

Chapter 4

Representations

In the previous chapter I proposed a new framework and it is time now to represent the operational rules of Aṣṭādhyāyī in this new framework. In contrast to the *sūtras* of Aṣṭādhyāyī which are meant to be interpreted and applied by a learned student of grammar, the operational rules are formulated in terms of statements. In the following, I will take a representative selection of the operational rules of Aṣṭādhyāyī and render them in the new framework. The task to represent all the operational *sūtras* of Aṣṭādhyāyī would require more time and space than I have at my command at this moment. My claim, however, is that the operational rules of the entire Aṣṭādhyāyī can be represented in this manner.

4.1 Operational statements

4.1.1 Characterizing the components

Consider the very first *sūtra* of Aṣṭādhyāyī: *vṛddhirādaic*. It says that *āt* and *aic* are termed *vṛddhi*. Traditionally, it is a definition (*sañjñā-sūtra*) specifying the technical term *vṛddhi*. In the new framework it is seen as an operational statement that provides for attachment of the attribute *vṛddhi* to those sounds that contain the attribute *āt* or *aic*. It is specified in the following manner.

+a: vṛddhi

1. $X_{m+a} \parallel X_m[\bar{a}t, aic]$

वृद्धिरादैच् ॥ १.१.१ ॥ ► vṛddhi stands for $\bar{a}t$ and aic .

The above statement consists of three lines. The first one is the header where the variable +a represents the type of operation, namely attachment of an attribute. This is followed by a semi-colon : and then the value i.e. the ID of the attribute which is to be attached. The attribute whose attachment is ordained by this rule is vṛddhi. So the first line says that this statement provides for attachment of the attribute vṛddhi.

The second line specifies that the attribute a is meant to be attached to a sound-set X_m . This is noted as X_{m+a} . Here, X_m is the m-th sound-set of some language-component X. This is followed by two parallel vertical lines || which separate the actual listing of the conditions. The condition in this case is noted as $X_m[\bar{a}t, aic]$. It means that the sound-set X_m should have either the ID: $\bar{a}t$ or the ID: aic . The second line is numbered as 1. The need for numbering will become clear once we meet cases where more than one mutually exclusive condition may trigger the operation. The core of the statement consists of the first two lines. It can be read as follows: attach an attribute with value vṛddhi. The attachment is to a sound-set. This sound-set must contain either the ID: $\bar{a}t$ or the ID: aic .

The third line which follows is useful for quick reference. It contains the original Pāṇinian *sūtra* which corresponds to the above statement together with an English translation.

The above statement is formulated within the formal framework introduced in the previous chapter. Thus, it provides for attachment of an attribute to a sound-set. Moreover, the condition which needs to be fulfilled is also specified in terms of the presence of certain IDs in that sound-set.

Two separate layers can be identified in the above statement. Firstly, its *structure* or *form* and secondly its *values* or *content*. The structure part is noted in the typewriter font. It is:

+a:—
 $X_{m+a} \parallel X_m[—]$

The content or values are the attributes vṛddhi, $\bar{a}t$ and aic . Thus, there is a clear separation between the form or structure of a statement on the one hand and its content or values on the other hand.

There are certain conventions employed in the new formulation. Some

of them correspond to the logical or structural properties of the statement and others are my choices for displaying them in print form. I collect and list these conventions in the grey boxes.

1. X stands for a language-component.
2. X_m stands for the m -th sound-set of some language-component X .
3. $+a$ stands for the type of operation, namely attachment of an attribute.
4. X_{m+a} says that the attribute a is attached to the sound-set X_m .
5. $X_m[ID1, ID2]$ represents the condition that the sound-set X_m should have either $ID1$ or $ID2$.

The next *sūtra* of Aṣṭādhyāyī is similar. In the grammatical corpus it is stated as *adeṅguṇaḥ*. It says that *at* and *eṅ* sounds are called *guṇa*. Its representation in terms of the new framework will be as follows:

+a: guṇa

1. $X_{m+a} \parallel X_m[at, eṅ]$

अदेङ्गुणः ॥१.१.२॥ ► *at* and *eṅ* are *guṇa*.

This statement can be read as follows: attach an attribute with value *guṇa*. The attachment is to a sound-set. This sound-set must contain either the ID: *at* or the ID: *eṅ*.

Now, if one compares the structure of this statement with the previous one, it becomes clear at once that both the statements have the following identical structure. Only the values of the IDs have changed.

+a: —
 $X_{m+a} \parallel X_m[—]$

The identical structure of the above statements tells us that from operational point of view, they are identical. In other words, both the statements can be implemented through a single operational function. In fact, the operation of attachment of an attribute to some component is a fundamental operation in the Pāṇinian system. Within the Pāṇinian corpus this operation is formulated and presented through different techniques. We list them in the following sections.

4.1.1.1 Explicit enumeration

A straight forward way to form a set is to enumerate its members explicitly. Pāṇini uses this technique extensively, where the components are listed together. As an example, consider the statement :

+a: niṣṭhā

1. $X+a \parallel X[(k)ta, (k)tavat(u)]$

कृत्तवत् निष्ठा ॥ १.१.२६ ॥ ► (k)ta and (k)tavat(u) are niṣṭhā.

Here the components (k)ta and (k)tavat(u) which form the set called niṣṭhā are mentioned explicitly. Again, the structure of this statement, namely

+a:—
 $X+a \parallel X[—]$

is similar to the structure of statements attaching the attributes vṛddhi or guṇa, namely:

+a:—
 $X_m+a \parallel X_m[—]$

There is, however, one important difference. This statement provides for attachment of the attribute niṣṭhā to the entire language-component, while the previous statements provide for attachment of attributes like vṛddhi or guṇa to a particular sound-set. Further, there are significant differences in the nature of values. While all the statements provide for attachment of some attribute, the conditions in the first two statements are formulated in terms of other attributes (like āt or aic), while in the case of the third statement, it is based on other fundamental components, namely (k)ta and (k)tavat(u). One can, at this point, speak of attributes that are attached to a sound-set or phonological features and those that are associated with a language-component or morphological characteristics.

Another example of attribute attachment to a language-component is:

+a: gha

1. $X+a \parallel X[tara(p), tama(p)]$

तरस्रमपौ घः ॥ १.१.२२ ॥ ► tara(p) and tama(p) are gha.

Apart from explicit enumeration of members of a set within the main

corpus, namely the Sūtrapāṭha of Aṣṭādhyāyī, there are extra lists or sets of components collected in the two large appendices—the Dhātupāṭha and the Gaṇapāṭha. Within these large lists there are several sub-groups as well. One common way of naming such a list is by mentioning its first element like bhū and then forming the compound *beginning with bhū* or bhvādi. The corresponding statement would be:

+a: bhvādi

1. X+a || X[bhū, paṭh(a), ..., ji, pū(n), dhe(t), ...]

The form of this statement is identical to the one for attachment of the attribute niṣṭhā. It says that whenever a language-component has any of the IDs for bhū, paṭh(a) etc., then the attribute bhvādi should be attached to it. All such sets that are specified in the grammatical corpus by explicit enumeration of their elements can be formulated within the new framework in a similar manner. For example, the statement for the next large set of verbal roots would be:

+a: adādi

1. X+a || X[ad(a), han(a), dviṣ(a), duh(a), dih(a), ...]

In both cases above, i.e. attachment of bhvādi or adādi, there is no mention of any *sūtra* of Aṣṭādhyāyī. This is because these statements do not correspond to any *sūtra* which is uttered explicitly in the grammatical corpus. Thus, the new formulation includes information that is specified in the grammatical corpus even if it is not mentioned in an explicit *sūtra* of the Aṣṭādhyāyī.

4.1.1.2 Formation of sigla (*pratyāhāra*)

The fundamental sounds are listed in what are called the Śivasūtras.¹ Compared to the listings of the sounds in Prātiśākhya, there are two novel features in Pāṇini's enumeration. Firstly, there is a new sequencing of the sounds and secondly, there are deleming markers placed between them. Following is the list of sounds in the Śivasūtras :

a i u ṛ ḷ k| e o ṛ ai au c| h y v r ṭ| l ṇ| ñ m ṇ ṅ n m| jh bh ṅ| gh ḍh
dh ṣ| j b g ḍ d ś| kh ph ch ṭh th c ṭ t v| k p y| ś ṣ s r| h l|

¹ The terms used for the list of units or phonemes are *akṣarasamāmnāya* (in Mahābhāṣya) and Śivasūtra or Maheśvarasūtra in later tradition. Nandikeśvara mentions in his Kāśikā that the lord Śiva sounded his drum (*dhakkā*) fourteen times revealing the fourteen *sūtras* to Pāṇini. Hence the name Śivasūtra or Maheśvarasūtra. See (Cardona 1997 p. 83). Important studies on the Śivasūtras include (Breloer 1935 p. 133-191), (Cardona 1969 p. 3-48), (Staal 1962 p. 1-10), (Kiparsky 1991a) and (Petersen 2004 p. 471-489 and 2009 p. 79-98).

This sequence is not according to the usual order found in the Prātiśākhya on the basis of place of articulation.² Moreover, certain consonants are inserted as delimiters. They are placed at particular positions indicating the final sound of a *sūtra*.³ Using delimiters, the groups of sounds can be named in a generic manner. For this, one begins from the initial non-delimiter sound and continues upto the final delimiter sound. All the non-delimiter sounds contained in this sequence belong to that group.⁴

The purpose of the special ordering as well as use of delimiters is to form groups and sub-sequences required for the functioning of grammar.⁵ Kātyāyana notes that “the teaching of the sounds is to provide a special ordering for the sake of functionality of rules”.⁶ Tradition uses the term *pratyāhāra* (lit. bringing together) for the groups formed in this manner using a marker sound as the end delimiter.⁷

Pāṇini performs the task of forming groups in a generic manner. Instead of enumerating individual groups, he provides a rule-based method for forming and naming them. The reason for this way of forming groups is brevity (*lāghava*).⁸ The technique employed for forming sets of sounds is employed for formation of groups of components as well. Examples include:

² Compare (RVPr. 1.1-14). B. Breloer (1929 p. 114-135) provides a detailed study of the organization of phonemes on the basis of place of articulation in comparison to the different ordering in the Śivasūtras. See also (Cardona 1965 p. 225-237).

³ These are also called it-markers. Usually the it-markers are attached to some component and this attachment is regulated by a set of meta-linguistic rules. In case of Śivasūtras however, they are placed as delimiters. In order to distinguish them from the it-markers appearing in the components, we write them in italics and not in ()-brackets. Cardona (1969 p. 12) employs a more appropriate formulation here than Joshi and Roodbergen (1986 p. 188), “placed” instead of “added”, as the it-markers are not attached to the previous sounds, they are just placed after them. They do not, for example, make the sound u in a i u ṅ | a ṅ it sound. P. S. Subrahmanyam (1999 p. 88-91) recognizes this in his notation of *pratyāhāras*.

⁴ This is specified by the rule: आदिरन्त्येन सहेता ॥ १.१.७१ ॥ ► an initial element together with the final it sound includes intervening elements.

⁵ The process which is at work here is to form sub-sequences. Given a sequence, a number of sub-sequences can be formed, not all of which are relevant for grammar specifications. Given a finite alphabet Σ^n upto 2^n sub-sequences, $\binom{n}{k}$ of length k can be generated, which need not all be different. The contiguous sub-sequences which can be generated are $\frac{n(n-1)}{2}$ in number. Pāṇini, however, employs 41 sub-sequences. There is a 42nd *pratyāhāra*, namely *cay*, mentioned by Kātyāyana in his Vārttika 3 under the rule नादिन्याक्रोशे पुत्रस्य ॥ ८.४.४८ ॥. See (Subrahmanyam 1999 p. 90).

⁶ वृत्तिसमवायार्थ उपदेशः (PV. 19). See (Joshi and Roodbergen 1986 p. 186-187).

⁷ Pāṇini does not use this term. See (Abhyankar 1986 p. 266-167).

⁸ Devasthali (1967) is a detailed study on the *anubandhas* of Pāṇini. The structure of the Śivasūtras and its explanation on the basis of brevity is worked out by Staal (1962 p. 1-10), Cardona (1969 p. 3-48), Kiparsky (1991a) and Petersen (2009 p. 79-98). Wiebke Petersen (2008) has proved using mathematical methods that the listing of units and the choice of positioning of markers are optimal.

$tiñ = [ti(p) \text{ tas } jhi \text{ si}(p) \text{ thas } tha \text{ mi}(p) \text{ vas } mas \text{ ta } \text{ātām} \text{ jha } thās \text{ āthām} \text{ dhvam}$
 $i(t) \text{ vahi } mahi(ñ)].$

$tañ = [ta \text{ ātām} \text{ jha } thās \text{ āthām} \text{ dhvam } i(t) \text{ vahi } mahi(ñ)]$

$sup = [s(u) \text{ au } (j)as \text{ am } au(t) \text{ (ś)as } (t)ā \text{ bhyām} \text{ bhis } (ñ)e \text{ bhyām} \text{ bhyas } (ñ)as(i)$
 $bhyām \text{ bhyas } (ñ)as \text{ os } \text{ām} \text{ ñi } os \text{ su}(p)]$

$sut = [s(u), \text{ au}, (j)as, \text{ am}, \text{ au}(t)]$

Here the non-marker portion of the first component is taken as the initial part, and the last marker sound of the final component of the sequence as the final part.

Pratyāhāras are names of groups and sub-sequences. This indicates that they belong to the category of attributes. Forming groups of sounds and naming them implies that each element of that group is assigned an attribute, namely the name of that group. Thus the sounds a, i, u are assigned the attribute *añ*, since they form the group {a, i, u}. The rule *tasya lopah*⁹ which is applied for elision of the marker sounds does not apply in case of *markers* appearing in these names. It is for this reason that in my notation the marker sounds originally coming from a component, but now forming the name of a group, are not placed within brackets but are denoted by *italics*.

In formal representation, *pratyāhāras* and other names for groups of components are attributes that are attached to the respective sounds or components.

+a: ac

1. $X_{m+a} \parallel X_m[a, i, u, \text{ṛ}, \text{ḷ}, e, o, ai, au]$

अ इ उ ण् ॥१॥ ► a, i, u, (ñ). ऋ लृ क् ॥२॥ ► ṛ, ḷ, (k). ए ओ ङ् ॥३॥ ► e, o, (ñ). ऐ औ च् ॥४॥ ► ai, au, (c). आदिरन्त्येन सहेता ॥१.१.७१॥ ► an initial element together with the final it sound includes intervening elements.

+a: tiñ

1. $X+a \parallel X[ti(p), \text{ tas } jhi \text{ si}(p), \text{ thas } tha, \text{ mi}(p), \text{ vas } mas, \text{ ta } \text{ātām}, \text{ jha } thās, \text{ āthām}, \text{ dhvam}, i(t), \text{ vahi } mahi(ñ)]$

आदिरन्त्येन सहेता ॥१.१.७१॥ ► an initial element together with the final it sound includes intervening elements. तिस्रिङ्गिसिप्थस्थमिष्वस्मस्तातांझथासाथांञ्वमिङ्गिमहिङ् ॥३.४.७८॥ ► $ti(p) \text{ tas } jhi \text{ si}(p) \text{ thas } tha \text{ mi}(p) \text{ vas } mas \text{ ta } \text{ātām} \text{ jha } thās \text{ āthām} \text{ dhvam } i(t) \text{ vahi } mahi(ñ)$ are the substitutes of the cover term *l* or a *lakāra*.

Sometimes the order of the sounds within a *pratyāhāra* is important.

⁹ तस्य लोपः ॥१.३.९॥ ► its elision (takes place).

Consider, for example, the rule *eco'yavāyāvah*¹⁰ where the order of sounds [e, o, ai, au] in *ec* must necessarily be maintained to correspond with the components [ay, av, āy, āv]. Sometimes, however, the order of sounds within a *pratyāhāra* is of no importance. For example, in the rule *vṛddhirādic*¹¹ the order of [ai, au] in *aic* does not need to be fixed.

The attributes *at*, *āt*, *it*, *ūt* etc. characterize the respective length of the vowel. For example:

+a: āt

1. $X_m+a \parallel X_m[a][dīrgha]$

तपरस्तत्कालस्य ॥१.१.७०॥ ► an *ac* followed by the marker *t* stands for sounds having the same time duration.

The condition clause $X_m[a][hrasva]$ specifies that both the IDs, namely the one corresponding to *a* and the one to *hrasva*, must be present in the sound-set X_m . The following convention is used here:

6. $X_m[—][—]$ says that both the variables within the two square bracket must be simultaneously present within the sound-set X_m .

4.1.1.3 Use of attributes

Within the grammatical corpus, the names of smaller sets are used to constitute a larger one. For example, the rule *tiñ śit sārvaadhātukam* specifies that the elements of the sets *tiñ* and *śit* together form the set called *sārvaadhātuka*.¹² Now, as mentioned above, *tiñ* is a set of 18 suffixes and *śit* also is the name of the group of components having *ś* as it-marker. This can be seen as set union where a larger set is formed on the basis of the union of two or more smaller sets.

+a: sārvaadhātuka

1. $X+a \parallel X[tiñ, śit]$

¹⁰ एचोऽयवायावः ॥६.१.७८॥ ► *ec* = [e o ai au] are replaced by ay av āy āv respectively when *ac* follows.

¹¹ वृद्धिरादिच् ॥१.१.१॥ ► *vṛddhi* stands for *āt* and *aic*.

¹² Because of the *anuvṛtti* of *dhātoḥ* 3.1.91, strictly speaking, these suffixes are termed *sārvaadhātuka* once they are introduced after a verbal root. But for the sake of simplicity, I am not taking this into consideration here.

तिङ् शित् सार्वधातुकम् ॥ ३.४.११३ ॥ ► *tiñ* and those having *ś* as it marker are called *sārvadhātuka*.

The above representation says that if a language-component has either *tiñ* or *śit* as its attribute, then the attribute *sārvadhātuka* should be attached to it.¹³

4.1.1.4 The it-markers

The it-markers attached to a component give rise to a set which is named as *the set of components with a particular it marker*. For example, *śit* components are those that have *ś* as it, like *(ś)a(p)*, *(c)āna(ś)* etc. These are represented by including the attribute *śit* in the corresponding sound-sets. Thus, the new representation of the component *(ś)a(p)* would be:

$$X = \{[a, (ś)a(p), śit, pit, \dots]\}$$

The primary list of the components records this information about the it-markers by including attributes like *śit* or *pit* in the new representation of the component *(ś)a(p)*.

Sometimes components not originally marked with it-markers are assigned markers through specific rules. At other times, the characteristics of having a marker is removed in certain instances. We will address such dynamic assignment of it-markers later in sections 4.1.1.12 and 4.1.1.13.

4.1.1.5 Groups based on some identifying sound

Sometimes the set of components is specified by an indicatory sound which is shared by all the elements of the group. For example, in the rule *dādḥāghvoadāp* the intended components are the ones having the form *dā* or *dhā* with the exception of *dā(p)* and *dai(p)* i.e. *(ḍu)dā(ñ)*, *(ḍu)dhā(ñ)*, *dā(ñ)*, *de(ñ)*, *do*, *dhe(ṭ)*. Here the formulation of *sūtra* is not explicit and additional explanations are required to interpret it. There is no precise specification of the elements of the group. The intended components need to be enumerated in an explicit manner as follows:

+a: **ghu**

1. X+a || X[(ḍu)dā(ñ), (ḍu)dhā(ñ), dā(ñ), de(ñ), do, dhe(ṭ)]

¹³ In fact, here the condition that it must be a suffix or *pratyaya* which is introduced after a *dhātu* or verbal root is not mentioned. This is for the sake of simplicity and explanation.

दाघाघ्वदाप् ॥१.१.२०॥ ► (ḍu)dā(ñ), (ḍu)dhā(ñ), dā(ñ), de(ñ), do and dhe(ṭ) are ghu.

Thus, the instances where an explicit enumeration is sought, but not specified in clear terms are determined by exhaustive listing of the components meant to be listed.

4.1.1.6 Specification of the boundaries

A usual method employed in the Sūtrapāṭha of the Aṣṭādhyāyī is to specify the boundary within which the components that are mentioned are assigned some attribute. For example, the rule *prāgrīśvarānnipātaḥ*¹⁴ states that the components enumerated prior to *rīśvare* in the rule *adhirīśvare*¹⁵ are termed nipāta. Sometimes the boundary is not mentioned explicitly, but is indicated by the domain or *adhikāra*. For example, the attribute *pratyaya* is assigned on the basis of mentioning the domain in the rule *pratyayah*¹⁶, which says that the components introduced hereafter till the end of the fifth chapter are called *pratyaya*. It should be noted that there is no separate enumeration in this case, but the components are specified together with the conditions under which they are introduced and the associated operations that need to be carried out. Explicit statements are formulated in the new framework to attach such attributes.

+a: pratyaya

1. X+a || X[sa(n), (k)ya(c), kāmya(c), ..., l(a)(ṭ), ..., ti(p), ..., (ś)a(p), ...]

प्रत्ययः ॥३.१.१॥ ► pratyaya are components introduced subsequently.

4.1.1.7 Formation of groups of attributes

Pāṇini not only forms sets of components, he also defines the collections of attributes. For example, the attribute *kāraka* is the name of the group of attributes {kartṛ, karman, karaṇa, sampradāna, apādāna, adhikaraṇa}.

+a: kāraka

1. X+a || X[kartṛ, karman, karaṇa, sampradāna, apādāna, adhikaraṇa]

¹⁴ प्राग्ग्रीश्वरान्निपातः ॥१.४.५६॥ ► Before the rule 97 the units introduced are assigned nipāta.

¹⁵ अधिरीश्वरे ॥१.४.९७॥ ► adhi is assigned karmapravacanīya when it conveys lordship.

¹⁶ प्रत्ययः ॥३.१.१॥ ► pratyaya are components introduced subsequently.

It should be noted that although the semantic definition of *kāraka* is not considered here, as the *Aṣṭādhyāyī* does not provide it in an explicit manner through some meaning-expression, the term *kāraka* stands for the group of attributes mentioned above.

4.1.1.8 Specifying the complementary set

Pāṇini also specifies a set by defining it as complementary to some other sets. For example, in the rule *arthavadadhāturapratyayaḥ prātipadikam*¹⁷ the set of nominal stems (*prātipadika*) is defined as consisting of components that are meaningful (*arthavat*) and do not belong to the sets of verbal roots (*dhātu*) and suffixes (*pratyaya*).¹⁸

+a: *prātipadika*

1. X+a || XM[*arthavat*] ∧ XNOT[*dhātu*] ∧ XNOT[*pratyaya*]

अर्थवदधातुरप्रत्ययः प्रातिपदिकम् ॥ १.२.४५ ॥ ► a meaningful component which is not a *dhātu* and not a *pratyaya* is *prātipadika*.

All the above methods are different ways to specify the formulation of sets or sequences of components. The attribute in these cases is the name of the group and is attached to each element that belongs to this group.

Theoretically, it is possible to specify them in an explicit and precise manner by enumerating the set. Although, in the oral framework of Pāṇini there are some interesting and elegant ways to formulate formation of a group, it is neither precise nor explicit in all cases. In the new representation, all such instances are specified explicitly.

4.1.1.9 Naming the distribution of components

Apart from group formations, attributes also signify a specific distribution of the components in the derivational process. Consider the attachment of the attribute *saṃyoga*. It is stated as follows:

¹⁷ अर्थवदधातुरप्रत्ययः प्रातिपदिकम् ॥ १.२.४५ ॥ ► a meaningful component which is not a *dhātu* and not a *pratyaya* is *prātipadika*.

¹⁸ For the sake of simplicity we leave here other conditions mentioned in the rule *कृत्तद्धितसमासाश्च* ॥ १.२.४६ ॥ ► components ending with *kṛt* or *taddhita* or those which are *saṃāsa* as well.

+a: saṃyoga

1. $X_m X_{n+a} \parallel X_m[ha/] \wedge X_n[ha/] \wedge IDX[n=m+1]$

हल्लोऽनन्तराः संयोगः ॥ १.१.७ ॥ ► *hal* in contiguous sequence are saṃyoga.

Here, $X_m X_{n+a}$ specifies that the attribute *a* should be attached to both the sound-sets, namely to X_m as well as X_n . Thus saṃyoga is attached to both the sound-sets. The condition $X_m[ha/]$ states that the sound-set X_m must contain the attribute *hal*. Similarly, $X_n[ha/]$ says that the sound-set X_n must also contain *hal*. Moreover, $IDX[n=m+1]$ specifies that the indices *m* and *n* are contiguous. The logical \wedge sign specifies that the three conditions are related with the logical AND operator. The new conventions that are needed here are:

7. $X_m X_n$ are consecutive sound-sets (phonemes). The order is FIXED.
8. $IDX[n=m+1]$ says index *n* is equal to the index *m+1* i.e. *n* is the next contiguous index following *m*.

It should be noted that this type of convention is a personal choice of the editor to note down the eventualities. However, from the point of view of complexity of grammar formulation, *the concept of consecutive sounds* is important.

The form or structure of this statement can be specified as follows:

+a:—
 $X_m X_{n+a} \parallel X_m[—] \wedge X_n[—] \wedge IDX[—]$

The form of this statement is different from forms of the previous statements. This implies that the attachment of an attribute like saṃyoga needs a very different operational function than attachment of attributes like *vṛddhi*, *guṇa* etc. In this case, it is the nature of the adjacent sound-set which would decide whether the two adjacent sound-sets can be assigned the attribute saṃyoga or not. This aspect of positional distribution requires the use of $IDX[—]$ clause. Here, however, there are no numbers as indices, but only the constraint that the sound-sets X_m and X_n need to be adjacent.

Another example is the rule *aco'ntyādi ṭi*. It assigns the attribute *ṭi* to that part of the sound sequence which begins with the last vowel. Thus, the attribute *ṭi* is attached dependent upon the distribution of the language-component. It is specified by the statement:

+a: ṭi

1. $X_b e+a \parallel X_b[ac] \wedge X_m \text{NOT}[ac] \wedge IDX[m=(b+1 \text{ TO } e)]$

अचोऽन्त्यादि टि ॥ १.१.६४ ॥ ► that part which begins with last ac is \dot{t} .

This states that the attribute \dot{t} is attached to a sub-sequence of the language-component X , namely from the sound-set X_b upto the sound-set X_e . Moreover, X_e is also the final sound-set of that language-component. Further, the initial sound-set of the sub-sequence should have the attribute ac and the subsequent sound-sets should not contain the attribute ac . In the representation above, the suffixes be denote a range from X_b upto X_e . Thus, X_{be} represents the sub-sequence $[X_b, X_{b+1}, \dots, X_e]$. Further, X_m where the index IDX ranges from $m = b+1$ TO e says that the sub-sequence $[X_{b+1}, \dots, X_e]$ of sound-sets is meant. Here, the necessity of checking a particular range of sound-sets indicates that the assignment of the attribute sometimes depends upon the distribution of various components in a derivational state. The following new conventions are introduced:

9. X_{be} represents the range of sound-sets from X_b till X_e where X_e is the final sound-set of that language-component. X_m is a variable sound-set which ranges from the index $b+1$ till e .
10. X_m NOT denotes that the sound-set X_m should NOT contain any of the IDs mentioned in this condition clause.

The next attribute *upadhā* is attached to the penultimate sound-set of a language-component.

+a: upadhā

1. $X_{u+a} \parallel X_u[a] \wedge X_e[a] \wedge IDX[u=e-1]$

अलोऽन्त्यात्पूर्वं उपधा ॥ १.१.६५ ॥ ► an a which is penultimate is *upadhā*.

The subscript e in X_e indicates that it is the final sound-set of the language-component. Moreover, the condition under the IDX clause provides that X_u is the penultimate sound-set. As a convention:

11. X_u is reserved for the penultimate (*upadhā*) sound-set.

As the next example, consider the definition of *laghu* and *guru*. In the *Aṣṭādhyāyī* it is specified through the following three *sūtras* : *hrasvaṃ laghu, saṃyoge guru, dīrghaṃ ca*. Together, they say that a *hrasva* sound (short vowel) is *laghu* (light), except when *saṃyoga* (consonant cluster) follows, then it is *guru* (heavy), as also a *dīrgha* sound (long vowel).

From the perspective of the new formal framework, there are two instances of attachment of attributes, namely *laghu* and *guru*. Accordingly, there are two different statements. Consider first the attachment of the attribute *laghu* :

+a: laghu

1. $X_m+a \parallel X_m[\text{hrasva}] \wedge X_n\text{NOT}[\text{saṃyoga}]$

ह्रस्वं लघु ॥१.४.१०॥ ► hrasva is laghu. संयोगे गुरु ॥१.४.११॥ ► when saṃyoga follows, it is guru.

Both the *sūtras* 1.4.10 and 1.4.11 mentioned above need to be taken into account. It has to be made explicitly clear that a hrasva sound is only then laghu when saṃyoga does not follow. This information is implicit in the oral formulation. $X_n\text{NOT}[\text{saṃyoga}]$ notes this explicitly. It says that the next following sound-set X_n should not contain the ID saṃyoga. The two conditions are joined by the logical AND operator, which is represented in this book through the \wedge sign. Moreover, a convention is used here, namely that X_m and X_n represent two consecutive sound-sets.

The statement for attachment of guru is as follows:

+a: guru

1. $X_m+a \parallel X_m[\text{hrasva}] \wedge X_n[\text{saṃyoga}]$
2. $X_m+a \parallel X_m[\text{dīrgha}]$

ह्रस्वं लघु ॥१.४.१०॥ ► hrasva is laghu. संयोगे गुरु ॥१.४.११॥ ► when saṃyoga follows, it is guru. दीर्घं च ॥१.४.१२॥ ► dīrgha as well.

The conditions are now listed in two separate lines. They represent two disjoint cases when the attribute guru is to be attached. The first is when the sound is hrasva (short vowel) and is followed by saṃyoga or consonant cluster, and the second case is when the sound itself is dīrgha (long vowel). The individual lines contain the conditions that can be combined together with the logical OR operator. The reason for keeping them separate is not just for the sake of readability, but to distinguish between disjoint sets of conditions. This, as will be made clear, is important for noting the complexity of the conditions in an explicit manner (see section 4.2.2).

4.1.1.10 Associating attributes with meaning-expressions

The cases mentioned thus far are all dependent in one way or another upon the grammatical information stated in the grammatical corpus. The next big category of attribute assignment is through semantic characterization. This is usually achieved by associating the attributes with a meaning-expression.

The following statement associates the expression *mukhanāsikāvācana* (an utterance spoken simultaneously through mouth and nose) with the term *anunāsika*. In this case, the meaning of the expression *mukhanāsikāvācana* must be clear to the person using the grammar. In the present case, the user needs to be consulted in order to ascertain whether the sound represented by the sound-set X_m is *mukhanāsikāvācana* or not.

+a: anunāsika

1. $X_{m+a} \parallel X_m[a, i, r, l, u, e, ai, o, au, y, l, v] \wedge X_m M[mukhanāsikāvācana]$

मुखनासिकावचनोऽनुनासिकः ॥१.१.८॥ ► from mouth and nose uttered sound is *anunāsika*.

The new representation indicates the semantic character of the conditions by using the letter M in conditional clauses. Thus the M part in $X_m M$ says that the sound-set X_m takes the attribute *anunāsika*, if it fulfils the semantic condition judged through the user that the sound is uttered simultaneously through the oral and the nasal cavities (*mukhanāsikāvācana*). The first condition, namely, the sound-set X_m must contain one of the above mentioned sounds like a, i, r etc. is not mentioned explicitly in the original *sūtra*, but is included on the basis of the explanations of it. The following convention is used here:

12. $X_m M$ is a meaning-condition associated with X_m . It implies that the user needs to be consulted in order to ascertain the admissibility of the meaning-expression.

The next statement is of different kind. Instead of attaching an attribute it provides an answer to a particular kind of relation between two sound-sets. The relation to be tested is with respect to the attribute a.

?a: savarṇa

1. $X_p X_q ?a \parallel X_p X_q M[tulyāsyaprayatna] \wedge X_p[ac] \wedge X_q[ac]$
2. $X_p X_q ?a \parallel X_p X_q M[tulyāsyaprayatna] \wedge X_p[hal] \wedge X_q[hal]$

तुल्यास्यप्रयत्नं सवर्णम् ॥१.१.९॥ ► sounds with same articulatory effort are *savarṇa*.
नाञ्जलौ ॥१.१.१०॥ ► but not *ac* together with *hal*.

The *sūtra*: *tulyāsyaprayatnaṃ savarṇam* says that two sounds are *savarṇa* when they have the same place of articulation (*tulyāsyaprayatna*). Further, *nājjhalau* clarifies that a vowel (*ac*) and a consonant (*hal*) can not be *savarṇa*, even if they have same place of articulation. This implies that either both of them are *ac* or both of them are *hal* sounds. This is specified by the condition clauses $X_p[ac] \wedge X_q[ac]$ which posit that both the sound-sets must contain

ac. The other option that both of them should contain *hal* is comprehended in the next part of the statement. It must be noted that for the application of this statement, one needs to know what the places of articulation are and which sounds are articulated from which part of the mouth. Thus, the meaning-expression needs further explanations. The conventions used in this case are recorded as follows:

13. $X_p X_q$ are two sound-sets (not necessarily contiguous).
14. $X_p X_q ? a$ represents the question whether the sound-sets X_p and X_q are related with respect to the attribute a . The answer would be a boolean TRUE or FALSE.

4.1.1.11 Attributes based on intention

There is another category of attributes that are defined through a meaning-expression where the intention (*vivakṣā*) of the speaker plays a central role. For example, attachment of the attribute *karṭṛ* to any specific component shall depend upon the intention of the speaker, whether she or he intends to express *karṭṛ* through that component or not. Thus, although the rule *svatantraḥ karṭṭā* defines *karṭṛ* to be that *kāra* which is independent of others (*svatantra*), yet its attachment to a particular component depends upon the intention of the speaker.

+a: karṭṛ

1. $X+a \parallel XM[svatantra]$

स्वतन्त्रः कर्त्ता ॥ १.४.५४ ॥ ► that *kāra* which is *svatantra* or independent of others is *karṭṛ*.

Here M in the condition clause $XM[—]$ specifies that the intention of the speaker through the meaning-expression should be taken into consideration.

4.1.1.12 Extending an attribute

Sometimes, certain attributes are extended to components under particular circumstances. Tradition calls these provisions *atideśa* (extention) rules.

+a: ñit

1. $X_i+a \parallel X_h[gā(ñ), kuṭādi] \wedge X_i[pratyaya] \wedge X_i \text{NOT}[\ñit][ñit]$

गाङ्कटादिभ्योऽङ्गिण्डित् ॥ १.२.१ ॥ ► after gā(ñ) and kuṭādi those pratyaya not having ñit or ṅit are assigned ñit.

Here the positions of X_h and X_i have to be in this order. That means a suffix in the language-component X_i which has neither ñit or ṅit and which comes after the component X_h, having either the component gā(ñ) or the attribute kuṭādi, is attached the attribute ñit.

4.1.1.13 Removing an attribute

There are cases when an attribute is removed under certain conditions. Consider the following example:

-a: kit

1. X_i-a || X_g[śī(ñ), ṣvid(ā), (ñi)mid(ā), (ñi)kṣvid(ā), (ñi)dhṛṣ(ā)] ∧ X_h[i(ṭ)] ∧ X_i[niṣṭhā]

निष्ठाशीङ्गिदिमिदिद्विदिधृषः ॥ १.२.१९ ॥ ► niṣṭhā preceded by i(ṭ) and coming after śī(ñ), ṣvid(ā), (ñi)mid(ā), (ñi)kṣvid(ā), (ñi)dhṛṣ(ā) loses kit.

Here, instead of adding, an attribute is removed. This is denoted by -a: which says that the attribute following after this should be removed from the appropriate language-components. The condition clauses specify the constellation. There are three language-components, X_g, X_h and X_i in this order. The language-component from which the attribute kit should be removed is X_i, specified by the attribute niṣṭhā, which according to the rule *ktaktavatū niṣṭhā*¹⁹ stands for the components (k)ta and (k)tavat(u). Further, this will happen only when it is preceded by X_h having the augment i(ṭ). The whole complex should follow X_g with one of the components listed in it.

4.1.2 Combining the components

The process of derivation involves the combination of the constituent components with one another. This leads to a change at the form level. A change at the form level can happen when a component is introduced. Further, changes can also be induced by replacement of a component, augmentation or when some of the phonetic features are changed, for example, when a short vowel becomes long.

¹⁹ क्तवत् निष्ठा ॥ १.२.२६ ॥ ► (k)ta and (k)tavat(u) are niṣṭhā.

second line lists the conditions. The locus of the component which is to be replaced is specified in the first part before the vertical lines. In this case the component which is to be replaced is X_i , and the replacement is noted by the variable y . Finally, the conditions are stated. The two components X_h and X_i should be in this order. This is recorded in the meta-linguistic conventions of the new formulation.

15. X_h and X_i indicate that the two components have to be in this order.

Although a different operation, replacement is not a fundamentally new operation, and in the formal representation it can be considered as a combination of introduction of a component and attachment of an attribute. Those sound-sets that get replaced are attached the attribute δ . The new component is placed after the replaced component. In the example above it would imply that the replaced language-component X_i gets the attribute δ and the new component $t_i(p)$ is placed after it.

4.1.2.3 Augmentation

Another operation is augmentation (*āgama*) by phoneme-sequences that do not carry any specific meaning for the sake of attaining the desired surface form. For example, the rule *ārdhadhātukasyeḍvalādeḥ* provides the initial increment $i(t)$ which is inserted at the head of an *ārdhadhātuka* suffix that begins with a *val* phoneme.²⁰

<y: $i(t)$

1. $y > X_i \parallel X_h[dhātu][aṅga] \wedge X_i[ārdhadhātuka] \wedge X_i b[va]$

आर्धधातुकस्येड्वल्लादेः ॥७.२.३५॥ ► the increment $i(t)$ is inserted at the head of an *ārdhadhātuka* affix which begins with a *val* phoneme.

This is modeled in the same manner as the introduction of a new component.

16. $y > X_i$ indicates that the attachment here is an augmentation.

17. In $X_i b$ the suffix b represents the initial sound-set.

²⁰ The *val* phonemes are {v, r, l, ñ, m, ṅ, n, jh, bh, gh, dh, dh, j, b, g, d, d, kh, ph, ch, ṭh, th, c, ṭ, t, k, p, ś, ṣ, s, h}

4.1.2.4 Change of phonetic form

The form of a language-component may also change if the phonetic attributes are modified. For example, the short (hrasva) vowel may be changed to a long (dīrgha) vowel. Similarly, the form level is also modified by the non-appearance of a sound. A component, or parts thereof, may undergo elision (lopa) i.e. non-appearance at the form level. For example, the rule *lopo vyorvali*²¹ says that the sounds v or y are elided if a suffix beginning with a val sound follows.

4.2 Structure of a statement

Statements follow a fixed syntax. The structure of a general statement can be specified as follows:

```
Operation-Declaration:ID
1. Placement-Distribution || ANDeD Conditions
2. Placement-Distribution || ANDeD Conditions
3. Placement-Distribution || ANDeD Conditions
...
```

There are two main divisions. The first line, depicted in bold-case letters, declares the unique operation and the other lines appear as a numbered list in the printed version, and specify an independent set of conditions that need to be met in order to carry out the above operation.

Within the operational declaration there are two parts separated by a colon. The first part specifies the nature or type of the operation. For example, attachment of an attribute is noted by +a. The other part specifies the ID of the component, either the ID of the attribute which is to be attached, or of the constituent component which is to be added.

After the header line, there may follow one or more lines, appearing as a numbered list in the printed version, that provide conditions for the above operation. Each of the numbered condition lines constitutes a particular case, when the operation specified in the header line can be carried out. The conditions specified in different lines are mutually disjoint.

A condition line itself consist of two parts separated by || two vertical lines. The first part consists of the structure or distribution of the derivational state and the location where the attachments or additions are to be made. The

²¹ लोपो व्योर्वलि ॥ ६.१.६६ ॥ ► lopa replaces v or y if a suffix beginning with val follows.

second part records the conditions in terms of IDs that need to be present. The conditions within a line are ANDed. The different lines combined together with the logical OR cover all the cases when a particular operation is to be performed.

The locus where a component should be added or an attribute should be attached is specified clearly using the exact variables for the corresponding sound-sets or language-components. The meta-rules in the Aṣṭādhyāyī regarding the locus of grammatical changes are taken care of by explicitly specifying the relative positions of the variables and use of sub-scripts.

The formal framework facilitates new methods and parameters to look into the complexity of grammar and its application for the derivational process. This can be formulated in terms of the types of operations, conditional complexity of a statement as well as inter-dependence and inter-relation between the statements.

4.2.1 Types of operations

The processes specified in the Aṣṭādhyāyī can be summarised in terms of the new framework in the following types:

- +a: Attachment of an attribute. An attribute can be attached to one or more sound-sets, or to an entire language-component.
- a: Removing an attribute. There are instances when some attribute is taken out or removed from a sound-set or a language-component. For example in certain cases the attribute kit is removed (see the rules 1.2.7-1.2.26).
- ?a: Checking the consistency. As a consistency check, statements are modeled as a question whose answer can either be TRUE or FALSE.
- <y: Addition of a component.

These are the four fundamental types of operations. Other operations like replacement or elision can be implemented as a combination of the above fundamental operations. Thus,

- <<y: Replacement or substitution can be implemented as a combination of (i) attachment of a new attribute δ to that part which is replaced and (ii) addition of the component which is the replacement at the appropriate place. Elision or lopa would involve attaching the attribute lopa to the concerned parts in the language-component. The sound-sets containing the attribute lopa would then not be expressed at the form level which is the audible layer.

4.2.2 Complexity of a statement

Consider again the representation of attachment of the attribute *vṛddhi* in the new framework.

+a: vṛddhi

1. $X_{m+a} \parallel X_m[\bar{a}t, aic]$

वृद्धिरादैच् ॥१.१.१॥ ► *vṛddhi* stands for $\bar{a}t$ and *aic*.

Leaving aside the grammatical elements, the structural form of this statement would be as follows:

+a:—
 $X_{m+a} \parallel X_m[—]$

We can term this as the *signature* of the above statement. The signature of a statement comprehends primarily the structural complexity of the conditions that need to be satisfied in order to apply that statement.

Looking at the following representation of attachment of the attribute *guṇa*, it is apparent that it has the same signature as the previous statement for attachment of the attribute *vṛddhi*.

+a: guṇa

1. $X_{m+a} \parallel X_m[at, eñ]$

अदेङ्गुणः ॥१.१.२॥ ► *at* and *eñ* are *guṇa*.

Let us now consider attachment of the attribute *laghu*.

+a: laghu

1. $X_{m+a} \parallel X_m[hrasva] \wedge X_nNOT[samyoga]$

ह्रस्वं लघु ॥१.४.१०॥ ► *hrasva* is *laghu*. संयोगे गुरु ॥१.४.११॥ ► when *samyoga* follows, it is *guru*.

The corresponding signature would be as follows.

+a:—
 $X_{m+a} \parallel X_m[—] \wedge X_nNOT[—]$

Similarly, for attachment of the attribute *guru*, we have the following statement.

+a: guru

1. $X_{m+a} \parallel X_m[\text{hrasva}] \wedge X_n[\text{samyoga}]$
2. $X_{m+a} \parallel X_m[\text{dīrgha}]$

ह्रस्वं लघु ॥१.४.१०॥ ► hrasva is laghu. संयोगे गुरु ॥१.४.११॥ ► when samyoga follows, it is guru. दीर्घं च ॥१.४.१२॥ ► dīrgha as well.

The signature for attachment of guru is as follows.

+a:—
 $X_{m+a} \parallel X_m[—] \wedge X_n[—]$
 $X_{m+a} \parallel X_m[—]$

If one now compares the statements for attachment of vṛddhi or guṇa with that of laghu or guru, one notices that the operation is the same in all cases, namely attachment of an attribute to some sound-set. What is different is the nature and complexity of the conditions. There are three different types of structures for the conditions:

$X_{m+a} \parallel X_m[—]$
 $X_{m+a} \parallel X_m[—] \wedge X_n\text{NOT}[—]$
 $X_{m+a} \parallel X_m[—] \wedge X_n[—]$

Attachment of many of the attributes discussed before have signatures similar to the one mentioned above. In contrast, attachment of attributes like samyoga, upadhā or ṭi that depend on the distribution of adjacent sounds have very different signatures.

+a: samyoga

1. $X_m X_{n+a} \parallel X_m[\text{hal}] \wedge X_n[\text{hal}] \wedge \text{IDX}[n=m+1]$

ह्रलोऽनन्तराः संयोगः ॥१.१.७॥ ► hal in contiguous sequence are samyoga.

The corresponding signature would be:

+a:—
 $X_m X_{n+a} \parallel X_m[—] \wedge X_n[—] \wedge \text{IDX}[—]$

The conditions for grammatical operations can be summarized as a combination of the following basic types:

The intention (*vivakṣā*) of the speaker plays a central role in the introduction of

many components. It is formulated through meaning-expressions and is usually stated in the locative case. For example, consider the introduction of the suffix $l(a)(t)$. This is introduced if the speaker intends to express present tense.

<y: l(a)(t)

1. $X <_y \parallel X[\text{dhātu}] \wedge yM[\text{vartamāna}]$

वर्तमाने लट् ॥ ३.२.१२३ ॥ ► to express present time, introduce $l(a)(t)$.

The signature of this statement is as follows:

<y: —
 $X <_y \parallel X[—] \wedge yM[—]$

The second part of the condition clause $yM[—]$ denotes that the intention of the speaker communicated through the meaning-expression is required for the application of the statement.

The presence (or sometimes absence) of attributes often provides conditions for the grammatical operations. For example, in the above statement for introducing the suffix $l(a)(t)$, the first part of the condition clause $X[—]$ requires the presence of the attribute *dhātu* (verbal root) in the component to which the suffix can be added. The presence of specific components quite frequently conditions the grammatical operations.

<y: sa(n)

1. $X <_y \parallel X[\text{gup}(a), \text{tij}(a), \text{kit}(a)]$

गुप्तिज्किञ्च्यः सन् ॥ ३.१.५ ॥ ► after $\text{gup}(a)$, $\text{tij}(a)$, $\text{kit}(a)$ introduce $\text{sa}(n)$.

Here, the condition clause $X[—]$ is similar in structure to the previous example. The only difference lies in the type of elements that populate this condition. In the previous case it was the *attribute*, and in the present example these are the specific *components*, namely, $\text{gup}(a)$, $\text{tij}(a)$ and $\text{kit}(a)$.

A specific constellation or distribution of the components also provides a condition for certain operations. Take the example of attachment of the attribute $\ddot{t}i$.

+a: $\ddot{t}i$

1. $Xb e + a \parallel Xb[ac] \wedge X m \text{NOT}[ac] \wedge \text{IDX}[m = (b+1 \text{ TO } e)]$

अचोऽन्त्यादि टि ॥ १.१.६४ ॥ ► that part which begins with last ac is $\ddot{t}i$.

The condition has to take into account a specific distribution of sound-sets, namely that part which begins with the last vowel and extends to the end of the language-component. Similarly, the rule *yasmātpratyayavidhistadādi pratyaye'ṅgam*²² specifies aṅga to be that portion after which a suffix is prescribed and when the suffix follows. Such instances of attribute attachment, therefore, require *looking* at the current derivational state and, based upon how the different components are placed there, deciding whether a particular attribute should be attached or not. These are dynamic attributes.

Specific grammatical processes may also form a condition. In certain cases not only a particular derivational state needs to be looked at, but the progress or change from one state to the next is important.

For example, the rule *igyaṇaḥ samprasāraṇam*²³ terms samprasāraṇa to the *ik* sounds, i.e. [i, u, r, l] which come in place of *yaṇ* i.e. [y, v, r, l]. In order to represent conditions of this kind, we need to look into the *history* of a particular component. This is facilitated by looking into the derivational states and slices that store the derivational process.

Mutual relations of certain grammatical processes or changes also set conditions. For example, the rules listed in the last three sections of the eighth chapter of the Aṣṭādhyāyī. By the rule *pūrvatrāsiddham*²⁴ the rules listed later are in effect suspended with respect to previous rules. Consider the following situation in which a derivational state st_1 advances to the next state st_2 after application of a rule A.

$$A(st_1) \rightarrow st_2$$

If there is another rule B which is related to the rule A in such a manner that A is suspended (*asiddha*) with respect to B, it implies that B can not operate on the state st_2 even if the conditions for the application are fulfilled. Since A is suspended with respect to B, it means that for rule B it is as if A was not applied at all. So only the state st_1 is visible to B. The implementation of the statements from this section would again require access to the derivational *history* by accessing the earlier derivational states.

²² यस्मात्प्रत्ययविधिस्तदादि प्रत्ययेऽङ्गम् ॥ १.४.१३ ॥ ► that part which enjoins a pratyaya based operation, before that the sequence is aṅga.

²³ इग्यणः सम्प्रसारणम् ॥ १.१.४५ ॥ ► *ik* replacing *yaṇ* is samprasāraṇa.

²⁴ पूर्वत्रासिद्धम् ॥ ८.२.१ ॥ ► that which follows from here onwards is treated as if suspended in view of what precedes.

4.3 Relation between statements

The signature of a statement specifies its structural form and comprehends the form of the conditional clauses. The manner in which any two components of grammar are related can now be formulated in terms of the categories of the new framework. Consider again the statement for attachment of the attribute $vṛddhi$:

+a: $vṛddhi$

1. $X_{m+a} \parallel X_m[\bar{a}t, aic]$

वृद्धिरादैच् ॥ १.१.१ ॥ ► $vṛddhi$ stands for $\bar{a}t$ and aic .

The condition clause requires the presence of the attribute $\bar{a}t$ or aic . This implies a hierarchy between $vṛddhi$ on the one hand and $\bar{a}t$ or aic on the other hand. This would also imply that the statement that attaches the attribute $vṛddhi$ will only then be relevant once the statements for attachment of $\bar{a}t$ or aic have been applied. The statements that attach the attributes $\bar{a}t$ and aic to some sound-set are as follows:

+a: $\bar{a}t$

1. $X_{m+a} \parallel X_m[a][dīrgha]$

तपरस्तत्कालस्य ॥ १.१.७० ॥ ► an ac followed by the marker t stands for sounds having the same time duration.

+a: aic

1. $X_{m+a} \parallel X_m[ai, au]$

ऐ औ च् ॥ ४ ॥ ► $ai, au, (c)$. आदिरन्त्येन सहेता ॥ १.१.७१ ॥ ► an initial element together with the final it sound includes intervening elements.

One can say that the statement for attachment of the attribute $vṛddhi$ presupposes the application of the statements for the attachment of the attributes $\bar{a}t$ or aic .

Given two statements: $St-A$ and $St-B$, $St-B$ is dependent on $St-A$ if the application of $St-B$ requires the results of the application of $St-A$.

The *dependency graph* for the components and attributes of Aṣṭādhyāyī would provide an order in which the statements will have to be applied. The problem of inter-dependence or circularity, i.e. $St-B$ is dependent on $St-A$ and $St-A$ is dependent on $St-B$, can be resolved by introducing a new statement, let us say, $St-B1$ with a different ID.

The examples from the operational rules of Aṣṭādhyāyī which I have represented in the new framework show that a formal representation of Aṣṭādhyāyī is possible. It is also possible to reduce the role of an individual for applicational purposes, although grammar functions integrally together with the speaker or user. The new representation also aims to clearly separate the form or structural complexity of the grammar from the inter-relatedness of its components. It provides a mechanism to look into these relations at the more granular level of individual components, in contrast to attempts to organize them within the categories of semantics, syntax, morphology and phonology. The present framework allows a flexible integration of information which is either not explicitly mentioned in the grammatical corpus or which can be included from other sources, e.g. the inclusion of the suggestions of Kātyāyana in his Vārttika or the Uṇādi-sūtras.