front-to-back ordering in the vocal tract. A framework that stresses both constriction degree and location is particularly relevant to Pali gemination (and lack thereof), as Suzuki (2002a,b) previously noted.

4.2. Byrd's (1994, 1996b) temporal Phase Windows

For Byrd, coordination between associated gestures is assumed to be variable but constrained to particular ranges specific to the types of gestures involved (e.g. C-to-C, V-C, and V-V) (1996b:148). These ‘ranges’ are specified by the lexical representation and are called Phase Windows. A Phase Window acts to limit the temporal compressibility or disassociation of gestures. Furthermore, it is also useful for capturing the timing variability observed in the coordination of gestures.

Though the Phase Window is lexically-specified, Byrd notes that window width or variability of a particular temporal interval is language-specific and context-specific (1996b:149). For Pali consonant clusters, I follow Cho’s (1998a:271) alignment of the Phase Window in that the left edge is aligned with the c-center of the coda nasal and the right edge is aligned with the release offset, as in:

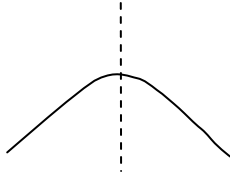


Figure 2: Phase Window alignment for Pali nasals in coda position

In the above figure, the left and right edges of the Phase Window are set in reference to the coda nasal in the cluster. In short, the notion of a Phase Window is an important one because it acts to restrict gemination by prohibiting entry of the following onset gesture into the Window.

4.3. Pali gemination within a gestural approach

In the previous sections, I discussed the gemination of Pali consonant clusters. The phenomenon is relatively transparent in that we can predict, in most cases, which consonant will assimilate to the other. Researchers have structured their analyses principally around sonority, offering the formula that the consonant with the lesser degree of sonority is that which ‘spreads’ its features and results in a gemination of the cluster. Suzuki (2002a,b) has postulated his argument on oral closure/stricture; an argument that is convincing and one that compels us to view Pali gemination in a different light. For this very reason, my motivations for carrying out the current study were to visually capture the oral closure/stricture in the form of a gestural score. A gestural score illustrates the relationship each gesture has with other gestures; each gesture is represented two-dimensionally in both spatial and temporal dimensions. The spatial dimension, along the y-axis, refers to the vocal tract and each category connotes a ‘tier’. The temporal dimension, along the x-axis, refers to the duration along each tier in relation to the other gestures. With specific regard to a gestural approach, Pali gemination occurs when the oral constriction location of the coda consonant is *not* the velum. That is to say, the active articulator must either be the lips or the tongue for the consonant coda in order for gemination to occur. In those cases in which both consonants are of the same mode of articulation (e.g, a stop and a stop), I defer to Suzuki’s (2002a,b) explanation that the onset will dominate the coda. The following figure illustrates a consonant cluster in Sanskrit, followed by a discussion regarding its gemination in Pali:

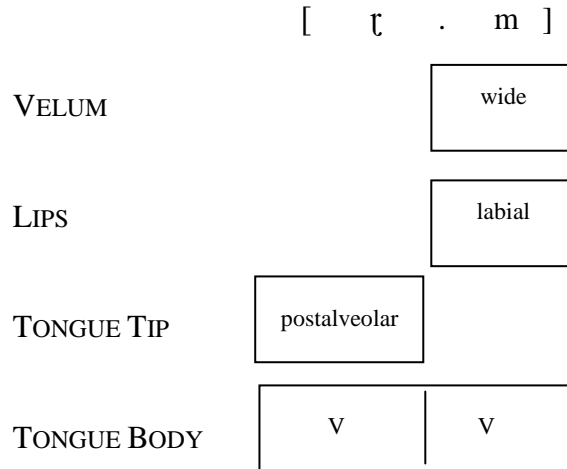


Figure 3: [ɽ.m] sequence in Sanskrit: *dharma* ‘righteousness’

In the above figure, we note the velum is wide, but it is for the gesture in onset position; therefore, gemination occurs. Utilizing Suzuki’s (2002a) aforementioned consonant strength hierarchy (98), we know that the liquid will assimilate to the nasal for the result in Pali, *dhamma* ‘righteousness’. Finally, recall that in a gestural framework, vowels are viewed as underlying; we ‘stack’ consonants on top of them to create syllables, hence the division between the two vowels along the syllable boundary.

It has been well-documented (Junghare, 1979; Cser, 2000; Suzuki, 2002a,b) that Pali has a restriction on gemination for a nasal + stop heterosyllabic sequence. For convenience, I repeat the example from (3):

(9) Sanskrit: *danta* ‘subdued’ → Pali: *danta*

The following figure is a gestural score of *danta* ‘subdued’:

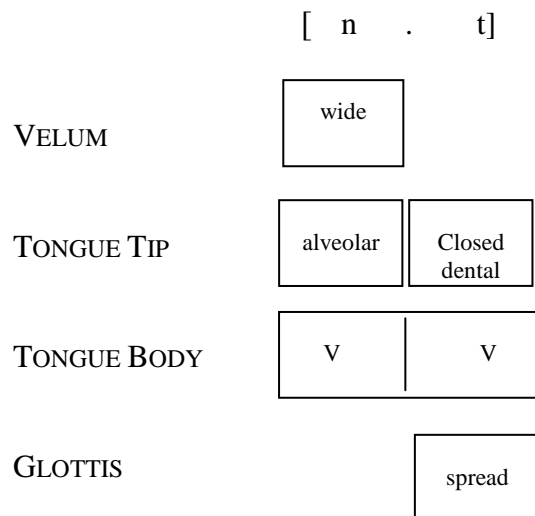


Figure 4: [n.t] sequence in Sanskrit: *danta* ‘subdued’ → Pali: *danta*

In the above figure, observe that the velum is wide during the articulation of the first gesture. The restriction on gemination is not only because /n/ and /t/ are homorganic in Pali, however. The cluster may be heterorganic, as well. There are cases in which Pali substitutes a nasal for another consonant from Sanskrit, as in:

(10) Sanskrit: sagkalpa Pali: sankappa⁶ ‘thought’

In the above example, notice that the voiced velar stop is realized as a nasal in Pali. Also observe that the newly-formed [n.k] cluster does not geminate:

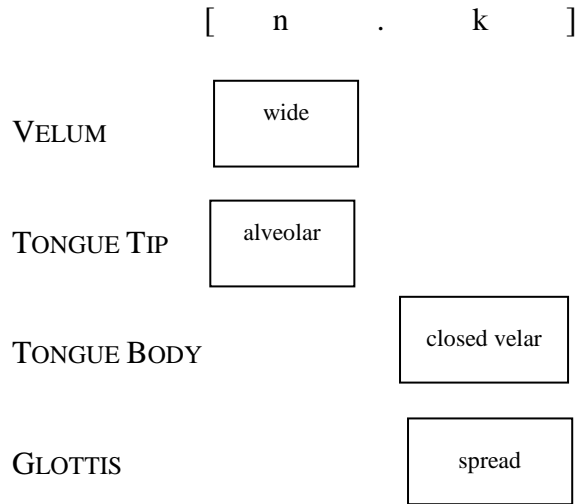


Figure 5: [n.k] cluster in Pali

In the current proposal, when the velum is active in coda position, gemination is blocked. Nonetheless, why does an active velum gesture in coda position entail gemination blocking in Pali? Crucially, in Pali consonant clusters in which the coda consonant is a nasal, a Phase Window is employed for the nasal coda which prohibits overlap in the window with a following oral gesture, as in:

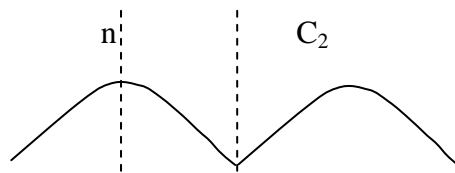


Figure 6: A Phase Window representation of [n.C₂]

In the above figure, the Phase Window abstractly restricts the following onset (C₂) from spreading its features, causing gemination. Recall that the Phase Window is language-specific

⁶ I do not address the [l.p] cluster and its consequent gemination in this example, given previous explanation and that the focus for this particular example is on the [g.k] cluster.

and context-specific. In this particular case, Pali employs a Phase Window when a nasal is in coda position due to two factors. First, the velum tier is activated at the beginning of the first gesture and second, to ensure optimal perceptibility of the nasal in the cluster. Optimal perceptibility is especially important in the case of a homorganic nasal + stop sequence, which ‘is a single articulatory and acoustic gesture...and tends to be perceived and realized as reduced’ (Downing, 2005:209). In articulatory terms, the velum may widen to produce the nasal *while* the tongue tips forms the constriction for the dental stop. Provided that it is considered a single gesture, it is not surprising that it does not geminate. In the case of a heterosyllabic nasal + stop sequence, recent research has suggested that ‘different consonant types have different perceptual cues, and the salience of the cues may be different’ (Jun, 2004:59). I propose that in Pali, all nasal + stop sequences are phonologically a single gesture and a Phase Window is employed to ensure the perceptual cues of both consonants.

5. Conclusions

In recent years, gemination has garnered tremendous interest (Kawahara, 2007, Suzuki, 2002a,b). Moreover, assimilation has been equally of interest (Jun, 2004; Downing, 2005; Ladd and Scobbie, 2003). In the case of Pali, the phenomenon of gemination has been well-established. That said, certain linguists (Junghare, 1979; Cser, 2000) have focused their analysis on sonority, whereas others (Suzuki, 2002a,b) view it in terms of consonant strength, which is defined by oral stricture. The current study has added to the previous work by discussing the phenomenon in articulatory terms, based on Suzuki’s findings. In sum, it considered those cases (nasal + stop) in which gemination is blocked. Activation of the velum tier at the beginning of the first gesture, along with viewing the sequence as a single gesture, entails geminate prohibition.

Future research will need to test the effect of palatalized nasals on gemination. The cluster ‘jñ’ in Sanskrit is realized as ‘ññ’ in Pali, which again appears to be an exception, especially when we consider that nasal geminates are cross-linguistically marked (Kawahara, 2007). In terms of sonority value, the fricative has a lower sonority value, therefore our prediction would be:

(11) Sanskrit: *yajña* Pali: *yajja* ‘sacrifice’

In the above example, the actual realization in Pali is *yañña*, which is problematic to the analysis. In addition, further investigation will need to consider the effects that morphology plays on gemination and our description of it in Pali. For example, the prefix *ud* ‘out, of’ is often problematic in our analysis because its resultant gemination cannot be explained by previous analyses: if we view it in terms of a sonority value, the consonant with the higher sonority value assimilates to the one with a lower one. In terms of consonant strength, a stop has greater oral stricture than a nasal. According to both analyses, in a heterosyllabic stop + nasal sequence, our prediction would be:

(12) Sanskrit: *ud + majjati* Pali: **uddajjati* ‘out from submersion’

The actual realization, however, is *ummajjati*. Further accounts will need to address this apparent exception and investigate to a greater extent the exact role of morphology in Pali gemination.

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