# Consonant Cluster Changes in Pali : Toward Restricting the Phonological Patterns (Part 2)

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# Consonant Cluster Changes in Pali:

## Toward Restricting the Phonological Patterns Part II

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Part I briefly outlined the proposed analysis (section 1), illustrated changes of medial and initial bi-consonantal clusters (sections 2), and critically evaluated three previous approaches and concluded that none of them can properly handle all of the observed data (section 3). As an alternative, this paper claims that Pali assimilation is governed by the consonant strength hierarchy: stops – nasals – sibilants – *l* – *v* – *y* – *r* and that apparent exceptions to assimilation follow from factors that interact with assimilation, e.g. constraints on distribution of aspiration and on coda nasal. Part II outlines six assumptions that underlie the proposed analysis (section 4.1) and exemplifies how the proposed analysis treats different types of consonant cluster changes in the framework of Optimality Theory (section 4.2). It further shows that other changes in Pali, i.e. two-mora conspiracy (section 5.1), monophthongization (section 5.2), and changes and loss of word-final consonants (section 5.3), follow from the analysis of medial and initial bi-consonantal clusters given in section 4.

### 4. A proposal

I propose that Pali assimilation results from the strength relation among consonants and the dominance of onset-position over the preceding coda position. Assimilation affects all the bi-consonantal clusters with simultaneous simplification of syllable structure and interacts with other factors such as positional restrictions on certain features and restrictions on altering the input structure. Apparent counterexamples to assimilation are due to such interacting factors. The theoretical framework used in this work is Optimality Theory whereby the highest rated candidate is selected as an output based on the hierarchically ranked set of constraints (cf. Prince and Smolensky 1993 and Kager 1999 among others). This framework is chosen because an analysis in terms of Optimality Theory reflects the direction and the effects of the changes better than a rule-based approach.

In what follows, section 4.1 discusses six assumptions that underlie the proposed analysis. Section 4.2 exemplifies different types of developments in terms of the proposed analysis: medial cluster assimilation and initial cluster simplification (section 4.2.1), consonant clusters that result in aspirated stops (section 4.2.2), clusters where apparent metathesis is involved (section 4.2.3), clusters with a coda nasal (section 4.2.4), and *jñ* and some NT-clusters that result in geminate nasals (section 4.2.5). The final section gives a categorized list of constraints as a summary (section 4.3).

### 4.1. Assumptions

The analysis proposed in this paper consists of the following six assumptions. Each assumption is accompanied by a formulation of constraints in terms of Optimality Theory which will be exemplified below in section 4.2.

(i) Pali medial cluster assimilation and initial cluster simplification is governed by the following hierarchy of consonant strength, whereby stronger consonants dominate weaker ones.

(42) Consonant strength hierarchy of Pali assimilation

| T | N | S | R |
|---|---|---|---|
| | | | *l v y r* |

stronger ⟵⟶ weaker

This hierarchy is different from the sonority hierarchy (cf. (26) in section 3.1) and similar to von Hinüber's (2001: § 226; also Oberlies 2001: 99) hierarchy in that nasals are placed between stops and sibilants (cf. section 3.1). The reason for this is that the hierarchy in (42) 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, i.e. stops and nasals, are preferred to those without one, i.e. sibilants and semivowels. Among consonants with an oral closure, stops are preferred to nasals because stops are the unmarked consonants, although sometimes the strength relation between stops and nasals appear to be reversed (cf. sections 2.2, 3.1, and 4.2.5). Among other consonants, sibilants are stronger than semivowels because obstruents as opposed to sonorants are the unmarked consonants. Among semivowels, *l* is the strongest presumably because of the lateral articulation with a closure with the tongue tip and the alveolar ridge.

The hierarchy given in (42) cannot determine the strength relation of two distinct stops and nasals in TT/NN-clusters. In this case the survivor is determined by the position in the syllable. That is, the onset, i.e. the second consonant, dominates over the coda, i.e. the first consonant. As already discussed in section 3.3, the choice of the survivor depends otherwise on the strength relation of the two members of the cluster rather than their position in the syllable.

Consonants that lack an oral gesture, *h*, visarga, and anusvāra, cannot be placed in the hierarchy of (42) because this hierarchy depends crucially on the degree of oral aperture. Wherever possible, these consonants gain an oral gesture from an adjacent consonant, in which case they appear to assimilate to the adjacent consonant (cf. assumption (v) below).

In the framework of Optimality Theory Pali assimilation is defined by a set of hierarchically ranked constraints that determine which types of consonants have a better chance of surviving. Following Jun (1994, 1995), I use Preserve constraints which dictate that certain sets of feature specifications, such as stops, sibilants, or *l*, be preserved. The relevant constraints are listed below in the order of ranking, whereby the constraint which precedes >> is higher ranked than the one which follows it:

| | | |
|---|---|---|
| | PRESТ | Preserve [−continuant, −nasal] |
| >> | PRESN | Preserve [−continuant, +nasal] |
| >> | PRESS | Preserve [+continuant, −voice] |
| >> | PRES*l* | Preserve *l* |
| >> | PRES*v* | Preserve *v* |
| >> | PRES*y* | Preserve *y* |
| >> | PRES*r* | Preserve *r* |
| >> | PRESONS | Preserve onset consonant |

For example, sibilants assimilate to stops because the Preserve constraint for stops is higher ranked than the Preserve constraint for sibilants. The last constraint is responsible for the dominance of the onset consonant over the preceding coda consonant and is applied to TT/NN-clusters, as has been just stated.

Assimilation affects all the consonant clusters. It is in part blocked when the relevant Preserve constraints interact with higher ranked Faithfulness constraints or paradigmatic constraints on feature cooccurrence. In the proposed analysis, the Preserve constraints deal with the features that spread, while Faithfulness constraints deal with the features that persist but do not spread. The Preserve constraints may be partially violated. For example, if a higher ranked constraint defines the manner of articulation but not the place, a Preserve constraint, wherever applicable, may not override this higher ranked constraint but may fill the place features.

In addition to the hierarchical relationship among consonants, one other factor that motivates assimilation is the dominance of onset consonant over the preceding coda consonant. That is, the coda consonant must share its oral gesture with the following onset consonant (cf. assumption (vi) below). However, the oral gesture that survives assimilation is whichever is stronger in the hierarchy instead of the one in onset in the input except when the two consonants that form the cluster belong to the same class in the hierarchy. As such the proposed analysis reflects both the hierarchy-based approach (cf. section 3.1 in Part I) and the syllable structure approach (cf. sections 3.2 and 3.3 in Part I).

(ii) Both onset and coda allow at most one consonant in Pali (cf. Vaux 1992: 293 among others). Syllables that do not fit this pattern are subject to cluster simplification. As a result, word-initial clusters are simplified into single consonants.

Relevant constraints (cf. Kager 1999: 97):

| | |
|---|---|
| *COMPLEX$^{ONS}$ | A syllable may not have more than one consonant in onset. |
| *COMPLEX$^{COD}$ | A syllable may not have more than one consonant in coda. |

These constraints are also motivated by the two-mora conspiracy which will be discussed in section 5.1 below.

(iii) Sibilants as well as aspirated stops are accompanied by aspiration (cf. Wetzels and Hermann 1985: 221 and Vaux 1998). As a glottal gesture, aspiration behaves independently from the oral gesture and is not affected by assimilation. Aspiration must be associated with the onset position and aspiration which cooccurs with a consonant is associated with the release of that consonant (cf. Hock 1985 and Lombardi 1995; also section 2.3). The position of aspiration in the output must remain in the same sequence of consonants as the input.

Relevant constraints:

| | |
|---|---|
| FAITHASP | Aspiration must be preserved in the same consonant sequence as the input. |
| ASPONS | Aspiration must be associated with onset. |

(iv) Orthographic Nh/Rh-clusters in medial position and initial NVh/RVh in Pali are aspirated sonorants (cf. von Hinüber 2001, Oberlies 2001, and the discussion in sections 2.3 and 2.5 above). Thus apparent metathesis is assimilation of *h* to the following sonorant, or spread of oral gesture of the onset sonorant to the preceding coda slot that lacks an oral gesture (cf. assumption (v) below): hN/hR > $NN^h$/$RR^h$ = Nh/Rh. Similarly, the change SN > N(V)h is assimilation of the sibilant to the following nasal with aspiration left behind: SN > $NN^h$ = Nh in medial position or SN > $N^h$ = NVh in initial position (cf. von Hinüber 2001: § 239). This development follows from the hierarchy in (42) where nasals are stronger than sibilants. The proposed analysis obviates the need to posit the unattested intermediate stage of hN in the development of SN-clusters. Also, there is no need to posit unmotivated restrictions on assimilation.

Metathesis of *h* and a sonorant is actually a change in timing of aspiration due to the positional restriction on aspiration in Pali (cf. Hock 1985). Due to assumption (iii) aspiration is associated with the end of consonant articulation.

(v) Segments must have an oral gesture wherever possible. In Pali anusvāra and *h* lack an oral gesture and occur in the environment where it cannot share an oral gesture with a neighboring element. That is, anusvāra occurs preceding a sibilant or a semivowel (and word-finally; see section 5.3 below); nasals have an oral closure and thus cannot share its oral gesture with consonants that lack an oral closure. *H* occurs either word-initially preceding a vowel or between two vowels.

Relevant constraints:

ORALGEST Segments must have an oral gesture.

NASPLACE Nasals may not share its point of articulation with a [+continuant] segment.

(vi) The coda consonant may only have nasality of its own. All the other features must be shared with the following onset consonant. It follows from this assumption that medial bi-consonantal clusters are either geminates or NC. Clusters that consist of a sonorant and *h* are realizations of aspirated geminate sonorants and thus are not exceptions to this generalization (cf. assumption (iv) above). Any input clusters which violate this restriction must be altered by assimilation. Thus, as shown in (43), the medial bi-consonantal clusters in Pali are geminates with or without aspiration and NC.

(43) Medial consonant clusters in Pali (same as (23) in section 2.6 in Part I)

<table>
<tr><th>T</th><th>N</th><th>S</th><th>R</th><th>segment type</th></tr>
<tr><td>$TT^h$</td><td>Nh</td><td rowspan="2">SS</td><td>Rh</td><td>geminate with aspiration</td></tr>
<tr><td>TT</td><td rowspan="2">NN</td><td>RR</td><td>geminate without aspiration</td></tr>
<tr><td>$NT^{(h)}$</td><td>ṁS</td><td>ṁR</td><td>NC</td></tr>
</table>

The proposed inventory of medial clusters in (43) exhausts all the logical possibilities with no unexplained gaps.

Because of the proposed constraint on coda consonant, all input clusters result in geminates or NC in Pali. Which member of the input cluster remains depends on the hierarchical relationship among consonants, as discussed above under assumption (i). Geminates are not affected because they observe the restriction on coda consonant. Similarly, homorganic NT-clusters might be interpreted as quasi-geminates because the coda consonant share place and part of manner features with the following onset consonant although not all.

Nasality in coda may not be affected by assimilation. This constraint dominates various Preserve constraints discussed under assumption (i). Thus, clusters with a nasal as its first member appear to be exempted from assimilation. This exemption follows from the stability of coda nasality. Any feature specification which is not compatible with nasality may not spread to the coda nasal. Specifically, in NT-clusters with a voiceless stop [ – voice] may not spread to the preceding coda position.

Relevant constraints:

| | |
|---|---|
| CODA | A coda consonant may not have an oral gesture of its own. |
| CODANASAL | Nasality in coda must be preserved. |
| NASVOICE | Nasals may not be voiceless. |

Various processes that affect consonant clusters in Pali including assimilation, metathesis, and initial cluster simplification, are due to the above interacting factors, i.e. maximization of contrast between syllable nucleus and onset/coda (cf. assumption (i)), restriction on syllable structure and especially on coda position (cf. assumptions (ii) and (vi)), independence of aspiration from assimilation (cf. assumption (iii)), and stability of nasality in coda (cf. assumption (vi)). As discussed in section 3, the previous analyses cannot effectively distinguish among consonant clusters that undergo different developments. The proposed analysis imposes no restrictions on assimilation. Different outcomes are due to factors interacting with assimilation.

### 4.2. Analyses

In Optimality Theory grammar consists of hierarchically ranked universal constraints that may be violated. A set of possible outputs or 'candidates' are evaluated in terms of how many constraint violations they incur and how highly ranked these constraints are. The candidate which incurs the least serious violation, i.e. the candidate that violates lower ranked constraints and/or has fewer violations, is 'optimal' and thus is chosen as the output of the grammar. The evaluation is based on the table called 'tableau' that shows which of the relevant constraints each candidate violates. This section shows how various constraints interact with each other to account for the observed facts in Pali. Sections 4.2.1 – 4.2.5 below discuss different types of developments in terms of the constraints proposed in section 4.1 above.

#### 4.2.1. Medial cluster assimilation and initial cluster simplification

Assimilation results from CODA, which prohibits the coda consonant from having its own oral gesture, and hierarchically arranged Preserve constraints. As discussed under assumption (i) in section 4.1, the strength relation of consonants determines which member of a given bi-consonantal cluster survives. Thus assimilation can either be progressive if the stronger consonant is the first member of the cluster (cf. (44) below) or regressive if the stronger consonant is the second member of the cluster (cf. (45) below).

The tableau in (44) shows evaluation of five possible outputs for *svapna*.

(44) sva**pn**a > sa**pp**a 'sleep'

| Candidate | CODA | PREST | PRESN | PRESONS |
|---|---|---|---|---|
| sapna | *! | | | |
| ☞sappa | | | * | * |
| sanna | | *! | | |
| satta | | (*)! | (*) | (*) |
| samma | | (*)! | (*) | (*) |

Each row represents constraint evaluation of each candidate. A solid line between constraints indicates that the constraint on the left is higher ranked than the constraint on the right. A star * in the tableau indicates a violation of the constraint in the same column and (*) indicates partial violation. The violation marked with ! is the crucial violation which invalidates the candidate with which it is associated. Thus the shaded area on the right of this mark is irrelevant for evaluation. The candidate which incurs the least serious violation is rated as optimal and is shown with ☞.

The first candidate *sapna* violates CODA, which prohibits the coda consonant from having an oral gesture of its own. This constraint is undominated and thus its violation is a serious offense. The second candidate *sappa* violates PRESN and PRESONS, but these two constraints are lower ranked than CODA and PREST, which the other four candidates violate. The third candidate *sanna* violates PREST but observes both PRESN and PRESONS ranked lower than that. The next two candidates *satta* and *samma* are a result of mutual assimilation. Thus they violate partially the three constraints PREST, PRESN, and PRESONS, marked with an asterisk in parentheses. Due to the constraint ranking as given, the winner is *sappa*. Hence assimilation is progressive.

In (45), on the other hand, the preserve constraint for the second consonant is higher ranked than the preserve constraint for the first consonant. Thus *vaggu* with regressive assimilation is the winner.

(45) **valgu** > **vaggu** 'beautiful'

| Candidate | CODA | PRESТ | PRES*l* |
|---|---|---|---|
| valgu | *! | | |
| ☞vaggu | | | * |
| vallu | | *! | |
| vaddu | | (*)! | (*) |

The tableau in (46) shows the change of bi-consonantal clusters which consist of two consonants of the same class.

(46) sa**pt**a > sa**tt**a 'seven'

| Candidate | CODA | PREST | PRESONS |
|---|---|---|---|
| sapta | *! | | |
| sappa | | * | *! |
| ☞satta | | * | |

The first candidate *sapta* is invalidated due to the violation of the highest-ranked CODA even though it does not violate either of the two other constraints given in this tableau. The other two candidates, i.e. *sappa* and *satta*, both incur one violation of PREST and are equal in this respect. However, *sappa* violates the next ranked constraint PRESONS, while *satta* does not. The winner is thus *satta* and the assimilation in this case is regressive due to PRESONS.

Simplification of initial clusters involves *COMPLEX$^{ONS}$ instead of CODA, but otherwise is treated in the same manner as medial cluster assimilation. In (47) *d* is chosen over *v* because PREST is ranked higher than PRES*v*.

(47) **dv**ija > **d**ija 'twice-born'

| Candidate | *COMPLEX$^{ONS}$ | PREST | PRES*v* |
|---|---|---|---|
| dvija | *! | | |
| ☞dija | | | * |
| vija | | *! | |

In the proposed analysis medial cluster assimilation and initial cluster simplification follow from an interaction of syllable structure constraints and a set of Preserve constraints that determine the hierarchical relationship among consonants. The following sections will show that the same type of analysis as given in this section can be extended to other types of developments. As such assimilation in the proposed analysis is free from any restrictions which are necessary in the previous analyses (cf. section 3).

#### 4.2.2. Consonant clusters that result in aspirated stops

When the input cluster includes a stop and some form of aspiration, i.e. an aspirated stop, a sibilant, or visarga, the output is an aspirated stop even when the stop in the input is not aspirated (cf. section 2.2). In the proposed analysis this persistence of aspiration follows from the constraint FAITHASP, which is higher ranked than the set of Preserve constraints that govern assimilation. Thus aspiration is not affected by assimilation.

For example, a sequence of an aspirated stop and a semivowel results in a geminate aspirated stop, as in (48).

(48) **ad$^h$van > add$^h$an** 'way'

| Candidate | CODA | FAITHASP | ASPONS | PREST | PRES*v* |
|---|---|---|---|---|---|
| ad$^h$van | *! | | * | | |
| addan | | *! | | | * |
| ☞add$^h$an | | | | | * |
| ad$^h$d$^h$an | | | *! | | * |
| haddan | | *! | | | * |
| avvan | | *! | | * | |
| avv$^h$an | | | | *! | |

In this tableau the constraints on either side of a dotted line are equal in ranking. Thus the first three constraints, i.e. CODA, FAITHASP, and ASPONS, are all undominated. Among the candidates with a geminate stop *addan* without aspiration is excluded because it violates FAITHASP. Also, *ad$^h$d$^h$an* is excluded by ASPONS because aspiration is associated with the coda position in addition to the onset position. *Haddan* should also be excluded by FAITHASP because, although aspiration is preserved and is associated with the onset position, it is detached from the consonant sequence with which it is originally associated. Hence the winner is *add$^h$an*.

The tableau in (49) shows evaluation of six candidates for *āścarya*. The first four candidates are excluded because they violate one of the three highest ranked constraints. Of the last two, *acc$^h$ariya* violates the lower ranked constraint PRESS and thus is the winner.

(49) **āścarya > acc<sup>h</sup>ariya** 'miraculous'

| Candidate | CODA | FAITHASP | ASPONS | PREST | PRESS |
|---|---|---|---|---|---|
| ascariya | *! | | | | |
| accariya | | *! | | | * |
| accar$^h$iya | | *! | | | * |
| ac$^h$cariya | | | *! | | |
| ☞acc$^h$ariya | | | | | * |
| assariya | | | | *! | |

For the purpose of medial and initial cluster changes there is no hierarchical relationship between FAITHASP and ASPONS. In section 5.3 below I will show with the examples of word-final consonant deletion that aspiration must disappear because it cannot be associated with the onset position. In this case ASPONS dominates FAITHASP.

Simplification of onset clusters into an aspirated stop is treated in the same manner except that CODA is replaced by *COMPLEX$^{ONS}$. The tableau in (50) shows that *p$^h$assa* is the most optimal candidate.

(50) **sparśa > p$^h$assa** 'touch'

| Candidate | *COMPLEX$^{ONS}$ | FAITHASP | PREST | PRESS |
|---|---|---|---|---|
| spassa | *! | | | |
| passa | | *! | | * |
| ☞p$^h$assa | | | | * |
| sassa | | | *! | |

As shown, aspiration as a glottal gesture is independent of assimilation and thus is not affected by assimilation. In the proposed analysis this fact follows from the assumption that aspiration and assimilation are conditioned by two mutually independent but interacting sets of constraints. While treatment of aspiration is a problem for the sonority approach (cf. section 3.1) and Murray's (1982) gemination approach (cf. section 3.3), the proposed analysis is free from such a problem along with the other previous approaches.

#### 4.2.3. Consonant clusters where apparent metathesis is involved

Apparent metathesis is caused by the positional constraint on aspiration, i.e. ASPONS, and the Preserve constraints that govern assimilation, on the assumption that a sonorant followed by *h* is an aspirated sonorant. Clusters that undergo apparent metathesis are parallel with clusters that result in aspirated geminate stops (cf. section 4.2.2 above) in that both are affected by assimilation, leaving aspiration behind.

As an example of apparent metathesis, the tableau in (51) shows that the candidate with an aspirated geminate is optimal due to the interaction of two constraints on aspiration, i.e. ASPONS and FAITHASP, and a Preserve constraint.

(51) ji**h**vā > ji**vv$^h$**ā 'tongue'

| Candidate | CODA | ASPONS | FAITHASP | PRES*v* |
|---|---|---|---|---|
| jihvā | | *! | | |
| jivhā | *! | | | |
| jivvā | | | *! | |
| jihhā | | | | *! |
| ☞jivv$^h$ā | | | | |

SN-clusters become Nh (= NN$^h$) by the same interaction of constraints on aspiration and Preserve constraints. However, while *h* may cooccur with any consonant with an oral gesture as in (51) above, in (52) below a sibilant cannot cooccur with a nasal and thus must be reduced to *h*. The tableau in (52) is comparable to (49) above except that PRESN is involved instead of PREST. Again the winner is the output with an aspirated geminate.

(52) vi**sm**aya > vi**mm$^h$**aya 'astonishment'

| Candidate | CODA | FAITHASP | PRESN | PRESS |
|---|---|---|---|---|
| vismaya | *! | | | |
| vissaya | | | *! | |
| vimmaya | | *! | | * |
| vimhaya | *! | | | |
| ☞vimm$^h$aya | | | | * |

Simplification of onset clusters involves *COMPLEX$^{ONS}$ instead of CODA, as shown in (53). In parallel with (52), the winner is the output with an aspirated nasal.

(53) **smita** > **m$^h$ita** 'smiling'

| Candidate | *COMPLEX$^{ONS}$ | FAITHASP | PRESN | PRESS |
|---|---|---|---|---|
| smita | *! | | | |
| sita | | | *! | |
| mita | | *! | | * |
| ☞m$^h$ita | | | | * |

So far I have presented an analysis based on the interpretation that medial Nh/Rh and initial NVh/RVh are a geminate aspirated sonorant and a single aspirated sonorant, respectively. However, the proposed analysis can cope with the possibility that medial Nh/Rh and initial NVh/RVh are a sequence of a sonorant and *h* and a sequence of a sonorant, a vowel, and *h*, respectively, as the orthography shows. In this case the following constraint which prohibits aspirated sonorants is at work.

(54) *ASPSON

Aspiration may not be associated with a sonorant.

Nh and Rh result from the interaction of *ASPSON and ASPONS. However, since these sequences violate CODA as it is formulated above, CODA must be weakened so that it would allow Nh and Rh but exclude any combination of two distinct consonants such as SN. Nh- and Rh-clusters have one oral gesture, while other consonant clusters involve two distinct oral gestures. Thus the weaker version of CODA in (55) below allows Nh/Rh because the oral gesture of the first consonant is non-distinct from that of the second consonant which lacks an oral gesture.

(55) CODA (weaker version)

The coda consonant may not have an oral gesture which is distinct from that of the following onset consonant.

It also allows geminates where the coda consonant shares its oral gesture with the following onset consonant, but excludes sequences of two distinct consonants with an oral gesture. Although this weaker version also allows illegitimate clusters such as Th and Sh, these clusters are excluded by ORALGEST, which dictates that segments have an oral gesture. In order to allow Nh/Rh and TT$^h$ but disallow NN$^h$/RR$^h$ and Th/Sh, *ASPSON that excludes NN$^h$/RR$^h$ but not TT$^h$ is higher ranked than ORALGEST that excludes any sequence of a consonant and *h*, as in (56). This way NN$^h$/RR$^h$ as well as Th/Sh are correctly excluded.

(56) Evaluation of CC$^h$ and Ch

| Candidate | *AspSon | OralGest |
|---|---|---|
| ☞TT$^h$ | | |
| Th/Sh | | *! |
| NN$^h$/RR$^h$ | *! | |
| ☞Nh/Rh | | * |

The tableaus in (57) and (58) below show candidate evaluation which yields a sequence of a sonorant and *h* instead of an aspirated geminate sonorant. In (57) none of the candidates including *jivhā* violates Coda as it is formulated in (55) above. While *jivhā* incurs one violation of OralGest, *jivv$^h$ā* violates a higher constraint *AspSon. Thus *vh* is preferred to *vv$^h$*.

(57) **jihvā** > **jivhā** 'tongue'

| Candidate | Coda | *AspSon | AspOns | FaithAsp | Pres*v* | OralGest |
|---|---|---|---|---|---|---|
| jihvā | | | *! | | | * |
| ☞jivhā | | | | | | * |
| jivvā | | | | *! | | |
| jihhā | | | | | *! | ** |
| jivv$^h$ā | | *! | | | | |

Similarly, in (58) *vimhaya* does not violate Coda but incurs one violation of OralGest, which is ranked lower than the Preserve constraints. As in (57), *vimm$^h$aya* is excluded by the undominated constraint *AspSon.

(58) **vismaya** > **vimhaya** 'astonishment'

| Candidate | Coda | *AspSon | FaithAsp | PresN | PresS | OralGest |
|---|---|---|---|---|---|---|
| vismaya | *! | | | | | |
| vissaya | | | | *! | | |
| vimmaya | | | *! | | * | |
| ☞vimhaya | | | | | * | * |
| vimm$^h$aya | | *! | | | * | |

The corresponding outcome in word-initial position is NVh/RVh with epenthesis (cf. section 2.4 in Part I). This form can be obtained by the interaction of the constraints that prohibits a complex onset (i.e. *Complex$^{Ons}$) and an aspirated sonorant (i.e. *AspSon) on the one hand

and the following faithfulness constraint in (59) that prohibits epenthesis on the other hand (cf. Kager 1999: 100-101).

(59) DEPENDENCY-IO/DEP-IO

Output segments must have input correspondents.

However, if the form SN is taken as input, the outcome would be SVN without reduction of the sibilant. Concerning the development of NVh from SN in initial position, von Hinüber (2001: §§240-241) states that the epenthesized form NVh developed later because the orthographic NVh, which earlier did not form a metrical position, came to occupy one metrical position. This fact suggests that the epenthesized form developed via an aspirated nasal and not directly from SN. Thus the input form for the output NVh is $N^h$ rather than SN.

The tableau in (60) shows evaluation of various candidates for the input *$m^h$ita*. Since DEP-IO which prohibits epenthesis is lower ranked than the Preserve constraints, the optimal output is *mihita*.

(60) **$m^h$**ita > **mih**ita 'smiling'

| Candidate | *COMPLEX$^{ONS}$ | *ASPSON | FAITHASP | PRESN | DEP-IO |
|---|---|---|---|---|---|
| $m^h$ita | | *! | | | |
| mhita | *! | | | | |
| hita | | | | *! | |
| mita | | | *! | | |
| ☞mihita | | | | | * |

The output *mihita* does not violate FAITHASP. Although aspiration is separated from the nasal by an epenthetic vowel, it is not moved from its original place in conformity with FAITHASP. Further, the nasal and the aspiration are aligned in this order because aspiration is associated with the end of a consonant (cf. assumption (iii) in section 4.1 above) and thus follows the articulation of this consonant. Therefore the opposite order hVN is excluded.

As has been shown, apparent metathesis falls under assimilation in the proposed analysis. Unlike in the previous analyses, it is not necessary to posit a separate treatment for metathesis.

#### 4.2.4. Consonant clusters with a coda nasal

Consonant clusters with a coda nasal are apparently exempted from assimilation because CODANASAL, which requires preservation of nasality in coda, is higher ranked than the Preserve constraints which govern assimilation. The tableau in (61) shows that the best candidate is the same as the input which violates neither CodaNasal nor PresT. The second candidate with a voiceless *n̥*, where [−voice] has spread from the stop to the preceding nasal, is excluded by NasVoice because voiceless nasals are not allowed in Pali.

(61) **pañca** > **pañca** 'five'

| Candidate | CodaNasal | NasVoice | PresT | PresN |
|---|---|---|---|---|
| ☞pañca | | | | |
| pañ̥ca | | *! | | (*) |
| pacca | *! | | | * |
| paññа | | | *! | |

The output does not violate Coda as it was originally formulated in section 4.1 above because the coda nasal shares place features with the following stop and thus does not have an oral gesture of its own.

As for the clusters with anusvāra as the first member, the contrast between partial assimilation in (62) and lack of assimilation in (63) follows from NasPlace, which requires that the place of nasals must be shared with consonants with an oral closure, i.e. stops and nasals (cf. (62)), but not with consonants without one, i.e. sibilants and semivowels (cf. (63)).

(62) **saṁg**ata > **saṅg**ata 'met'

| Candidate | CodaNasal | NasPlace | PresT | OralGest |
|---|---|---|---|---|
| saṁgata | | | | *! |
| ☞saṅgata | | | | |
| saggata | *! | | | |
| saṁṁata | | | *! | ** |

(63) **haṁsa** > **haṁsa** 'goose'

| Candidate | CodaNasal | NasPlace | PresS | OralGest |
|---|---|---|---|---|
| ☞haṁsa | | | | * |
| hansa | | *! | | |
| hassa | *! | | | |
| haṁṁa | | | *! | ** |

Again the output in (63) does not violate Coda in lack of oral gesture for anusvāra in coda.

Thus in the proposed analysis NT-clusters and the clusters with anusvāra as the first member do not have to be stipulated as exceptions to assimilation as is necessary for all the previous analyses (cf. section 3 in Part I). Instead they appear so due to interference of an independent constraint, i.e. CODANASAL.

#### 4.2.5. *jñ* > *ññ/ñ* and NT-clusters which develop into NN-clusters

Among TN-clusters which underwent assimilation in Pali, *-jñ-* is the only cluster where both place and voice are shared by the two members of the cluster (cf. section 2.2 in Part I). As discussed in section 3.1, the development from *-jñ-* to *-ññ-* is most likely an extension of the Sanskrit sandhi of *-dn-* to *-nn-*. Formally this result is obtained by ranking PRESN higher than PREST, as in (64).

(64) yajña > yañña 'sacrifice'

| Candidate | CODA | PRESN | PREST |
|---|---|---|---|
| yajña | *! | | |
| yajja | | *! | |
| ☞yañña | | | * |

The same ranking of PRESN over PREST applies to the alternate development of NT-clusters to geminate nasals as discussed in section 3.1: e.g. *ālambana* > *ārammaṇa* 'basis, object', *pañcāśat* > *paññāsa* 'fifty' (cf. Murray 1982: 168). However, it may not be necessary to assume occasional reranking of the Preserve constraints.

What is common with these developments to geminate nasals is that the two members of the input cluster share place of oral closure. Similar alternations are not observed with clusters without an oral closure or heterorganic clusters. Since the two consonants of these clusters share all the features other than nasality and in some cases voice, they might have been interpreted as quasi-geminates which cannot be altered by assimilation. The development of some of the NT-clusters to NN suggests that since the coda nasal must be preserved and since the outcome of assimilation is a geminate, the nasality which should be restricted to the coda position spread to the following onset position. In case of *jñ*, nasality in onset spreads to the preceding coda position because, in terms of position of the syllable, onset dominates coda. At any rate, the fact that the aberrant pattern is restricted to homorganic clusters with an oral closure supports the proposed assumption that oral closure/stricture plays a central role in Pali assimilation.

As a summary of sections 4.1 and 4.2, the advantage of the proposed analysis is that various developments of consonant clusters follow from the interaction of well-motivated constraints with no 'mysterious' restrictions. While the proposed analysis is indebted in various ways to the previous analyses, especially von Hinüber's (2001), it is different from any of the previous work, first, in that apparent metathesis is also part of assimilation, second, in that nasality in coda is not affected by assimilation, and, third, in that the inventory of medial clusters follow from the proposed constraints. There are several factors such as distribution of aspiration and persistence of coda nasality which interact with but are not affected by assimilation. These factors led to apparent exceptions to assimilation, which have caused a problem to the previous analyses. The assumptions in the proposed analysis obviate the need to posit any restriction on assimilation.

#### 4.3. Summary of constraints

The following is a classified list of constraints with ranking which is used in the analysis in this section.

(i) Syllable structure constraints (undominated)

| | |
|---|---|
| *COMPLEX | Onset and coda must be simple. |
| CODA | Coda consonant may not have an oral gesture of its own. |

(ii) Faithfulness constraints

a. Undominated

| | |
|---|---|
| FAITHASP | Aspiration must be preserved in the same consonant sequence as the input. |
| CODANASAL | Nasality in coda must be preserved. |

b. Preserve constraints (violable)

| | | |
|---|---|---|
| | PREST | Preserve [−continuant, −nasal] |
| >> | PRESN | Preserve [−continuant, +nasal] |
| >> | PRESS | Preserve [+continuant, −voice] |
| >> | PRES*l* | Preserve *l* |
| >> | PRES*v* | Preserve *v* |
| >> | PRES*y* | Preserve *y* |
| >> | PRES*r* | Preserve *r* |
| >> | PRESONS | Preserve onset consonant |

(iii) Positional constraints (undominated)

| | |
|---|---|
| ASOPNS | Aspiration must be associated with the onset position. |

(iv) Paradigmatic constraints/Feature cooccurrence restrictions

a. Undominated

NASVOICE A nasal may not be voiceless.

NASPLACE A nasal may not share its point of articulation with a [+continuant] segment.

b. Violable

ORALGEST Segments must have an oral gesture.

## 5. Other changes that alter the syllable structure in Pali

The preceding sections focused on changes of bi-consonantal clusters which are the main interest of earlier work. Other than the changes discussed so far, Pali underwent several processes that altered its syllable structure. 'Two mora conspiracy' attained maximum two moras in the syllable by vowel shortening, anaptyxis, and cluster simplification (section 5.1). Monophthongization prohibited a vocalic second mora from having its own feature specification in height and backness (section 5.2). Word-final nasals were changed into anusvāra, while all other final consonants were lost (section 5.3). All these changes are directed towards the maximum syllable structure with simple onset and two moras, as pointed out in earlier literature (e.g. Hock 1991a, Vaux 1992, Geiger 1994, Hazra 1994, Oberlies 2001). In addition, the second mora is specified only in vocalicness and nasality, and shares other features with an adjacent element. Thus the second mora is either the second part of a long vowel, the first part of a geminate, or a nasal. The proposed analysis in section 4 is extended to incorporate these data.

### 5.1. Two-mora conspiracy

Another well-known phenomenon of Pali historical phonology beside assimilation is two-mora conspiracy that consists of vowel shortening, anaptyxis, and simplification of consonant clusters (cf. Mayrhofer 1951: 42-43, Hock 1991a: 159-161, Geiger 1994: § 5, Hazra 1994: 54-55, von Hinüber 2001: § 108, Oberlies 2001: 17). These processes interacted with assimilation, as shown below. Which of these alternatives were chosen in a particular case to attain two moras depends partly on the type of consonant clusters and partly on dialectal variations.

The first two processes are vowel shortening and anaptyxis, as exemplified in (65) and (66), respectively (cf. Geiger 1994: §§ 6, 8, Hazra 1994: 54, 62, 69, von Hinüber 2001: 152-156, Oberlies 2001: 18).

(65) Vowel shortening

| | | | |
|---|---|---|---|
| jīrṇa | > | jiṇṇa | 'old, exhausted' |
| māṁsa | > | maṁsa | 'flesh' |
| rājñaḥ | > | rañño | 'of a king' |
| kārya | > | kayya | 'action, duty' |

(66) Anaptyxis

| | | | |
|---|---|---|---|
| utplavate | > | uppilavati | 'emerges, jumps up' |
| niḥśrīka | > | nissirīka | 'unfortunate' |
| rājñaḥ | > | rājino | 'of a king' |

Anaptyxis as given in (66) was not limited to eliminating three-mora syllables, but also applied to bi-consonantal clusters in both initial and medial positions as an alternative to assimilation (Mayrhofer 1951: §93-95, Geiger 1994: §8, Oberlies 2001: 33, 44, 53-54, 100, 112-113).

(67) a. Anaptyxis in medial bi-consonantal clusters

| | | | |
|---|---|---|---|
| ratna | > | ratana | 'jewel' |
| vihanti | > | vihanati | 'strikes' |
| arśas | > | arisa | 'piles' |

b. Anaptyxis in initial position

| | | | |
|---|---|---|---|
| glāna | > | gilāna | 'ill' |
| sneha | > | sineha | 'love' |
| vyakta | > | viyatta | 'learned' |
| hrī | > | hirī | 'shame' |

Sometimes both shortening and anaptyxis applied to create one mora syllables, as shown in (68) (Mayrhofer 1951: §82, Geiger 1994: §8, Oberlies 2001: 19).

(68) Shortening and anaptyxis

| | | | |
|---|---|---|---|
| ārya | > | ariya | 'noble' |
| sūrya | > | suriya | 'sun' |

As the third possibility of attaining two moras, consonant clusters of any length and make-up were simplified to either single consonants (cf. (69a)), geminates (cf. (69b, c)), or NC (cf. (69d)) (cf. Geiger 1994: §58, Hazra 1994: 80-81, Oberlies 2001: 18-19, 104-105).

(69) Cluster simplification

a. CC > C

| | | | |
|---|---|---|---|
| dīrg$^h$a | > | dīg$^h$a | 'long' |
| śīrṣa | > | sīsa | 'head' |

b. CCC > TT$^{(h)}$

| | | | |
|---|---|---|---|
| mārttika | > | mattika | ‘made of clay’ |
| utkṣepa | > | ukk$^{h}$epa | ‘lifting up’ |
| alakṣmī | > | alakk$^{h}$ī | ‘bad luck’ |
| ūrd$^{h}$va | > | udd$^{h}$a | ‘being above’ |
| niḥṣṭ$^{h}$ita | > | niṭṭ$^{h}$ita | ‘finished’ |

c. CCC > SS

| | | | |
|---|---|---|---|
| pārśva | > | passa | ‘side’ |

d. NCC > NC

| | | | |
|---|---|---|---|
| indra | > | inda | ‘the god Indra’ |
| saṁskāra | > | saṅk$^{h}$āra | ‘preparation’ |
| saṁsyandayati | > | saṁsandēti | ‘joins’ |

As shown, cluster simplification follows the patterns of bi-directional assimilation discussed in section 2.2 (cf. von Hinüber 2001: § 260). That is, a stronger consonant wins over a weaker one and aspiration as well as nasality in coda persist.

The results of the above changes are: (i) simple onset, (ii) two moras at most, and (iii) three possibilities for the second mora: the second part of a long vowel, the first part of a geminate, and a nasal. That is, the second mora is specified for two features only, i.e. [vocalic] (whether it is a vowel or consonant) and [nasal] (whether it is a nasal or non-nasal). That these three types of the second mora are parallel is seen from the sporadic instances of long vowels, geminates, and NC, with no etymological basis, as given in (70) (Mayrhofer 1951: § 81, Geiger 1994: § 6, Hazra 1994: 55, von Hinüber 2001: §§ 111-112, Oberlies 2001: 20-23).

(70) a. Long vowel

| | | | |
|---|---|---|---|
| valka | > | vāka | ‘bark’ |
| sarṣapa | > | sāsapa | ‘mustard seed’ |
| viṁśati | > | vīsati | ‘twenty’ |
| siṁha | > | sīha | ‘lion’ |

b. Geminate

| | | | |
|---|---|---|---|
| ābṛhati | > | abbahati | ‘pulls out’ |
| nīḍa | > | niḍḍa | ‘nest’ |

c. NC

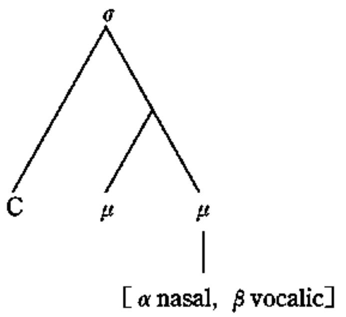
| | | | |
|---|---|---|---|
| matkuṇa | > | maṅkuṇa | ‘bug’ |
| śarvarī | > | saṁvarī | ‘night’ |

| | | | |
|---|---|---|---|
| $g^h$arṣati | > | $g^h$aṁsati | 'rubs' |

The data given in (70) show that there are random alternations of the second mora. The fact that the alternations are restricted to the three possibilities discussed above supports the proposed assumption that the second mora is specified only in [vocalic] and [nasal].

Thus the three processes that form two-mora conspiracy in Pali together with assimilation all aim at restricting the syllable structure to the one given in (71).

(71) Maximum syllable in Pali




While simple onset and maximum two moras have been repeatedly mentioned in literature (e.g. Vaux 1992, Geiger 1994, Oberlies 2001), to my knowledge the restriction on the second mora has not been mentioned earlier in the way it is formulated above. The next two sections discuss two further processes that aim at the same target.

### 5.2. Monophthongization

In Pali inherited diphthongs *ai* and *au* were monophthongized to *e* and *o*, respectively, as shown in (72) (cf. Mayrhofer 1951: 74-77, Geiger 1994: §15, Hazra 1994: 64, Oberlies 2001: 60, 65).

(72) a. ai > e

| | | | |
|---|---|---|---|
| naiva | > | neva | 'not indeed' |
| vaiśya | > | vessa | 'member of the third caste' |

b. au > o

| | | | |
|---|---|---|---|
| aurasa | > | orasa | 'innate, natural' |
| paura | > | pora | 'urban' |

As a result, Pali no longer allows a vocalic second mora which has its own specifications for height and backness.

### 5.3. Change and loss of word-final consonants

In Pali anusvāra is the only possible consonant in word-final position (cf. von Hinüber 2001:

§§ 168-169). This restriction on word-final consonant follows from the proposed analysis. In contrast to the coda consonant in medial position, the word-final consonant cannot be a non-nasal consonant in lack of the following consonant which may supply it with an oral gesture. It cannot be associated with aspiration because aspiration must be associated with the onset position. The word-final consonant can only be a nasal without an oral gesture, i.e. anusvāra, because coda consonant may be specified [+nasal] but may not have an oral gesture of its own.

In Pali nasals regularly changed to anusvāra, as shown in (73).

(73) Final N > ṁ

| | | | |
|---|---|---|---|
| aśvam | > | assaṁ | 'horse (acc.sg.)' |
| $b^h$aran | > | $b^h$araṁ | 'bearing (pres.ppl.)' |

Non-nasals were lost word-finally. Final *-aḥ* from either *-as* or *-ar* mostly became *-o* (cf. (74a)), and other final non-nasals were lost, occasionally with concomitant lengthening, shortening, or nasalization of the preceding vowel (cf. (74)) (Mayrhofer 1951: § 187-191, Geiger 1994: § 66.2, Hazra 1994: 57, Oberlies 2001: 25-26).

(74) Loss of final consonants

| | | | |
|---|---|---|---|
| a. manas ~ manaḥ | > | mano | 'mind' |
| punar ~ punaḥ | > | puno | 'again' |
| b. $d^h$anus | > | $d^h$anu | 'bow' |
| pariṣat | > | parisā | 'retinue' |
| abravīt | > | abravi | 'he spoke' |
| tiryak | > | tiriyaṁ | 'obliquely' |

As shown in (73), nasality in coda persists in word-final position as well as in medial position. However, as shown in (74), word-final aspiration must disappear in lack of an adjacent onset position, while in medial position aspiration in coda is transferred to the following onset position. In order to cope with the loss of aspiration in final position, the constraint FAITHASP should be reformulated as violable when there is no adjacent onset position which may serve as a host for aspiration (cf. section 4.2.2 above).

In sum, not only shortening, anaptyxis, and cluster simplification, which participate in the so-called two-mora conspiracy, but 'assimilation' in the sense I propose in this paper (cf. section 4 above), monophthongization, and several processes which affected word-final consonants all conspired to restrict the phonological patterns of Pali. The conspiracy is more extensive than has been generally assumed and can be seen not only in regular patterns, but also in sporadic alternations of the second mora such as in (70). The mechanism and direction of the changes which affected the phonological structure of Pali, as discussed in this section, offer further support for the proposed analysis of assimilation. It is only under the proposed analysis that such a generalization is made possible.

## 6. Conclusions

This paper has shown that a number of phonological processes in Pali, i.e. assimilation of medial clusters, metathesis, reduction of sibilants, simplification of initial clusters, two-mora conspiracy, monophthongization, and changes of word-final consonants, follow from several independent but interacting factors, especially consonant strength relation based mainly on oral stricture, syllable structure constraints, distribution and persistence of aspiration, and persistence of the coda nasal. The following are the two points that characterize the proposed analysis.

First, Pali assimilation affects all the consonant clusters and is governed by the consonant strength hierarchy: stops – nasals – sibilants – *l* – *v* – *y* – *r* instead of the sonority hierarchy or the onset-initial consonant. This hierarchy is based mainly on the degree of oral stricture and assimilation involves mainly oral gesture. Consonants without an oral stricture, i.e. *h*, visarga, and anusvāra, cannot be placed in this hierarchy.

Second, the second mora may only have vocalicity and nasality of its own and must share other features with an adjacent element. This dominance of the onset consonant over the coda consonant supplies a second motivation for assimilation in addition to the consonant strength relation. As a result of this restriction on coda position, possible medial clusters in Pali are geminates with and without aspiration and clusters with a nasal as its first member.

The proposed analysis not only conforms to the attested data, but also reflects more clearly the overall direction of the various changes towards restricting the phonological patterns in Pali. The proposed analysis is free from those unexplained gaps in the consonant cluster inventory or unmotivated restrictions on assimilation and other processes which accompany the previous analyses.

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