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Some issues in formalizing the *Aṣṭādhyāyī*

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Abstract: Scharf and Bunker (2014) describe their project to produce
a computational implementation of Pāṇinian derivation. In that pa-
per they describe their motivation for modeling *Aṣṭādhyāyī* rules in
XML, the scheme of their formalization and their translation of that
formalization into Javascript. Scharf (2015) describes the structure of
their XML formalization in detail. In the present paper we present
issues that came up while we were encoding rules. We discuss how we
structured our formalization in order to remain faithful to principles
and techniques employed in the *Aṣṭādhyāyī* and the limits of our for-
malization in capturing some of the more abstract principles. Some of
the issues we encountered would appear trivial to a Pāṇinian scholar,
yet are essential to address to achieve a computational implementa-
tion and would hardly have been noticed if such an enterprise had not
been undertaken.

1   Introduction

Scharf, Goyal, et al. (2015) survey in detail various attempts to formalize
Pāṇini's *Aṣṭādhyāyī*. Scharf and Bunker (2014) describe the motivation for
modeling the *Aṣṭādhyāyī* in XML and translating it into executable code in a
separate step. Scharf (2015), the preceding chapter in this volume, describes
the structure of the XML formalization in detail. Over the past two years the
authors have formalized the entire *Aṣṭādhyāyī* in this structure. While we
were formalizing rules, a number of interesting issues came to our attention.
In this paper, we present some of those issues. We treat those issues under

the following categories: metalanguage, filling gaps, problems of recurrence, application of technical terms, and the association of semantic conditions with specific speech units.

2 Metalanguage

2.1 The representation of metarules

As is well known, Pāṇini formulated metarules that describe the specific significance of certain cases in particular contexts. Along with ordinary uses of cases, Pāṇini uses the ablative and locative cases to indicate left hand context and right hand context respectively, and explicitly describes this usage in two metarules: *A. 1.1.66 tasminniti nirdiṣṭe pūrvasya*, and *A. 1.1.67 tasmād ity uttarasya*. We formalize these metarules by using the two elements `pUrva` and `para`. Pāṇini uses the genitive case to indicate the substituend in place of which an item is taught and describes this usage in the metarule *A. 1.1.49 ṣaṣṭhī sthāneyogā*. We formalize this metarule by using the element `sTAnin`. Pāṇini provides several metarules that specify the precise sound within an element indicated in the genitive case that is to be replaced. These metarules include *A. 1.1.52 alo 'ntyasya*, *A. 1.1.53 ṅic ca*, *A. 1.1.54 ādeḥ parasya*, *A. 1.1.55 anekālśit sarvasya*, and *A. 1.1.3 iko guṇavṛddhī*. In our current formalization we have chosen to incorporate these metarules into the interpretation of each rule in which they are relevant instead of formalizing them independently and allowing them to be called into play by conditions. We either explicitly mention the specific sound to be replaced in the `sTAnin` element or mark it as a group within a regular expression and refer to it in a replacement expression. We use attributes to locate elements that refer to parts within larger elements. As Scharf (2015) details, we use the attribute `locus` with the values `Adi` and `anta` to pin the specific sound at the beginning or end of the string in which it occurs, and we use the `n` attribute to specify the sequence of contiguous constituents. For example, in *A. 6.4.140 āto dhātoḥ*, which replaces the final *ā* of a root which is termed *bha* by lopa, the final *ā* is indicated in a `sTAnin` element furnished with the `locus` attribute with the value `anta` as shown in the following rule fragment:

```
<avayavin saYjYA="DAtu"
    phone="^[@(al)]*[@(hal)]A$">
```

```
    <attribute saYjYA="Ba"/>
    <sTAnin phone="A" locus="anta"/>
  </avayavin>
  <AdeSa phone="" saYjYA="lopa"/>
```

A. 1.3.10 *yathāsaṅkhyam anudeśaḥ samānām*, which stipulates that operations that apply to lists of operands of equal number applies to pairs of them matched sequentially, is formalized by similarly building the principle into the XML structure using a `cases` element.

2.2   Double Statement

There are multiple functions of the particle *ca* in the *Aṣṭādhyāyī*. One of them is indicating that a rule states more than one operation. For example, *A.* 3.1.6 *mānbadhadānśānbhyo dīrghaś cābhyāsasya* uses the particle *ca* to conjoin two statements: one that provides the suffix, and one that replaces a sound in the base. The first provides the suffix *san* after the listed verbal roots, and the second replaces the vowel of the reduplicate syllable (*abhyāsa*) by a long vowel. In such cases we formalize each operation in a separate `div` element subordinate to the `rule` element.

3   Filling in gaps in rules

Pāṇinian rules are terse. They conform to a specific metalanguage with a specific syntax and terminology. Although many of the metarules and technical terms used in the grammar are explicitly defined, there are gaps. A human user of the grammar may fill in those gaps unconsciously due to his familiarity with the target language and the grammar. Unlike a human being, however, a machine requires explicit information at every step. Therefore it is necessary to supplement rules with explicit statements to cover the gaps. In the process of formalizing the rules we were forced to recognize these gaps. To fill them in, we consult the commentaries, and, in cases where even the commentaries leave gaps, we rely on our own understanding. Below we give examples in which it was necessary to provide additional information regarding rule interaction by supplying an attribute, and in which it was necessary to provide additional rules by creating subordinate divisions.

3.1   Filling gaps in rule interaction

A. 7.1.1 *yuvor anākau* replaces *yu* and *vu* in suffixes like **lyu*ṭ***, **ṭ*yul***, **ṇ*vul*** and **ṣ*vu****n* by *ana* and *aka* respectively. However the replacement is not desired in the suffix *yus* provided by *A.* 5.2.123 *ūrṇāyā yus* and by *A.* 5.2.140 *ahaṁ-śubhamor yus*. Yet, Pāṇini does not state any exception for this suffix. The *Kāśikā*, while commenting on *A.* 7.1.1, states that the *y* and *v* of the *yu* and *vu* which undergo replacement by this rule are nasalized whereas in the suffix *yus* stated by *A.* 5.2.123 and *A.* 5.2.140 the *y* is not nasalized. The commentary concludes that *ana* and *aka* occur only in place of nasalized *yu* and *vu*; hence *A.* 7.1.1 is not applicable to *yus* in *A.* 5.2.123 and *A.* 5.2.140. Although we do not accept that the semivowels are nasalized in this rule, we accept that an exception has to be stated for the suffix *yus*. We achieve the desired result by explicitly stating that *A.* 5.2.123 and *A.* 5.2.140 are exceptions to *A.* 7.1.1. In our formalization, we explicitly designate that a rule *x* is an exception to a rule *y* by incorporating the `apodita` attribute given the value of the rule number of rule *y* in the rule element of rule *x*. In the present case, we add the attribute-value pair `apodita="A7.1.1"` in the `rule` element of *A.* 5.2.123 and *A.* 5.2.140.

    In the example described in the preceding paragraph, although we do not accept the solutions by the commentary, the commentary disclosed the presence of the gap in the rules. Regarding the problem in the following example, the commentaries are silent. *A.* 7.1.2 *āyaneyīnīyiyaḥ phaḍhakha-cchaghāṁ pratyayādīnām* replaces *ph*, *ḍh*, *kh*, *ch*, and *gh* at the beginning of a suffix by *āyan, ey, īn, īy*, and *iy* respectively. However the rule assumes that the initial sounds in the substituends listed in this rule have not been designated as markers and have not been deleted. In other words, they should not be termed *it* by *A.* 1.3.2–8 and should not be deleted by *A.* 1.3.9. Yet, *A.* 1.3.7 *cuṭū* has scope to apply here. *A.* 1.3.7 prescribes the term *it* to palatal and retroflex stops initial in an affix. Once these sounds get termed *it*, they are deleted by *A.* 1.3.9 *tasya lopaḥ*. Affixes with initial *ch* and *ḍh* ostensibly fall within the scope of *A.* 1.3.7. Hence affixes such as *cha* and *ḍha**k*** would have their initial stops termed *it* and deleted prior to the application of *A.* 7.1.2. This is not desired. There is conflict between *A.* 1.3.7 and *A.* 7.1.2 and it is not clear which rule should take precedence. The commentaries are silent regarding this problem. It is evident, however, that if *A.* 1.3.7 is permitted to apply to the affixes that begin with *ch* and *ḍh* then *ch* and *ḍh* mentioned in *A.* 7.1.2 would have no scope because all

ch and *ḍh* initial in affixes would be deleted before *A.* 7.1.2 had the chance to apply. It is an established principle that a rule that otherwise would have no scope takes precedence over any competing rule, and this principle of rule priority takes precedence over any other principle of rule selection. Therefore *A.* 7.1.2 must be recognized as an exception to *A.* 1.3.7. We represent the exception in our formalization by inserting the attribute-value pair `apodita="A1.3.7"` in the rule element of *A.* 7.1.2.

3.2 Filling gaps by creating subordinate divisions

§2.2 introduced our method of formalizing multiple operations provided by a single rule by using the `div` element in cases where an original statement in the *Aṣṭādhyāyī* warranted it. The subsequent discussion describes cases similarly solved by supplying `div` elements where such original statements are lacking.

    A. 5.2.52 *bahupūgagaṇasaṅghasya tithuk* provides the final augment *ti-thuk* to the nominal bases *bahu*, *pūga*, *gaṇa* and *saṅgha* when the suffix *ḍaṭ* follows. *A.* 5.2.48 *tasya pūraṇe ḍaṭ* provides the suffix *ḍaṭ* after nominal bases termed *saṅkhyā* if an ordinal number (*pūraṇa*) is to be denoted. Of the nominal bases to which *A.* 5.2.52 adds the augment *tithuk*, the bases *bahu* and *gaṇa* will be eligible to get the suffix *ḍaṭ* because they are termed *sa-ṅkhyā* by *A.* 1.1.23 *bahugaṇavatuḍati saṅkhyā*. The nominal bases *pūga* and *saṅgha*, however, are not termed *saṅkhyā*. So the suffix *ḍaṭ* is not applicable to them by *A.* 5.2.48. Yet, their inclusion in *A.* 5.2.52 indicates that the suffix *ḍaṭ* does indeed occur after them in spite of the fact that no rule in the *Aṣṭādhyāyī* makes such a provision. The *Kāśikā* on *A.* 5.2.52 recognizes that this rule serves as an indication that these two bases are indeed eligible for the provision of the suffix stating, *pūgasaṅghaśabdayoḥ asaṅkhyatvāt idam eva jñāpakaṁ ḍaṭo bhāvasya*. In order for *A.* 5.2.52 to apply to the nominal bases *pūga* and *saṅgha*, a separate statement must be supplied. We supply such a statement in our formalization of *A.* 5.2.52. Thus our formalization of *A.* 5.2.52 contains two divisions, the first of which states the suffix *ḍaṭ* after the nominal bases *pūga* and *saṅgha*, and the second of which provides the final augment *tithuk* to these nominal bases.

    Another situation where it is necessary to divide a rule into two divisions occurs where exceptions apply only to one subsection of the rule's domain but it is necessary that the rule apply outside that subsection whether or not those exceptions are triggered. In this case we do not want the exceptions, if

triggered, to prevent the general rule from applying outside that subsection. Consider the case of the non-deletion of nominal terminations. *A.* 2.4.71 *supo dhātuprātipadikayoḥ* provides deletion of a nominal termination (***sup***) that occurs within a nominal base or a verbal root. For instance, in the *ṣaṣṭhī tatpuruṣa* compound *rājapuruṣaḥ* 'a royal servant', formed by *A.* 2.2.8 *ṣaṣṭhī*, the first constituent is a *pada* ending in the nominal termination ***ṅas***, and the second constituent is a *pada* ending in the nominal termination ***su***. The compound is termed *prātipadika* by *A.* 1.2.46 *kṛttaddhitasamāsāś ca.* Both nominal terminations are deleted by *A.* 2.4.71. Section *A.* 6.3 contains a number of rules (*A.* 6.3.1–24) that state partial negations of *A.* 2.4.71. They negate the deletion of the nominal termination of the constituent that is immediately followed by the final constituent. For instance, *A.* 6.3.2 *pañca-myāḥ stokādibhyaḥ* negates the deletion of a fifth-triplet nominal termination in words meaning *stoka* 'little', *antika* 'near', and *dūra* 'distant', and in the word *kṛcchra* 'painful', when an *uttarapada* follows. Hence we get forms such as *stokānmuktaḥ.* After the compound is formed by *A.* 2.1.39 *stokāntikadū-rārthakṛcchrāṇi ktena*, the nominal terminations in both constituent padas are susceptible to deletion by *A.* 2.4.71. *A.* 6.3.2 negates the deletion of the fifth-triplet nominal termination of the first constituent. However, *A.* 2.4.71 is still applicable to the nominal termination of the second constituent. In order to prevent rules such as *A.* 6.3.2 from negating the application of *A.* 2.4.71 outside the specific sub-domain in which they apply, it is necessary to split *A.* 2.4.71 into two divisions one of which is susceptible to the negation and other of which is not. We achieve this division in our formalization by creating two numbered `div`s and by adding a `pratizidDa` attribute with the value *A.* `2.4.71[1]` to the rule element of each of the rules *A.* 6.3.1–24.

4   Problems in *anuvṛtti*

Pāṇini achieves brevity by extensive use of ellipsis. Elided terms necessary to complete the meaning of a rule are supplied from preceding rules by recurrence (*anuvṛtti*). The range of recurring terms is indicated by commentators, is shown in certain editions of the *Aṣṭādhyāyī* such as Shastri and Pande's (2011), and is discussed extensively by modern scholars such as Joshi and Bhate (1984). Scharf indicated *anuvṛtti* in the *anuvṛtti* file of his analytic database of the *Aṣṭādhyāyī* (described in Scharf 2013) based on Gopala Shastri's edition and comments in the *Kāśikā*. The process of

formalizing the *Aṣṭādhyāyī* in XML forced us to check each and every occurrence of recurrence and to determine whether in fact the recurring term should or should not be included in the rule. In some cases we found that the recurring term should be discontinued prior to the extent indicated, and in other cases that the term should be continued beyond the terminus indicated.

4.1   Curtailing recurrence

Shastri and Pande (2011: 29) show the recurrence of *kriyāyāṁ kriyārthā-yām* from *A.* 3.3.10 through *A.* 3.3.134, and it was adopted in the analytic database of the *Aṣṭādhyāyī*. If the recurrence were followed then the condition would be included in every rule through *A.* 3.3.134. In contrast, none of the commentaries on the *Aṣṭādhyāyī* show recurrence of these terms beyond *A.* 3.3.13.[1] Apart from the lack of textual evidence for continuing the terms through *A.* 3.3.134, internal evidence demonstrates that Pāṇini does not intend that *kriyāyāṁ kriyārthāyām* recur beyond *A.* 3.3.13. The evidence is *A.* 3.3.11. *A.* 3.3.11 provides that the suffixes provided in the sense of *bhāva* by *A.* 3.3.18–112 also occur under the additional conditions that the root occur in future time (*bhaviṣyati*) and that there be a subordinate word that denotes action that is for the purpose of the action denoted by the roots after which these suffixes, which denote *bhāva*, occur. Since action for the purpose of action constitutes a subdomain of the sense of bhāva, this rule reiterates what is already provided by *A.* 3.3.18–112. The purpose of stating *A.* 3.3.11 is to clarify that derivates denoting bhāva, if that bhāva is an action that is the purpose of another action, are susceptible to provision of the dative by *A.* 2.3.15. *A.* 2.3.15 provides a fourth-triplet nominal termination after an action noun denoting an action that is the purpose of another action. Consider, for example, the sentence *yāgāya gacchati* 'he goes for the sake of sacrifice'. Here the nominal base *yāga* is derived by adding the suffix **ghañ** after the verbal root *yaj* in the sense of *bhāva* by *A.* 3.3.18. When the sacrifice is the purpose of the action of going, then it is provided with a fourth-triplet nominal termination by *A.* 2.3.15. Thus *A.* 2.3.15 is applicable to derivates formed by rules in the section *A.* 3.3.18–112

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[1]Commentaries consulted include the *Kāśikā* (Sharma and Deshpande 1969), *Bhāṣāvṛtti* (Chakravarti 1918), *Prakriyākaumudī* (Mishra 2000), *Siddhāntakaumudī* (Caturveda and Vidyabhaskar 1961), *Prakriyāsarvasva* (Sāṁbaśivaśāstrī 1938).

headed by *A.* 3.3.18 *bhāve.* Recurrence of *kriyāyāṁ kriyārthāyām* through
A. 3.3.112 would not only make *A.* 3.3.11 redundant but also erroneously
restrict the sense in which the affixes provided in that section occur. Simi-
larly recurrence of this phrase in *A.* 3.3.114–116, which also provide suffixes
in the sense of *bhāva*, would erroneously restrict that sense there as well.
Moreover the recurrence of *kriyāyāṁ kriyārthāyām* does not serve any pur-
pose in *A.* 3.3.16–17. These rules provide the suffix **ghañ** in the sense of an
agent in accordance with *A.* 3.4.67 *kartari kṛt* not in the sense of *bhāva.* Nor
does the recurrence of this phrase in rules subsequent to *A.* 3.3.116 make
any sense whatsoever. In fact to be gracious to Gopal Shastri, it is likely
that the number 134 printed in bold type in his *sūtrapāṭha* as an indication
of the terminus of *anuvṛtti* is simply a typo for 13 shamelessly repeated by
incompetent editors for over half a century!

In another example of erroneous recurrence, Shastri and Pande (2011:
69) show *nāmanyatarasyām* recurring from *A.* 6.1.177 through *A.* 6.1.187
ādiḥ sico 'nyatarasyām. Commentaries accept only the word *nām*, not the
word *anyatarsyām* 'alternatively' recurring through *A.* 6.1.178 *ṅyāś chanda-
si bahulam.* The latter does not recur because the term *bahulam* 'variously'
in *A.* 6.1.178 stops its recurrence. The term *halādiḥ* in *A.* 6.1.179 *ṣaṭtricatu-
rbhyo halādiḥ* stops recurrence of *nām.* Therefore we understand that only
nām recurs and only as far as the next rule *A.* 6.1.178. Here too we believe
that the number 187 is simply a typo for the correct 178.

4.2 Extending recurrence

Previously discussed are those situations where we discontinue the recur-
rence of a term prior to the extent indicated. There are situations where we
extend the recurrence of a term beyond the terminus indicated, for example,
the recurrence of the term *parasmaipada* into *A.* 3.4.86 *er uḥ.* By this rule
the final sound *i* of verbal terminations that have replaced the *l*-affix *loṭ* are
replaced by *u* in the derivation of imperative forms. As the *Kāśikā* states
while commenting on this rule, *loḍādeśānām ikārasyokārādeśo bhavati.* In
specifying the substituends that are eligible to undergo this replacement,
the rule states only that the verbal terminations have a final *i.* Seven af-
fixes qualify for this condition: *ti**p**, si**p**, mi**p**,* and *jhi* (the first, second, and
third person singular and third person plural parasmaipada terminations),
and *iṭ*, *vahi*, and *mahiṅ* (first person singular, dual, and plural ātmanepada
terminations). The rules *A.* 3.4.87 and 3.4.89 provide replacements for *si**p***

and *mip* in exception to *A. 3.4.86*. The application of *A. 3.4.86* is desired for the other two parasmaipada terminations *tip* and *jhi*, but if the rule were applied to the ātmanepada terminations then incorrect forms would be produced. Correct forms are produced only if these ātmanepada terminations are subject to *A. 3.4.79 ṭita ātmanepadānāṃ ṭer e*. This rule replaces by *e* the final vowel and any following consonants (*ṭi*) of all *ātmanepada* verbal terminations that are replacements of *l*-affixes marked with *ṭ*. *loṭ* is marked with *ṭ*. Therefore this rule has scope to apply to all nine ātmanepada verbal terminations. In the absence of any additional specific condition in *A. 3.4.86*, a conflict arises between *A. 3.4.86* and *A. 3.4.79* in the domain of the ātmanepada terminations. Although the conflict could be properly resolved by the nitya conflict-resolution principle, we consider that it is straightforward simply to have the term *parasmaipadānām* recur from *A. 3.4.82*. In our formalization we include the additional condition that the verbal terminations subject to replacement by *A. 3.4.86* be parasmaipada by adding the attribute-value pair `pada="parasmE"` in the `avayavin` element that describes the substituends.

We continue the term *parasmaipadānām* from *A. 3.4.82* in every following rule *A. 3.4.83–89* until it is blocked in *A. 3.4.90*. While the particular verbal terminations mentioned in most of these rules obviate the need to explicitly include the term *parasmaipada*, the situation with *A. 3.4.85* is not so clear because it is an extension rule and what it applies to depends upon the scope of the operations it extends. *A. 3.4.85 loṭo laṅvat* allows operations provided for verbal terminations that are replacements for the *l*-affix *laṅ* (terminations of the past imperfect) to apply to verbal terminations that are replacements for the *l*-affix *loṭ* (terminations of the imperative). The extended operations include the following: (1) deletion of the final *s* of first person dual and plural verbal terminations by *A. 3.4.99 nityaṃ ṅitaḥ*, and (2) replacement of *tas*, *thas*, *tha*, and *mip* by *tām*, *tam*, *ta*, and *am* respectively by *A. 3.4.101 tasthasthamipāṃ tāntantāmaḥ*. That these are the operations extended by *A. 3.4.85* is stated in commentaries. For example, the *Kāśikā* states, *tāmādayaḥ salopaś ca*. These operations are only applicable to parasmaipada terminations, not to ātmanepada terminations. This fact is known because only parasmaipada terminations meet the specific conditions mentioned in the rules themselves. The substituend stated in *A. 3.4.99* is the final *s* of an uttamapuruṣa (first person) verbal termination which is a replacement of an *l*-affix marked with *ṅ*. The only qualifying

terminations that end in *s* are the parasmaipada terminations *vas* and *mas*. The substituends stated in *A.* 3.4.101 are four specific terminations, all of which are also parasmaipada. Hence *A.* 3.4.99 and *A.* 3.4.101 are applicable only to parasmaipada terminations not to ātmanepada terminations. Therefore, in *A.* 3.4.85, as in other rules subsequent to *A.* 3.4.82, the particular verbal terminations involved obviate the need to explicitly include the term *parasmaipada*.

Now between the two rules extended by *A.* 3.4.85 is a third rule, *A.* 3.4.100, which applies to substituends that include both parasmaipada and ātmanepada terminations. *A.* 3.4.100 provides deletion (*lopa*) of the final *i* of verbal terminations that are replacements of an *l*-affix marked with *ṅ*. These include the four parasmaipada and three ātmanepada terminations listed in our discussion of *A.* 3.4.86 above. As in the case of *A.* 3.4.86, the application of *A.* 3.4.100 to ātmanepada terminations would lead to incorrect forms. To prevent this rule from applying to *ātmanepada* terminations, the *Kāśikā*, stating *parasmaipadeṣv ity eva*, continues the term *parasmaipadeṣu* from *A.* 3.4.97 *itaś ca lopaḥ parasmaipadeṣu*. Just as the *Kāśikā* continues the term *parasmaipadeṣu* in *A.* 3.4.100 from *A.* 3.4.97 after silence concerning its recurrence in *A.* 3.4.98–99, it would not be out of place to continue *parasmaipadānām* in *A.* 3.4.83–89 from *A.* 3.4.82. While the recurrence of the term *parasmaipada* in *A.* 3.4.83–89 is not absolutely necessary as it is in *A.* 3.4.100, it provides clarity, does no harm, and costs nothing.

Now the question arises as to what is the limit of the recurrence of the term *parasmaipada*? The rule that stops its recurrence is *A.* 3.4.90 *ām etaḥ*. This rule provides that the final *e* of a verbal termination that is a replacement of the *l*-affix *loṭ* is replaced by *ām*. The only verbal terminations that end in the sound *e* are ātmanepada after *A.* 3.4.79 has applied. Hence *A.* 3.4.90 presupposes the operation stated by *A.* 3.4.79 and concerns only ātmanepada terminations, not parasmaipada. Therefore the recurrence of *parasmaipada* makes no sense in *A.* 3.4.90 and thus stops in *A.* 3.4.89.

Determining the extent of anuvṛtti is a challenging task that involves more than mere dependence on traditional grammatical texts or the explicit presence of particles in rules; it requires proper analysis.

Table 1
Nadī in the Aṣṭādhyāyī

Rule no.	Rule	Meaning
2.1.20	*nadībhiś ca*	river
2.1.21	*anyapadārthe ca sañjñāyām*	river
4.1.113	*avṛddhābhyo nadīmānuṣībhyastannāmikābhyaḥ*	river
4.2.85	*nadyāṁ matup*	river
4.2.97	*nadyādibhyo ḍhak*	phonetic form
4.4.111	*pāthonadībhyāṁ ḍyaṇ*	river
5.4.110	*nadīpaurṇamāsyāgrahāyaṇībhyaḥ*	river
5.4.153	*nadyṛtaś ca*	technical
6.1.173	*śatur anumo nady ajādī*	technical
6.1.174	*udāttayaṇo halpūrvāt*	technical
6.2.109	*nadī bandhuni*	technical
7.1.54	*hrasvanadyāpo nuṭ*	technical
7.1.80	*ācśīnadyor num*	technical
7.1.81	*śapchyanor nityam*	technical
7.3.107	*ambārthanadyor hrasvaḥ*	technical
7.3.116	*ṅer ām nadyāmnībhyaḥ*	technical
7.3.117	*idudbhyām*	technical
8.3.89	*ninadībhyāṁ snāteḥ kauśale*	technical

5   Application of technical terms

There are many technical terms used in the *Aṣṭādhyāyī*. They are of two types: artificial such as *ṭi*, *ghu*, and *bha*; and conventional such as *vṛddhi*, *guṇa*, and *saṅkhyā*. The artificial technical terms do not pose any problem as their meaning is unambiguous. There is no possibility of more than one interpretation of artificial technical terms as they carry meaning only in the scope of Pāṇinian grammar. On the contrary the conventional technical terms in the *Aṣṭādhyāyī* do pose a problem as they carry meaning both in Pāṇinian grammar and in ordinary usage. Hence it is necessary to make it clear in every occurrence whether the conventional technical term used in a rule conveys the technical meaning or the conventional meaning. For instance, *nadī*, which means `a river' conventionally, in the *Aṣṭādhyāyī* is a technical term which stands for feminine stems ending in *ī* and *ū*. There are, in all, eighteen rules in which the term *nadī* is stated or recurs. Those rules are listed in Table 1.

Pāṇini uses the term *nadī* eleven times in the technical sense and seven times in the non-technical sense. Whether the term is used in the technical or non-technical sense was decided after consulting the *Kāśikā* on each rule. Wherever the term *nadī* occurs in its non-technical sense, the *Kāśikā* makes a comment to that effect either directly or indirectly. For example, while commenting on *A.* 2.1.20 the commentator states *nadīvacanaiḥ śabdaiḥ saha* … 'with the words which mean *nadī*', implying that the use of the term *nadī* in *A.* 2.1.20 is its non-technical use. In our formalization, whenever *nadī* is a technical term then the attribute-value pair `saYjYA="nadI"` is supplied in the element that describes the stem in question. When the term *nadī* is used in its non-technical sense, then we supply the attribute-value pair `other="nadI"` in an `arTa` element as a child of the element that describes the stem in question.

Even more difficult to deal with than the term *nadī* is the term *saṅkhyā* because it is not clear when Pāṇini intends the term *saṅkhyā* in its ordinary sense and when he intends it in its technical sense. Nor does his statement of the technical sense address the status of the ordinary sense. In its ordinary sense, the term refers to numbers. In its technical sense the term applies to specific nominal bases. *A.* 1.1.23 states that the nominal bases *bahu* and *gaṇa*, and the nominal bases that end in the affixes *vatup* and *ḍati* are termed *saṅkhyā*. The affix *vatup* is provided after the pronominal bases *yad, tad* and *etad* in the sense of measurement by *A.* 5.2.39 *yattadetebhyaḥ parimāṇe vatup*. The resulting words *etāvat, yāvat, tāvat* are therefore termed *saṅkhyā* by *A.* 1.1.23. *A.* 5.2.41 *kimaḥ saṅkhyāparimāṇe ḍati ca* provides the affix *ḍati* after the interrogative pronominal base *kim* in the sense of a numerical measure. Thereby the resulting word *kati* is termed *saṅkhyā* by *A.* 1.1.23.

Now, there are two issues regarding the use of the term *saṅkhyā* in the *Aṣṭādhyāyī*. Besides the issue of whether the term is used in its technical or ordinary sense, another issue arises: does the technical term *saṅkhyā* include words for numbers or just the specific nominal bases mentioned in *A.* 1.1.23? As Jinendrabuddhi clarifies, the *Kāśikā* concludes that the technical term includes ordinary words for numbers as well as the specific nominal bases mentioned in *A.* 1.1.23. They argue that the purpose of *A.* 1.1.23 is to extend the status of being words for numbers only to the specific nominal bases mentioned while denying that status to other words meaning 'many' such as *bhūri* and *prabhūta*. The *Kāśikā* states *bhūryādīnāṁ nivṛttyarthaṁ saṅkhyāsañjñā vidhīyate*. Although we are agnostic regarding their distinction between the words *bahu* and *gaṇa* versus other words meaning 'many', we positively accept their conclusion. They argued that it is because *bahu* and *gaṇa* denote numbers greater than two that they are included in the meaning of the term *saṅkhyā* while, in contrast, other words for many do not denote numbers. Jinendrabuddhi argues thus even while referring to

all such words as being of the same kind (*tulyajātīya*). It is difficult to evaluate this assertion where on the face of it all such words appear equally to denote or not to denote numbers greater than two. Nevertheless, regardless of what they denote, Pāṇini's explicit mention of specific nominal bases meaning `many', and lack of mention of others, extends the term *saṅkhyā* to the mentioned bases alone. In any case the technical sense of the term *saṅkhyā* in the *Aṣṭādhyāyī* includes ordinary words for number as well as the specifically mentioned nominal bases meaning `many'.

Regarding the question of when Pāṇini intends the term *saṅkhyā* in its ordinary sense and when he intends it in its technical sense, in certain cases an answer is clear, but in others an answer is elusive. The reason it is elusive is because it is not always specified in the commentaries whether the rule is applicable to the specifically mentioned nominal bases *bahu* etc. or not. For example, the question arises as to whether Pāṇini intends to include the nominal base *bahu* in the scope of the term *saṅkhyā* present by recurrence in *A*. 2.1.51. *A*. 2.1.51 *taddhitārthottarapadasamāhāre ca*, among other things, provides that a number word (*saṅkhyā*) combines with a coreferential nominal to form a tatpuruṣa compound if the resulting compound is subject to taddhita affixation. For example, the number word *pañca* combines with the word *kapālāḥ* to form the *tatpuruṣa* compound *páñcakapāla* which is subject to the taddhita affix *aṇ* by *A*. 4.1.83 in the sense indicated by *A*. 4.2.16 *saṃskṛtaṃ bhakṣāḥ*. The compound is termed *dvigu* by *A*. 2.1.52 and thereby by *A*. 6.2.29 *igantakālakapālabhagālaśarāveṣu dvigau* retains the high-pitched accent on the first vowel of its initial constituent as shown. Under *A*. 2.1.51-52, commentators give no indication that the scope of these rules should include *bahu* etc. However, *A*. 6.2.30 *bahv anyatarasyām* provides for the accentuation of *bahu* in the same circumstance just described for a number word as shown in the compound in the example *páñcakapāla*. *A*. 6.2.30 has scope only if the term *saṅkhyā* in A.2.1.51-52 does include *bahu* etc. Only if the word *saṅkhyā* in these rules is used in the technical sense including *bahu* can the compound having *bahu* as its first component be termed *dvigu* thereby permitting *A*. 6.2.30 to apply.

Similarly, that the term *saṅkhyā* recurring in *A*. 5.2.48 from *A*. 5.2.47 must include *bahu* etc. is known not from any comments under these rules but only by the necessity of the application of *A*. 5.2.48 as a prerequisite for the application of *A*. 5.2.51--53. The section of rules *A*. 5.2.48--58 deals with the formation of ordinal numbers from cardinal numbers. *A*. 5.2.48 *tasya pūraṇe ḍaṭ* provides the suffix *ḍaṭ* after a *saṅkhyā* in the sense of the completion of that particular number. The subsequent rules provide augments to *ḍaṭ*. For example, *A*. 5.2.51 *ṣaṭkatikatipayacaturāṃ thuk* provides the augment *thuk* to *ḍaṭ* when *kati* precedes. *A*. 5.2.52 *bahupūgagaṇasaṅghasya tithu-*

k provides the augment *tithuk* when *bahu* and *gaṇa* precede. *A.* 5.2.53 *vator ithuk* provides the augment *ithuk* when a word ending in *vatup* precedes. *A.* 5.2.51--53 are applicable only after *ḍaṭ* is obtained by *A.* 5.2.48, and *A.* 5.2.48 is applicable only if *bahu, gaṇa*, words ending in *vatup* and *ḍati* are designated as *saṅkhyā*.

Similarly, although it is not apparent that the term *saṅkhyā* in *A.* 5.1.22 *saṅkhyāyā atiśadantāyāḥ kan* includes *bahu* etc. just by examining that sūtra, it must in order for *A.* 5.1.23 to have any scope. *A.* 5.1.23 *vator iḍ vā* provides the augment *iṭ* optionally to the suffix *kan* when a word ending in *vatup* precedes. It is only by *A.* 5.1.22 that *vatup* is provided with the affix *kan*. Likewise *A.* 5.4.20 requires that the term *saṅkhyā* in *A.* 5.4.17 includes *bahu* etc.

In the preceding cases the provision of an operation in one rule required that the term *saṅkhyā* in another rule include *bahu* etc. In the next case, the negation of an operation implies that in the absence of that negation an operation stated to apply to a *saṅkhyā* would apply to *bahu* etc. too. *A.* 5.4.73 *bahuvrīhau saṅkhyeye ḍaj abahu-gaṇāt* provides the compound-final suffix *ḍac* to a *bahuvrīhi* compound that denotes a countable object, provided that the final constituent is not *bahu* or *gaṇa*. The rule prohibits the suffix *ḍac* if the final constituent is *bahu* or *gaṇa*. The compounds subject to this rule are formed by *A.* 2.2.25. *A.* 2.2.25 *saṅkhyayāvyayāsannādūrādhikasaṅkhyāḥ saṅkhyeye* provides that an indeclinable, one of the nominal bases *āsanna, dūra*, or *adhi-ka*, or a number word combines with a number word to form a *bahuvrīhi* compound if a countable object is to be denoted. The prohibition regarding the nominal bases *bahu* and *gaṇa* in *A.* 5.4.73 implies that the term *saṅkhyayā*, the instrumental singular of *saṅkhyā*, in *A.* 2.2.25 is the technical term including those nominal bases; otherwise the prohibition would be unnecessary.

While in the above instances, although not obvious, it was possible to determine that the term *saṅkhyā* was used in its technical meaning provided by *A.* 1.1.23 including the nominal bases specifically mentioned there in addition to number words. However, such a determination is not always possible. For example it is not clear whether the other term *saṅkhyā* in *A.* 2.2.25 includes *bahu* etc. Likewise a determination is extremely dubious in *A.* 3.2.21.

A. 3.2.21 *divāvibhāniśā* ... provides the suffix *ṭa* after the verbal root *kr̥ñ* on condition that an agent is to be denoted if one of the words in the list *divā* etc. occurs as a subordinate term connected with it. The list includes the term *saṅkhyā* and *bahu* separately. Now, if the term *saṅkhyā* here is used in its technical meaning including *bahu*, there would be no reason to mention it separately. Haradatta accepts that the term *saṅkhyā* here is used in its technical meaning including *bahu* but that the separate mention of the term *bahu* is not redundant because it has the sense of `many' (*vaipu-*

lya), not the sense of a number. He states *bahuśabdo vaipulyavacanaḥ saṅkhyāvacanasya tu saṅkhyāgrahaṇenaiva siddham*. `The word *bahu* in the rule denotes *vaipulya*. The other word *bahu* which means a number is already covered by the term *saṅkhyā*.' Thus Haradatta assumes that words such as *bahukara* are derived by the rule twice. In the first derivate *bahu* means `many', and in the second it means a number. In contrast to Haradatta, Puruṣottamadeva in the *Bhāṣāvṛtti* interprets *saṅkhyā* as referring to its own phonetic form, and not as the technical term. Hence he gives *saṅkhyākaraḥ* as an example derived by the rule. He goes on to say that others consider that the term *saṅkhyā* refers to number words, and subsequently gives the examples *ekakara*, *dvikara*, and *catuṣkara*. (*saṅkhyākaraḥ. saṅkhyety arthagrahaṇam ity eke: ekakaraḥ, dvikaraḥ, catuṣkaraḥ*.) Here he does not comment upon whether in the opinion of the others he cites the term *saṅkhyā* is considered to be used in its technical or non-technical sense. In sum, the evidence in the commentaries provides three possible interpretations of the term *saṅkhyā* in this rule: phonetic form, non-technical sense and technical sense.

Joshi and Roodbergen (1991: 29) consider that *A.* 1.1.23 is badly phrased by grammatical standards and is not an original Pāṇinian rule. They conclude this claiming that the purpose of the rule is exclusively relevant to taddhita derivation. Our study reveals that the technical term *saṅkhyā* provided by *A.* 1.1.23 is not restricted just to taddhita derivation but is relevant to compound formation in addition as is clear from its inclusion in *A.* 2.2.25.

Our examination of the six occurrences of the term *saṅkhyā* in five rules above determined that the sense of the term was its technical sense in four instances but was indeterminable in two. The above examination dealt with just five of forty-one rules in which the term occurs. A determinative answer regarding the exact reference of the term *saṅkhyā* generally would require one to check all the occurrences of *saṅkhyā* in the *Aṣṭādhyāyī*. If internal evidence and the discussion of commentators proved insufficient, it would be necessary to generate all of the forms derived by the broader interpretation of the term and to check to see which are found in accepted usage. Table 2 lists all of the rules that include the term *saṅkhyā* either explicitly or by recurrence.

Table 2
saṅkhyā *in the* Aṣṭādhyāyī

Rule no.	Rule
2.1.10	*akṣaśalākāsaṅkhyāḥ pariṇā*
2.1.19	*saṅkhyā vaṁśyena*
2.1.20	*nadībhiś ca*
2.1.50	*diksaṅkhye sañjñāyām*

2.1.51	*taddhitārthottarapadasamāhāre ca*
2.1.52	*saṅkhyāpūrvo dviguḥ*
2.2.25	*saṅkhyayāvyayāsannādūrādhikasaṅkhyāḥ saṅkhyeye*
3.2.21	*divāvibhāniśāprabhābhāskārāntānantādibahunāndīkiṁlipi-*
	libibalibhaktikartr̥citrakṣetrasaṁkhyājaṅghābāhvaharyatta-
	ddhanuraruṣṣu
4.1.26	*saṅkhyāvyayāder ñīp*
4.1.27	*dāmahāyanāntāc ca*
4.1.115	*mātur ut saṅkhyāsambhadrapūrvāyāḥ*
5.1.19	*ārhād agopucchasaṅkhyāparimāṇāṭ ṭhak*
5.1.22	*saṅkhyāyā atiśadantāyāḥ kan*
5.1.23	*vator iḍ vā*
5.1.39	*godvyaco 'saṅkhyāparimāṇāśvāder yat*
5.1.58	*saṅkhyāyāḥ sañjñāsaṅghasūtrādhyayaneṣu*
5.2.42	*saṅkhyāyā avayave tayap*
5.2.47	*saṅkhyāyā guṇasya nimāne mayaṭ*
5.2.48	*tasya pūraṇe ḍaṭ*
5.2.49	*nāntādasaṅkhyāder maṭ*
5.3.42	*saṅkhyāyā vidhārthe dhā*
5.3.43	*adhikaraṇavicāle ca*
5.4.1	*pādaśatasya saṅkhyāder vīpsāyāṁ vun lopaś ca*
5.4.17	*saṅkhyāyāḥ kriyābhyāvr̥ttigaṇane kr̥tvasuc*
5.4.43	*saṅkhyaikavacanāc ca vīpsāyām*
5.4.59	*saṅkhyāyāś ca guṇāntāyāḥ*
5.4.86	*tatpuruṣasyāṅguleḥ saṅkhyāvyayādeḥ*
5.4.87	*ahassarvaikadeśasaṅkhyātapuṇyāc ca rātreḥ*
5.4.88	*ahno 'hna etebhyaḥ*
5.4.89	*na saṅkhyādeḥ samāhāre*
5.4.140	*saṅkhyāsupūrvasya*
5.4.141	*vayasi dantasya datr̥*
6.2.35	*saṅkhyā*
6.2.163	*saṅkhyāyāḥ stanaḥ*
6.3.47	*dvyaṣṭanaḥ saṅkhyāyām abahuvrīhyaśītyoḥ*
6.3.48	*tres trayaḥ*
6.3.49	*vibhāṣā catvāriṁśatprabhr̥tau sarveṣām*

6.3.110	*saṅkhyāviṣāyapūrvasyāhnasyāhannanyatarasyāṁ ṅau*
7.3.15	*saṅkhyāyāḥ saṁvatsarasaṁkhyasya ca*
7.3.16	*varṣasyābhaviṣyati*
7.3.17	*parimāṇāntasyāsañjñāśāṇayoḥ*

In our formalization, any technical term in the *Aṣṭādhyāyī* is represented as the value of the attribute `saYjYA`. In the case of the term *saṅkhyā*, when it is decided that it is a technical term in a rule, then the attribute-value pair `saYjYA="saNKyA"` is included in the element that describes the speech forms referred to. This pair is utilized in *A.* 2.1.51, *A.* 2.2.25, *A.* 5.1.22, *A.* 5.2.48, and *A.* 5.4.17. An ordinary semantic condition, on the other hand, is represented as the value of the attribute `other` in an `arTa` element. When it is decided that the term *saṅkhyā* occurs in its ordinary sense of a number word then the attribute-value pair `other="saNKyA"` appears in an `arTa` element that is a child of the element that describes the speech forms referred to.

6 Semantic conditions

The *Aṣṭādhyāyī* contains 735 words used in the locative to state semantic conditions in rules (Scharf 2009: 103). Specific semantic factors serve as conditions for the classification of lexical items in the *Dhātupāṭha*, and for the introduction of kāraka terms and affixes. In many cases, these semantic conditions are the meanings denoted by the speech form of which they condition the introduction. In other cases, an affix is introduced on the condition that the derivate have a specific meaning, in which case the meaning is not specifically associated either with the stem or the affix but only with the derivate as a whole. In the formalization of rules, the question arises as to how to associate these semantic conditions with the specific speech form that denotes them. In our formalization, the semantic conditions are stated as values of attributes in an `arTa` element that is a child of the element that describes the speech form that denotes it. We associate the attribute-value pair with the speech form by adding that pair as the value of a `vAcya` attribute in the `AdeSa` element. If the meaning is denoted by the derivate as a whole, the `arTa` element is a direct child of the `rule` element and gets associated with the derivate by default.

Determining the precise speech form with which to associate the semantic condition is not always obvious. For several types of semantic conditions the association is clear. Semantic conditions for actions, for example, are clearly associated with verbal

roots because it is roots that denote action. Thus conditions stated in the *Dhātupāṭha* as the meaning of roots, and conditions regarding the time and manner of action, are indicated in `arTa` elements that are children of elements that describe those roots. Similarly, semantic conditions for the introduction of kāraka terms are clearly associated with the affixes that denote the objects subject to those kāraka terms. Hence *l*-affixes, *kṛt*-affixes, *taddhita*-affixes, and nominal terminations that denote kārakas must be supplied with attributes that describe the semantic conditions that introduce those kāraka terms. These semantic conditions whose association with the speech forms they condition is clear are categorized in our formalization by making them values of specific attributes. Thus the attributes include `Pala` and `kAla` for roots, and `kAraka` for the affixes just mentioned. Yet there are numerous semantic conditions that do not fit in these categories. For example, there are twenty-nine uncategorized semantic conditions in *A.* 3.2. These include conditions such as *tacchīla*, *taddharma*, *tatsādhukārin* in *A.* 3.2.134, and *vrata* in *A.* 3.2.80. We make these values of an `other` attribute in the `arTa` element.

A. 3.2.9 *harater anudyamane 'c* provides the suffix *ac* after the verbal root *hṝñ*, when it occurs in a meaning other than elevating on condition that an agent is to be denoted and a direct object (*karman*) occurs as a subordinate term *upapada* connected with it. In the sūtra itself, it is not clear with which speech form the semantic condition *anudyamana* `not elevating' is associated. Here we have associated the semantic condition with the verbal root based upon the *Kāśikā*'s paraphrase, *harater dhātor anudyamane vartamānāt karmaṇy upapade 'c pratyayo bhavati.* The *Kāśikā* clearly associates the semantic condition with the verbal root. Moreover the nañtatpuruṣa compound *anudyamana* contains the action noun *udyamana* which, because it denotes an action, must be associated with a verbal root. Although we associate the semantic condition with the verbal root, we do not make *udyamana* the value of a `Pala` attribute because *udyamana* is not the meaning given for the root in the *Dhātupāṭha*. Commentators often refer to nuances of roots which do not correspond to the categorical meanings provided for them in the *Dhātupāṭha*. Instead we make *udyamana* the value of an `other` attribute in the *arTa* element that is a child of the *pūrva* element that describes the root *hṝñ*.

A. 3.2.10 *vayasi ca* provides the suffix *ac* after the verbal root *hṝñ* on condition that an agent is to be denoted, a direct object (*karman*) occurs as a subordinate term *upapada* connected with the root, and the derivate denotes age. The *Kāśikā* gives two examples under this rule: *kavacaharaḥ* and *asthiharaḥ*. Although literally these words mean `one who lifts armor' and `one who lifts a bone', figuratively they mean a youth and a dog who have reached the age when they are capable to don armor and

lift bones respectively. The semantic condition stated by the term *vayas* `age' does not denote an action and therefore is not suitable to be denoted by a verbal root; nor is it suitable to be denoted by the suffix, which is provided in the sense of an agent (*kartṛ*) in accordance with *A.* 3.4.67 *kartari kṛt*. Therefore, the meaning is associated with the derivate as a whole. While commenting on this rule the *Kāśikā* paraphrases this semantic condition, *vayasi gamyamāne* ``when the meaning `age' is understood", thereby indicating that the meaning is not specifically associated with either the verbal root or the affix. In our formalization we accordingly make the meaning the value of an `other` attribute in an `arTa` element that is a direct child of the `rule` element.

A number of rules associate semantic conditions with the object denoted by the affix and can therefore be represented by indicating those semantic conditions as sub-categories of agent. Yet it is often unclear whether semantic conditions stated in rules are associated with the object denoted by the affix or are senses to be understood as belonging to the derivate as a whole without further differentiating any part of the derivate. For example, *A.* 3.2.25 *harater dṛtināthayoḥ paśau* provides the suffix *in* after the verbal root *hṛñ* on condition that an agent is to be denoted and either *dṛti* `a leather bag' or *nātha* `a master' occur as a subordinate term (*upapada*) denoting the direct object (*karman*) of the action denoted by the root. A further semantic condition is stated in the sūtra, namely, that an animal is denoted (*paśau*). Examples given in the *Kāśikā* are *dṛtihari* `one who carries a leather bag' and *nāthahari* `one who carries a master'. Now neither the sūtra nor the *Kāśikā*'s paraphrase clearly conveys that this semantic condition is denoted by the affix *in* rather than by the derivate as a whole. The *Kāśikā* states, *paśau kartari in pratyayo bhavati*. While it is likely that the word *paśau* is coreferential with the word *kartari* here, it is also possible that the word *gamyamāne* should be supplied, as is found coreferential with the word *vayasi* in *A.* 3.2.10. In the former case, to indicate that the semantic condition qualifies the agent, we would represent the condition in our formalization by putting the attribute-value pair `kAraka="kartf.paSu"` in an `arTa` element that is a direct child of the `rule` element and associate the pair with the affix provided by inserting `vAcya="kAraka=kartf.paSu"` in the `AdeSa` element. In the latter case, we would indicate that it is associated with the derivate as a whole by putting the attribute-value pair `other="paSu"` in an `arTa` element that is a direct child of the `rule` element. In the absence of a `vAcya` attribute, the pair would be associated with the derivate as a whole by default.

The formalization of rules reveals significant issues regarding the semantics of speech forms which are not directly stated by the tradition. Yet by the use of the expressions like *gamyamāne*, *arthe*, *abhidheye*, and *vartamānāt* commentators

do obliquely associate semantic conditions with particular speech forms involved in derivations. We have attempted to make their oblique treatments explicit in the formal representation of rules.

7 Conclusion

The issues discussed in this paper reveal that a great deal of information needs to be made explicit in the process of formalizing rules of the *Aṣṭādhyāyī*. We were forced to address issues crucial to the functioning of rules that have gone unnoticed or that might have been passed over as trivial by scholars learned in Pāṇinian grammar. The formalization of rules in a way that remains faithful to the mechanism of the *Aṣṭādhyāyī* has given us the opportunity to understand rules more deeply.

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