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Explicit codification in Pāṇini and generative grammar

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Abstract

Generative grammar and Pāṇini's grammar – so-called *Aṣṭādhyāyī*, dating from ca. fourth century BCE – differ in scope and goals: while generative grammarians search for the limits of variation in natural languages to explain what makes language acquisition possible in the first place, Pāṇini provides a distributional and variationist account of old Indo-Aryan, with the twofold goal of faithfully recording that language and of regularizing its usage in the relevant sacred texts. Despite these important differences, the codification of linguistic phenomena operated by generative grammarians bears some resemblance to the one operated by Pāṇini. Thus, in this study I analyze the codification of long-distance agreement in generative grammar and the codification of compounding in the *Aṣṭādhyāyī*. I show that both instances of codification are explicit, in the technical sense that they specify (rigorously formulate) the rules – filters and operations – that license all well-formed tokens of long-distance agreement and compounding while simultaneously excluding all ill-formed ones. Finally, I submit that the explicit character of these instances of codification is a major part of the reason why they are still likewise considered as successful in the contemporary scientific community.

Key Words – compounding; hierarchical dimension; long-distance agreement; old Indo-Aryan; zero-replacement

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1. Introduction

Codification is a polymorphous operation. Thus, in the domain of legislation, this term denotes an orderly and consistent arrangement of rules or norms (Treccani)[1]; in information theory, it refers to «the rule for the coordination of two different repertoires of signs, which can represent the same information» (Bussmann 1996: 193). On the other hand, in syntactic theory – which is the domain which concerns us most directly here – codification refers to the operation of arranging the signs taken from a code in keeping with the rules of that code, where the signs are identified with words and the code is identified with grammar. In this sense, codification is synonymous with encoding (see AA. VV. 1993: 182-183). Thus, in essence, codification in syntactic theory is *the operation of reducing a linguistic phenomenon to the interaction of grammatical rules*.

In the present study I examine two types of codification that are held in high regard by the contemporary scientific community: i) the codification of long-distance agreement in generative grammar; ii) the codification of compounding in Pāṇini's grammar (*Aṣṭādhyāyī*, ca. fourth c. BCE). By exposing the differences and similarities between (i) and (ii), I aim to answer a broader question: are there salient features, in the practice of linguistic codification, that allowed two types of codification which are so different in scope and goals (i.e., the codification operated by Pāṇini and the one operated by generative grammarians) to be likewise held in high regard by the contemporary scientific community?

The present study is organized as follows. Section 2 is given over to the phenomenon dubbed as "long-distance agreement" and to the way in which generative grammarians codified this phenomenon in the second half of the Twentieth century. Section 3 is devoted to providing the basics of Sanskrit compounding and to outlining Pāṇini's extremely original and sophisticated codification of this construction. Section 4 draws a comparison between the codification operated by Pāṇini and that operated by generative grammarians in search of a common thread running through them. Finally, section 5 contains my concluding remarks.

2. Long-distance agreement in generative grammar

In this section I specify what grammar is in the generative tradition; I take for granted no previous knowledge on the topic, and consequently only confine my attention to some foundational aspects of the generative framework. I subsequently show how generative grammarians codified long-distance agreement, i.e., how they reduced this linguistic phenomenon to the interaction of independently assumed principles of grammar.

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[1] <https://www.treccani.it/vocabolario/codificazione/> (accessed 25/06/2024).

2.1. What is grammar in the generative tradition?

Grammar is a code, i.e., a system of primitives (also called symbols) and rules for combining those primitives. In the generative tradition, and specifically in the so-called Principles and Parameters approach, grammar consists of a lexicon (set of primitives identified with words) and of filters (Chomsky 1993 [1981]: 5)[2]. Filters are rigorously formulated instructions that eliminate a subset of all possible combinations of words (Moro 2015: 3-4); the subset thereby eliminated is the subset of ill-formed sentences of a language; the remaining subset instead contains the well-formed sentences of the selfsame language. Put another way, filters separate ill-formed sentences from well-formed sentences.

In this view of grammar, the well-formedness and ill-formedness of a given language's sentences are the output of a function that takes as input words: the output is well-formedness when no filter is violated, and ill-formedness when at least one filter is violated. To better understand the innovative import of such a view of grammar, let us consider the concrete examples in (2)-(3), which are both interrogative counterparts of (1). The ill-formedness of (3) can be seen as falling out from "locality", a filter that in essence excludes dependencies between a trace and its antecedent when the trace is contained in a phrase that is *not* adjacent to a verbal element: (3) is ill-formed because the *before*-clause (i.e., the phrase containing the trace) is not adjacent to the verbal element *met*, the closing square bracket "]" intervening between them; conversely, (2) is well-formed because the sentence *John met* is adjacent to the complementizer *that*, which counts as a verbal element for the purposes of locality (see, among others, Cinque 1990; Rizzi 1990; Manzini 1992; den Dikken and Lahne 2013; Moro 2013: 128-148; Moro 2017: 106)[3].

(1) *I think* [*that* [*John met with Angela*] [*before talking with Julie*]].

(2) ***With which girl***$_{\mathbf{i}}$ *do you think* [*that* [*John met* ***t***$_{\mathbf{i}}$] [*before talking with Julie*]] ?

(3) ****With which girl***$_{\mathbf{i}}$ *do you think* [*that* [*John met with Angela*] [*before talking* ***t***$_{\mathbf{i}}$]]?

Thus, the well-formedness and ill-formedness of (2) and (3), respectively, is dealt with by generative grammarians in an algebraic fashion, as the resolution of an equation imposed by locality on phrases and their combination with verbal elements (Moro 1996: §2; Chomsky and Moro 2022: 84-85). Such decomposition of the well-formedness and ill-formedness of sentences into the interaction between grammatical filters and combinations of words is an instance of so-called *modularity*, i.e., a radically innovative view of grammar introduced in the 1970s whereby grammar consists of several interacting subsystems or modules, including locality. Chomsky compared the introduction of modularity with the shift from phonemes to abstract features in the structuralist tradition of the Prague school of phonology[4]:

[2] For a clear and concise introduction to the Principles and Parameters approach, see Burzio (1986: 3-19).
[3] Graphically, traces are notated as *t*, while the dependency between an antecedent and its trace is notated by co-indexing (*i*…*i*). The phrases from which extraction takes place are here marked via square brackets. On phrases see Section 2.4.
[4] For instance, the vocalic phonemes of Italian can be decomposed into a proper combination of the following four abstract features: [± rounded], [± high], [± low], [± retracted]. See Lepschy (1966: 37); Moro

> In early work in generative grammar it was assumed, as in traditional grammar, that there are rules such as "passive", "relativization", "question-formation", etc. […] These "rules" are decomposed into the more fundamental elements of the subsystems of rules and principles […] [i.e., lexicon, syntax, Phonetic Form, Logical Form; bounding theory, government theory, θ-theory, binding theory, Case theory, control theory]. This development, largely in work of the past ten years, represents a substantial break from earlier generative grammar, or from the traditional grammar on which it was in part modelled. It is reminiscent of the move from phonemes to features in the phonology of the Prague school, though in the present case the "features" (e.g., the principles of Case, government, and binding theory) are considerably more abstract, and their properties and interaction much more intricate. The notions "passive," "relativization," etc., can be reconstructed as processes of a more general nature, with a functional role in grammar, but they are not "rules of grammar." (Chomsky 1993 [1981]: 7)

This decomposition is necessary when it comes to exploring the neurobiological correlates of syntax: indeed, the traditional taxonomy, consisting of categories like "interrogative" and "passive sentence", «is far too removed from what we know of the brain's actual mechanisms to be used as a guide to inspect actual neurobiological networks» (Chomsky and Moro 2022: 69). Thus, if we are to study the neurobiological correlates of interrogative sentences like (2) and (3), it does not suffice to feed, as it were, (2) and (3) as a whole to the brain during a neurolinguistic experiment. Indeed, what is most necessary, in this connection, is to understand in what regard an interrogative sentence differs from any other sentence type (passive, relative, etc.), i.e., to isolate the defining feature of all and only interrogative sentences: it is such a defining feature that is to be tested experimentally by feeding it to the brain in comparison to the defining features of the other sentence types. In point of fact, were we not to proceed in this way, we would never be certain as to whether the datum found in the experiment is really a neurobiological correlate of interrogative sentences, rather than of some disturbing factor (see the classic works of Moro 2015; 2016 for a detailed discussion). Thus, if we are to isolate the defining feature of interrogative sentences like (2)-(3) it is necessary to decompose such sentences into the fundamental building blocks of grammar: the combinations of words and the filters on them.

All in all, grammar in the generative framework is a system of filters that constrain all possible combinations of words. In this framework, the codification of a linguistic phenomenon reduces to the application of the relevant filters to the relevant combination of words. In the remainder of this section, I will illustrate how long-distance agreement was codified in a grammar of this sort.

2.2. What is long-distance agreement?

Let us consider the examples in (4)-(5). The copula *is* ([+SINGULAR]) does not agree with the closer unit *dogs* ([-SINGULAR]) (4); rather, it agrees with the more distant unit *cat*

(2017: 85-88); Joseph (2022) on the continuity between structuralism and the generative framework; see also Graffi (2001) for a history of syntactic theory, including the structuralist tradition.

([+SINGULAR]) (5). This phenomenon, illustrated by (4)-(5) goes under the rubric "long-distance agreement", and belongs to the set of long-distance dependencies[5].

(4) **The cat*$_1$ *that was chased by the* ***dogs*****$_2$** ***are*****$_2$** *old.*

(5) *The* ***cat*****$_1$** *that was chased by the dogs*$_2$ ***is*****$_1$** *old.*

The question is how long-distance agreement is codified in the generative model. Indeed, this question is a central one: the birth of the generative model can be considered as an attempt to provide a solution to the problems posed by long-distance agreement – alongside closely related phenomena such as *if ... then* sentences – to pre-generative models (i.e., models that held sway until at least the Fifties of the last century – see Chomsky 1956; 2002 [1957]). Given the centrality of the question at stake (i.e., how to codify long-distance agreement) for the generative model, different solutions have been advanced – couched in different formalisms – throughout the different stages of development of this model (see at least Chomsky 1956; 1970; 1986b; 1993 [1981]; 1995; 2000; 2001; 2015 [1965])[6]. A comprehensive review of such solutions is beyond the scope of the present investigation. Indeed, my aim here is more limited: to show how long-distance agreement can be reduced to a simple interaction of filters on combinations of words, while at the same time emphasizing the fundamental innovations which made this reduction possible.

For this reason, I ground my presentation on two foundational works: Chomsky (1956), where a new method of symbol manipulation was discovered for the purposes of linguistic investigation; and Chomsky (1993) [1981], where the view of sentential well-formedness and ill-formedness as the output of the interaction of a system of filters was fully developed for the first time. Specifically, I revisit Chomsky's (1956) treatment of long-distance agreement in the light of Chomsky's (1993) [1993] general approach to grammar (so-called "Government and Binding"). On the other hand, no attempt is made, in the following, to rephrase the Government and Binding formalism in the terms of recent generative approaches to grammar, including minimalism (e.g., Adger 2003; Chomsky 1995; 2000; 2001) and the cartographic program (Rizzi 2013; Cinque and Rizzi 2015). This choice is motivated by the fact that recent approaches introduce notions – such as the decomposition of sentences into a constellation of functional heads (Rizzi and Cinque 2016), or the Agree operation defined over a probe-goal pair (Chomsky 2000: 123-124; 2001: 16-17) – which result as being unnecessary complications for the specific purposes of comparing the codification operated by Pāṇini with the one operated by generative grammarians. Indeed, all that is needed for such a comparison to be fruitful is already found in the Government and Binding approach, as we shall see below.

2.3. Pre-generative models

A good starting point to illustrate generative grammarians' codification of long-distance agreement is to show why long-distance agreement was problematic for pre-generative models, and specifically for so-called finite-state grammar (i.e., the reference model until the 1950s). Finite-state grammar consists of a finite number of states, i.e., loci which the

[5] Noun-verb agreement is here signaled by assigning the same numerical index (e.g., 1…1) to the noun and the verb involved.

[6] Cf. Graffi (2001: 425-485) for a history of the different stages of the generative framework.

system transits through during the derivation of a string: any symbol in the string is the output of the transition from a state S_1 to a state S_2 (see Chomsky 1956: 114-115 and Willsey 2006: 1 for the relevant technical details). Accordingly, finite-state grammar makes the following prediction about long-distance agreement, as exemplified in (4)-(5): that no more than α states are needed to capture the agreement between *cat* and *is*, where α is an integer. Let us see whether this prediction is borne out.

For one thing, infinitely many long-distance dependencies may in principle intervene between *cat* and *is*, as illustrated in (6), where the dots indicate the possibility of recursively inserting other comparable dependencies. Here, too, each dependency between two terms is marked by assigning the same numerical index to those terms (1…1; 2…2; etc.) – see Chomsky and Miller (1963: 286).

(6) *The* ***cat*****$_1$** *that was chased by the dogs which thought that, if*$_2$ *they took action in the morning, then*$_2$ *either*$_3$ *Peter would scold them, or*$_3$ *Sophie*$_4$*, who hates her cat, would*$_4$ *say that…* ***is*****$_1$** *old.*

Now, the presence of *is*$_1$ depends solely on the presence of *cat*$_1$, and the presence of *then*$_2$ depends solely on the presence of *if*$_2$. This implies that: i) the states the traversing of which generates *is*$_1$ (i.e., x_2-z) must be somehow related to the states the traversing of which generates *cat*$_1$ (i.e., x_1-x_2), thereby yielding x_1-*cat*$_1$-x_2-*is*$_1$-z; ii) the states the traversing of which generates *then*$_2$ (i.e., y_2-z) must be somehow related to the states the traversing of which generates *if*$_2$ (i.e., y_1-y_2), thereby yielding y_1-*if*$_2$-y_2-*then*$_2$-z; iii) x_2-z must be somehow unrelated to y_1-y_2; iv) y_2-z must be somehow unrelated to x_1-x_2 (see crucially Daly 1974: 36). Which is to say that the states needed to generate the two terms of a dependency (e.g., *cat*$_1$…*is*$_1$) can never be replaced by the states needed to generate the two terms of another dependency (*if*$_2$…*then*$_2$). A direct consequence of this is that the number of states needed to generate the two terms of multiple long-distance dependencies must be at least as great as the number of those dependencies. Indeed, as hinted above, infinitely many dependencies like 1…1, 2…2, 3…3, and 4…4 may in principle occur instead of the dots in (6), meaning that the states needed to generate such dependencies must be infinite in number. Therefore, the system has to transit through infinitely many states before concluding the derivation of (6); equivalently, the long-distance agreement between *cat* and *is* in (6) cannot be licensed unless an infinite number of states is deployed. This falsifies the prediction made by finite-state grammar[7].

All in all, at least a subset of instances of long-distance agreement between *cat* and *is* cannot be codified in finite-state grammar, namely the instances like (6) in which long-distance agreement is accompanied by a potentially infinite number of other long-distance dependencies. This is because the finite number of states imposed by such grammar conflicts with the need for infinitely many states in sentences like (6). When attention is instead confined to sentences like (5) where long-distance agreement is not accompanied by other long-distance dependencies, the codification of the agreement between *cat* and *is* in finite-state grammar may be possible in the form of a list[8]: *the* must be followed by

[7] For a full-fledged presentation of the present argument, see Chomsky (1956: 115); and the remarks by Svenonius (1958); Chomsky (1965: 108); Staal (1966: 246); Moro (2017: 243-244 n. 9); and especially Daly (1974: 35-36). Indeed, such an argument is not exempt from criticism: see Pullum (2011: 279-280). See Chesi and Moro (2014) for a broader perspective – including computational and neurobiological aspects – stemming from this strand of research.

[8] Let us recall that «a list is a trivial finite-state grammar» (Chomsky 1956: 115).

cat, which must be followed by *that*, which must in turn be followed by *was*, which must instead be followed by *chased*, etc., until we arrive at the bolded copula token *is* of (5). However, codification along these lines would be of very little interest for the grammarian, inasmuch as it would be equivalent to the compilation of a dictionary, rather than to the reduction of linguistic phenomena to the interaction of independently motivated principles (Chomsky 1956: 115; Chomsky and Miller 1963: 285).

2.4. The hierarchical dimension

To deal with long-distance agreement as exemplified in (4) through (6), generative grammarians made use of rewriting rules of the type reported in (7), dubbed as context-free rule[9]. Here A is a single-category symbol (e.g., S, NP, VP, etc.), Z is a nonnull string of symbols, and X and Y (i.e., the left- and right-hand context, respectively, for the application of the rule) are null.

(7) A→Z/X — Y

In the words of Chomsky, «This rule is interpreted as asserting that the category A is realized as the string Z when it is in the environment consisting of X to the left and Y to the right.» (Chomsky 2015 [1965]: 71-72). As a concrete example of context-free rules, let us focus on (8). The rules in (8a-e) introduce an apparently simple but crucial innovation: symbols that are not English words (S, NP, VP, PP, AP, D, and N, and P) now come to be deployed in the description of English (Chomsky 1956: 119; Moro 2017: 244 n. 9).

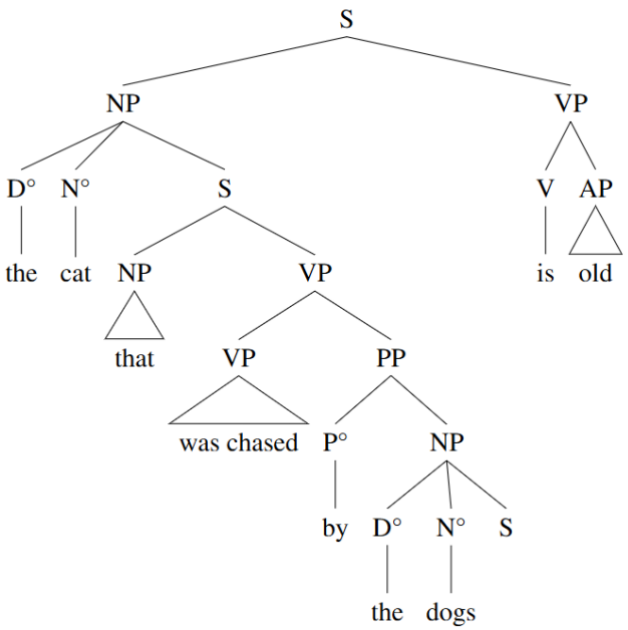
(8) a. S→NP VP
b. NP→D N S
c. VP→VP PP
d. VP→VP AP
e. PP→P NP

The cruciality of the use of symbols that are not English words does not merely lie in the fact that they permit English words to be grouped into phrases (i.e., units larger than words). Rather, it lies in the fact that they open up a new dimension for the description of linguistic phenomena, namely the *hierarchical* dimension: a dimension in which the metrics is not the precedence relations holding in the linear dimension (e.g., *the* precedes *cat*, which precedes *that*, which precedes *was*, which precedes *chased*, etc.), but rather the dominance relations between phrases (or between phrases and subparts thereof). To illustrate this point, let us apply (8a-e) to (5), thereby yielding the representation in (9). (9) is technically known as phrase marker or, equivalently, as syntactic tree. I shall refer to the symbols that are not English words as *nodes* of the tree[10].

[9] A grammar which makes use of context-free rules is dubbed as context-free grammar.

[10] See Greco and Mocci (2024: 6-7), from which the following discussion draws. I am abstracting away from many details that are immaterial for the present discussion, such as binary branching (Kayne 1984), the representation of sentences as endocentric phrases (Chomsky 1986b), the scope of the determiner *the* over the relative clause, and the position of the *by*-phrase within the VP. See Cinque (2020) and Manzini (2017) for an updated analysis of relative clauses and *by*-phrases, respectively.

(9)



The entire string *the cat that was chased by the dogs is old* counts as a sentence (S) in (9). The arrow in (8a) provides that this sentence dominates (i.e., contains) a verb phrase (VP, namely *is old*) and a noun phrase (NP, i.e., *the cat that was chased by the dogs*). The VP *is old* dominates the V *is* and the adjectival phrase (AP) *old*, as provided for by (8d). The NP *the cat that was chased by the dogs* in turn dominates a determiner (D, i.e., *the*), a noun (N, i.e., *cat*), as well as another sentence (S, i.e., the relative clause *that was chased by the dogs*), in compliance with (8b). The N *cat* qualifies as the head of such an NP, inasmuch as it is the closest noun dominated by NP. The S *that was chased by the dogs* can also be analyzed as dominating an NP (*that*) and a VP (*was chased by the dogs*) by virtue of another application of (8a). Moreover, (8c) provides that this VP dominates another VP (*was chased*) as well as a prepositional phrase (PP, i.e., *by the dogs*), which is made up of a preposition (P, namely *by*) and of an NP (*the dogs*) in keeping with (8e). Finally, a further application of (8b) brings it about that the NP *the dogs* dominates the head N (*dogs*), the D *the*, and an empty S. In this way, the phrase marker in (9) makes it possible to visualize the dominance relations involved in the context-free rules (8a-e) on a bidimensional space[11]. Such dominance relations define the hierarchical dimension, which owes its name to the fact that, in a phrase marker, some nodes result as being more prominent than others (Moro 2015: 61-62): e.g., the N *cat* is more prominent than the N *dogs* in (9).

The hierarchical dimension permits approaching the long-distance agreement between *cat* and *is* in (5) from a new perspective, as we shall see in the next subsection.

2.5. A new conception of distance

When we confine our attention to the linear dimension of (5) (repeated below as (10)), the bolded copula token *is* is linearly closest to *dogs* as well as to *old*. At the same time, *is* is furthest away from the determiner *the* introducing *cat*.

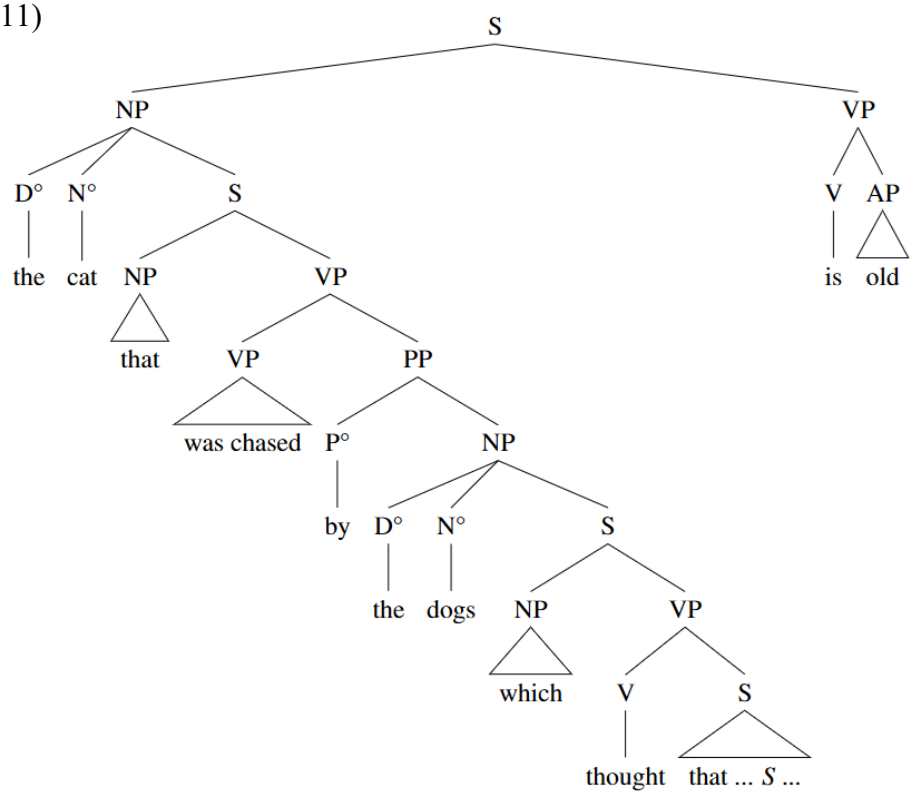
[11] Triangles underneath phrases in (9) indicate that the dominance relations involved in the phrases at stake are intentionally left unspecified.

(10) *The* ***cat***$_1$ *that was chased by the dogs*$_2$ ***is***$_1$ *old*.

When we turn to (9) (i.e., to the hierarchical dimension of (10)), instead, the possibility opens up of defining distance as a relationship holding between nodes rather than words: the lesser the difference between the number of nodes dominating a node X and the number of nodes dominating a node Y, the closer X and Y are. Thus, the V *is* now qualifies as hierarchically closest to three nodes in (9): the D *the* introducing *cat*, the N *cat*, and the S *that are chased by the dogs*. This is because the latter nodes (D, N, and S) are dominated by two nodes (NP and S) just like the V *is*, which is dominated by VP and S. On the other hand, the V *is* results as being hierarchically most distant to the D *the* introducing *dogs*, the N *dogs*, and the empty S, inasmuch as the latter three nodes (D, N, and S) are dominated by six nodes (i.e., NP, PP, VP, S, NP, S), whereas *is* is dominated by two nodes only.

We now have all the ingredients to codify the long-distance agreement between *cat* and *is* in (10). Indeed, the bold copula *is* does not agree with the linearly closest noun (*dogs*), but with the hierarchically closest one: i.e., with *cat*. Therefore, the rule that captures long-distance agreement can be descriptively formulated as follows: verbs agree with the noun that is hierarchically closest to them. This rule easily covers sentences like (6) where the long-distance agreement between *cat* and *is* co-occurs with potentially infinitely many other long-distance dependencies. Thus, *cat* is still the closest noun with respect to the V *is* in (11) (= (6)), even when infinitely many dependencies replace the "…*S*…" occurring in this phrase marker. In this way, the hierarchy-based treatment of agreement is descriptively more adequate than the one based on finite-state grammar, which falls short of accounting for sentences like (6) (see Section 2.3).

(11)



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Now that the descriptive rule for long-distance agreement has been pinpointed, we can proceed with the issue of codification. As mentioned above (Section 2.1), from the point of view of generative grammar the codification of a linguistic phenomenon is tantamount to the reduction of that phenomenon to the application of independently motivated filters to combinations of words. The filters at stake here can be simply dubbed as hierarchy and locality: hierarchy prevents establishing a dependency between two units identified based on linear considerations only (e.g., a dependency between the second and the penultimate unit in a string); locality instead prevents establishing a dependency (including agreement) between two units that are too distant from one another. When applied to the combinations of words in (5) as well as in (6), these two filters suffice to yield the desired outcome, namely the agreement of *is* with cat as opposed to *dogs*. Long-distance agreement is thereby codified in generative grammar.

2.6. Explicitness

In sum, finite-state grammar falls short of codifying long-distance agreement when this co-occurs with a potentially infinite number of long-distance dependencies. The codification devised by generative grammarians overcame this problem by making reference to the hierarchical dimension, which enables a new conception of distance between linguistic units based on nodes as opposed to words.

The hallmark of the generative codification of long-distance agreement is, I argue, its *explicitness*: not simply in the sense that it is consciously operated by an agent, but rather in the technical sense that it specifies the filters yielding certain outputs and excluding other outputs, ideally without shortcuts. Indeed, explicitness characterizes any codification operated by generative grammarians, so much so that *generative* may be taken as a mere synonym for *explicit*[12]:

> A grammar of a language purports to be a description of the ideal speaker-hearer's intrinsic competence. If the grammar is, furthermore, perfectly explicit – in other words, if it does not rely on the intelligence of the understanding reader but rather provides an explicit analysis of his contribution – we may (somewhat redundantly) call it a generative grammar. (Chomsky 2015 [1965]: 2-3)

In other words, rather than taking it for granted that an intelligent reader would know that the bolded copula token of (4)-(6) has to agree with *cat* as opposed to *dogs*, the codification operated by generative grammarians is concerned with specifying what that knowledge consists of, i.e., the principles needed to attain that knowledge:

> […] a good traditional or pedagogical grammar provides a full list of exceptions (irregular verbs, etc.), paradigms and examples of regular constructions, and observations at various levels of detail and generality about the form and meaning of expressions. […] Without too much exaggeration, one could describe such a grammar as a structured and organized version of the data presented to a child learning a language. Generative grammar, in contrast, is concerned primarily with the intelligence of the reader, the principles and procedures brought to bear to attain full knowledge of a language. (Chomsky 1986a: 6-7)

[12] See also Chomsky (1986a: 3); Moro (2015: 27).

3. Compounding in Pāṇini's grammar

After briefly introducing Pāṇini's grammar, in this section I show how compounding is codified in this grammar as the output of the interaction of a few precisely specified operations. Like in the case of generative grammar, in this case, too, I assume no previous knowledge of Pāṇini's grammar, with an eye to making this study accessible both to Pāṇinian scholars with no background in generative linguistics, and to generative linguists with no background in Pāṇinian studies.

3.1. A few words on Pāṇini's grammar

Pāṇini is the name of an ancient Indian grammarian coming from the settlement of Śalātura, in the ancient province of Gandhāra (modern-day Pakistan), and active around the fourth century BCE (see Houben 2020: 35 n. 1; cf. Lowe 2024: 3-4). His masterpiece is the *Aṣṭādhyāyī* 'eight-chapter [work]': a grammar divided into eight chapters and consisting of approximately 4000 concise rules (dubbed as *sūtra*s or aphorisms), which are written in a semiformalized form. Such rules are devoted to the fine-grained synchronic description of a variety of old Indo-Aryan (also known as old Indic). Such a variety, arguably to be identified with *late* Vedic (Freschi and Pontillo 2013: 8 n. 2), is based on the spoken language of Pāṇini's time. Nonetheless, the *Aṣṭādhyāyī* also takes account of early Vedic features as well as of regional and sociolinguistic variants[13]. The guiding principle inspiring each of the 4000 *sūtra*s is simplicity or – equivalently – maximum generalization, i.e., the ability to capture the largest number of forms with the shortest formulation (Kiparsky 2009: 34, 39).

Pāṇini's grammar has often been praised in modern linguistics. Thus, according to the great American structuralist Leonard Bloomfield, «For no language of the past have we a record comparable to Pāṇini's record of his mother tongue, nor is it likely that any language spoken today will be so perfectly recorded.» (Bloomfield 1929: 274)[14]; more concisely, Bloomfield (1984 [1933]: 11) considered the *Aṣṭādhyāyī* as «one of the greatest monuments of human intelligence». Chomsky, too, expressed his admiration for the *Aṣṭādhyāyī*, which would qualify as the first generative – hence, explicit – grammar: «it seems that even Panini's grammar can be interpreted as a fragment of such a "generative grammar," in essentially the contemporary sense of the term» (Chomsky 1965 [2015: xxi])[15]. Indeed, the *Aṣṭāḍhyāyī* proves to be extremely advanced when it comes to morphology and syntax. This claim is substantiated by several case studies discussed by Kiparsky (2009) and Lowe (2024). For example, Pāṇini devised an ingenuous mapping between semantic roles (agent, patient, instrument, source, etc.) and case endings (nominative, accusative, etc.): the insightfulness of this mapping can be compared to that of Fillmore (1968), which constitutes the basis of modern theories of semantic roles[16].

[13] See Giudice (2024) for the possibility that Pāṇini's grammar also accounted for features of Niya Prakrit. For an overview of Pāṇini's grammar see, among others, Kiparsky (1994, 2009); Cardona (1997); Houben (2020); Lowe (2024).
[14] Quoted in Lowe (2024: 8 n. 21).
[15] On the generative property of the *Aṣṭādhyāyī* see recently Lowe (2024: 18).
[16] See Lowe (2024: 117-119) for the differences and similarities between Pāṇini's system and Fillmore's (1968). If we limit our attention to the generative framework, an illuminating example of modern theory of semantic roles can be found in Hale and Keyser (1993, 2002).

In the next subsection I shall concentrate on another empirical domain in which the *Aṣṭāḍhyāyī* appears to be in the vanguard of linguistic theorizing: compounding, which lies at the crossroads of syntax and morphology.

3.2. What is compounding?

In English, two words may combine to yield a new word. For instance, the combination of the two words *horse* and *hoof* yields *horse-hoof*, which counts as a single word for grammatical purposes: e.g., *horse-hoof* is pluralized by affixing an *-s* to the whole unit (*horse-hoofs*), just like the run-of-the-mill words *horse* and *hoof*, which are pluralized as *horses* and *hoofs*. On the other hand, in old Indo-Aryan – and specifically in Vedic – two stems combine to yield a new stem (the stem of a word is what is left when any inflectional ending of that word is dropped; see Wackernagel 1905: 10): e.g., *áśva-* 'horse' may combine with *śaphá-* 'hoof' to form the new stem *aśva-śaphá-* 'horse-hoof'[17]. The single-stem status of *aśva-śaphá-* is proved, among other things, by the fact that it bears one single accent just like the run-of-the-mill stems *áśvá-* and *śaphá-*, and by the fact that the inflection of *aśva-śaphá-* is obtained by suffixing a nominal ending to the right-hand edge of the whole compound (> *aśva-śaphá-ḥ*), just like in the run-of-the-mill stems *áśvá-* (> *áśvá-ḥ*) and *śaphá-* (> *śaphá-ḥ*).

The formation of *horse-hoof* shares many relevant details with that of old Indo-Aryan *aśva-śaphá-*. In particular, the semantic relation of possession holding between *horse* and *hoof* is covert in *horse-hoof*, just like that between *áśvá-* and *śaphá-* in *aśva-śaphá-*. That is to say, we understand the hoof denoted by *hoof* to be possessed by (or zonally included in) the horse denoted by *horse* in both *horse-hoof* and *horse's hoof*; however, this semantic relation is morphosyntactically signaled only in *horse's hoof*, by means of the genitive ending *-s* attached to *horse*. The same holds for old Indo-Aryan *aśva-śaphá-* and *áśvasya śapháḥ* (12): while both *aśva-śaphá-* and (12) convey the idea that a hoof (*śaphá-*) is possessed by some horse, this possession relation is morphosyntactically signaled only in (12), via the genitive case ending *-sya* affixed to *śaphá-*. Expressions like *horse-hoof* and *aśva-śaphá-*, where the semantic relation between the internal members is morphosyntactically covert, are designated as compounds. The formation of compounds is instead referred to as compounding.

(12) *áśva-sya* *śaphá-ḥ*.
horse-GEN hoof-NOM
'horse's hoof'[18].

Despite the important similarities between *horse-hoof* and *aśva-śaphá-*, it is no easy task to provide a unified definition of compounds that covers both English and old Indo-Aryan data. This is because, as we saw above, compound-members are words in English (e.g.,

[17] *aśva-śaphá-* is attested, e.g., in *Śatapathabrāhmaṇa* 13.3.4.4: «***aśvaśaphéna*** *dvitī́yām ā́huti̯m juhoti paśávo vā ékaśaphā rudráḥ sviṣṭakṛ́t*» 'The second oblation he offers on a horse-hoof; for the one-hoofed (animals) are cattle, and the Sviṣṭakṛt is Rudra' (tr. Eggeling 1882-1900, 5: 339).

[18] Cf. *Ṛgveda* 1.117.6: «***śaphā́d áśvasya*** *śatáṃ […] kumbhā́n asiñcatam mádhūnām*» 'You two poured a hundred pots of honey from the horse's hoof'. It should be pointed out that while the ordering of stems is fixed in old Indo-Aryan compounds, the ordering of words in phrases like (12) enjoys more freedom. This distinction between words and stems can be disregarded for our purposes. However, for a detailed discussion of ordering constraints on old Indo-Aryan compounds, see Mocci (2022, 2024a, 2024b); Lowe and Mocci (2022).

horse and *hoof*), but stems in old Indo-Aryan (e.g., *áśvá-* and *śaphá-*). Here I shall adopt in their essentials the definitions put forth by Guevara and Scalise (2009) and Bauer (2017), which appear to be general enough to apply across languages and language families. Let us consider how.

The aforementioned authors capitalize on an important distinction drawn in modern linguistics between the concrete units which instantiate a certain abstract category, and the category itself. Thus, in Italian, the phoneme /r/ (the abstract category) is kept distinct from the phones [r] (voiced alveolar trill) and [ʀ] (voiced uvular trill), which are concrete realizations (technically designated as allophones) of /r/. In the same way, the English plural morpheme *-s* (abstract category) can be concretely realized as [s] or [z], which are referred to as allomorphs. A similar distinction can be found in the lexicon, too: root (*arrive-*), stem (*arrive-*), and inflected words (*arrive*, *arrives*, *arrived*, *arriving*) are all concrete realizations of a lexeme (ARRIVE), which is a mental entity; put another way, lexemes result from abstraction over the possible representations of a certain word (Bauer 2017: 4). Alternatively, we may abstract away from the possible representations of lexical categories – including at least nouns, adjectives, and verbs – rather than of a specific word, in which case the result of abstraction is a lexical category. Thus, what lexemes and lexical categories have in common is the fact that they can both be considered as hypernyms of words as well as of stems.

In this way, the possibility opens up of defining a compound as the linguistic unit that satisfies the conditions in (i)-(ii): i) it is a lexeme made up of two lexemes (Bauer 2017: 4) or, equivalently, a lexical category that is made up of two lexical categories (Guevara and Scalise 2009: 107); ii) a morphosyntactically covert semantic relation holds between the two lexemes, or, equivalently, between the two lexical categories that make up the compound. Following Guevara and Scalise (2009: 107), this definition may be summarized as in (13), where *r* is a morphosyntactically covert semantic relation, X and Y are the lexemes (or, equivalently, lexical categories) that serve as compound-members, and Z is the lexeme or lexical category serving as the compound.

(13) $[X\ r\ Y]_Z$

The definition in (13) manages to cover both English compounds such as *horse-hoof* and old Indo-Aryan compounds such as *áśva-śaphá-*[19]. Now that I have specified what compounds and compounding are, we can turn to the question of how compounding is codified by Pāṇini.

3.3. On silent case endings

Pāṇini's grammar – the *Aṣṭādhyāyī* (A for short) – may be divided into thematic sections. One of these is the compounding section, which spans A 2.1-2.2. In addition, ancillary information relevant for the proper understanding of the compounding section is contained in other rules from other sections of the grammar[20]. Therefore, a thorough treatment of Pāṇini's model of compounding, including the classification of compounds, should take into account the whole set of rules contained in A 2.1-2.2 over and above all

[19] The presentation of compounds given here abstracts away from many complications. See Bauer (2019) for an updated discussion.

[20] Reference editions of the *Aṣṭādhyāyī* include Böhtlingk (1887); Renou (1966); Katre (1987); Sharma (1987-2003).

related ancillary rules. Nonetheless, the gist of the codification of compounding in the *Aṣṭādhyāyī* can be captured by making reference to three fundamental rules: A 1.2.46; 2.1.4; 2.4.71. Thus, in what follows I shall confine my attention to these three rules, heavily following Mocci (2023: 283-287) and the references cited therein in my presentation of the material. I furthermore refer the interested reader to Radicchi (1985-1988), Cardona (1997: 205-229), Lowe (2015b), as well as several works by Candotti and Pontillo[21], for a detailed discussion of Pāṇini's model of compounding.

For one thing, Pāṇini teaches in A 1.2.46 that compounds, which he refers to as *samāsa* (lit. 'putting together', 'assembling'), are nominal stems: e.g., *aśva-śaphá-*. This successfully captures the fact that compounds typically behave just like run-of-the-mill nominal stems (e.g., *śaphá-*) with respect to accent and inflection (see Section 3.2)[22].

> A 1.2.46: *krṭtaddhitasamāsāś ca* [*prātipadikam* 1.2.45]
> 'Deverbal derivative nominals (*kṛt*), denominal derivative nominals (*taddhita*), and compounds (*samāsa*) also go under the rubric *nominal stem* (*prātipadika*)'.

On the other hand, in A 2.1.4 Pāṇini provides that compound-members, unlike the compound as a whole, are inflected words:

> A 2.1.4: *saha supā* [*sup* 2.1.2 *samāsaḥ* 2.1.3]
> 'A nominal inflected word (*sUP*) combines with another nominal inflected word in order to form a compound'.

Thus, the compound-members *áśvá-* and *śaphá-* which make up the compound *aśva-śaphá-* are to be considered as inflected nouns, i.e., as equivalent to *aśva-sya* and *śapha-ḥ*, respectively. In order to understand how this may be possible – i.e., how two inflected words can be contained in a stem, which is by definition a linguistic unit that is stripped of inflectional endings – we have to focus on A 2.4.71. In accordance with this rule, *aśva-śaphá-* (which qualifies as a nominal stem by A 1.2.46) is a combination of inflected words (i.e., *aśva-sya* and *śapha-ḥ*) whose case-endings (i.e., *-sya* and *-ḥ*) have been zero-replaced.

> A 2.4.71: *supo dhātuprātipadikayoḥ* [*luk* 2.4.58]
> 'A case ending that is part of a verbal or nominal stem (*dhātuprātipadikayoḥ*) is zero-replaced'.

Simplifying somewhat, the import of A 2.4.71 could be captured by assuming two levels of representation: a deep level and a surface level (Mocci 2023: 285-286). The deep level of representation contains all morphemes, including their allomorphs. At this level of representation, the compound shows up as *aśva-*Ø$^{\text{GEN}}$ *śapha-*Ø$^{\text{NOM}}$, inasmuch as the zeroed counterpart to the genitive morpheme -SYA (i.e., Ø$^{\text{GEN}}$) is a mere allomorph of -SYA in the *Aṣṭādhyāyī*, just as the zeroed counterpart to the nominative morpheme -Ḥ (i.e., Ø$^{\text{NOM}}$) is

[21] See at least Pontillo (2003b, 2005, 2018, 2021); Candotti and Pontillo (2017, 2019, 2022); Mocci and Pontillo (2019).

[22] In the quotation of *Aṣṭādhyāyī* rules, bracketed expressions such as "[*prātipadikam* 1.2.45]" indicate that the word *prātipadikam*, which occurs in A 1.2.45, has to be understood as recurring in A 1.2.46, too, by a mechanism technically designated as *anuvṛtti*. This mechanism is one of the devices deployed by Pāṇini to achieve maximum generalizations (see Section 3.1).

a mere allomorph of -Ḥ[23]. On the other hand, the surface level of representation only contains phonemes, so that a zeroed element is invisible at this level: the compound shows up as *aśva-śapha-* at this level of representation. The formation of *aśva-śapha-* can therefore be summarized along the lines of (14) (taken from Mocci 2023: 285), where *aśva-śapha-* is the surface representation of the compound and *aśva-Ø*^{GEN} *śapha-Ø*^{NOM} the corresponding deep representation.

(14) *aśva-sya śapha-ḥ* → *aśva-Ø*^{GEN} *śapha-Ø*^{NOM} = *aśva-śapha-*
horse-GEN hoof-NOM
'horse's hoof'.

The operation of zero-replacement graphically represented in (14) can be viewed as one of the devices deployed by Pāṇini to foster maximum generalization. To illustrate this point, let us briefly consider *aluk* compounds such as *ap-su-ṣád-* (lit. water-LOC-sitting) 'sitting amid the waters' (from *Ṛgveda* 3.3.5). Like ordinary compounds, *ap-su-ṣád-* bears one single accent; however, unlike in ordinary compounds, an overt case ending (*-su*) is affixed to the compound's left-hand member. These two facts are hard to reconcile: the single accent on *ap-su-ṣád-* should induce us to classify it as a compound, but the affixation of an overt case ending to *áp-* 'water' should induce us to classify *ap-su-ṣád-* as a combination of inflected words. On the other hand, these two facts naturally fall out from zero-replacement in the *Aṣṭādhyāyī*: *ap-su-ṣád-* is simply a compound in which the zero-replacement of the case ending affixed to *áp-* 'water' (*áp-su*) has been suspended (A 6.3.1: *alug uttarapade* '[a case ending] is not zero-replaced before a following constituent'); accordingly, *ap-su-ṣád-* is accented in keeping with the general rule for compound accentuation[24]. Since zero-replacement permits accounting for *ap-su-ṣád-* without further assumptions or rules, it simplifies grammar or, equivalently, maximizes the domain of application of the relevant *Aṣṭādhyāyī* rules[25].

3.4. Can Pāṇini be explicit?

In sum, the core of Pāṇini's codification of compounding relies on the combination of A 1.2.46 with 2.1.4 and 2.4.71. In keeping with this codification, compounding is an operation that takes as input inflected words and yields as output a form of a special sort: such a form is non-distinct from a nominal stem at the surface level of representation, but indeed, at the deep level of representation, it constitutes a combination of inflected words whose case endings have been zero-replaced. In this way, Pāṇini successfully identifies the set of Indo-Aryan compounds while simultaneously distinguishing them from other phenomena (e.g., deverbal and denominal derivatives).

[23] See in this connection Pontillo (2000, 2003a), where it was established for the first time that zero is systematically an allomorph of an overt morpheme in the *Aṣṭādhyāyī*.
[24] See Cardona (1997: 224); Candotti and Pontillo (2019: 31 n. 41) on A 6.3.1. The general rule for compound-accentuation is A 6.1.223 (*samāsasya* [*udāttaḥ* 6.1.156 *antaḥ* 6.1.220]), which provides that compounds bear one single accent, typically on the last syllable (Cardona 1997: 385).
[25] See Pontillo (2000, 2003a); Candotti and Pontillo (2013); Mocci and Pontillo (2023) for other morphological and syntactic patterns in which zero-replacement allows reaching maximum generalization. On the broader operation of substitution in the *Aṣṭādhyāyī*, including zero-substitution, I refer the interested reader to Candotti and Pontillo (2021). See instead Freschi and Pontillo (2013) on the historical links between grammatical substitution and substitution in Vedic ritual.

All in all, there is a sense in which Pāṇini's codification of compounding is explicit. This is not to say that the wording of the *Aṣṭādhyāyī* rules considered here is so clear and easy to understand that no one has doubts as to what they mean[26]: as a quick look at the wording of A 1.2.46, 2.1.4, and 2.4.71 (see Section 3.3) may have revealed, the correct application of any *Aṣṭādhyāyī* rule requires knowledge of several conventions, some of which are not stated in the grammar and must thus be inferred by the grammar user, thereby often making the interpretation of the *Aṣṭādhyāyī* a daunting task. Here I am using *explicit* in the technical sense championed by generative grammarians (see Section 2.6): in this sense, saying that Pāṇini's codification of compounding is explicit is tantamount to saying that he specifies the operations needed to yield all and only the compounds of old Indo-Aryan.

Indeed, I showed in the preceding subsection that compounding is reduced by Pāṇini to the interaction of a few, independently motivated grammatical operations, namely the combination of inflected words – needed to derive any sentence – and zero-replacement, which is instead needed to attain maximum generalization in the description of several morphological and syntactic patterns; the combination of these two simple operations takes care of all well-formed compounds of old Indo-Aryan, and successfully excludes most ill-formed ones (e.g., Pāṇini's model excludes the impossible formation of compounds having an inflected verb as compound-member)[27].

In some cases, Pāṇini has to resort to specific rules to block the formation of compounds that would otherwise be licensed by the general operations of combination and zero-replacement. For example, compounds in which one of the two members fulfills the function of partitive genitive (e.g., **manuṣya-śūratama-* 'the most heroic one among men') – which are perfectly derivable via the combination of *manuṣyāṇām* 'men.GEN' with *śūratamaḥ* 'most.heroic.NOM' and the subsequent zero-replacement of their case endings[28] – are indeed deemed as ill-formed by Pāṇini, who accordingly rules such a compound type out in A 2.2.10: *na nirdhāraṇe* [*samāsaḥ* 2.1.3] [*saha supā* 2.1.4] [*tatpuruṣaḥ* 2.1.22] [*ṣaṣṭhī* 2.2.8] (Cardona 1997: 216; Mocci and Pontillo 2019: 7 n. 16). Nonetheless, this recourse to specific rules does not hinder the qualification of Pāṇini's codification of compounding as explicit: Pāṇini attempted to codify the well-formedness and ill-formedness of all Indo-Aryan compounds via some explicitly specified means, which is enough for Pāṇini's codification to qualify as explicit; the fact that the explicitly specified means by which Pāṇini codifies compounding includes not only general operations such as the combination of inflected words and zero-replacement of case endings, but also some more specific rules such as 2.2.10, merely proves that the generality of some operations may be limited, possibly also due to grammar-external factors. Of course, limitations on generalizations characterize any empirical science, including linguistics[29].

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[26] Cf. the definition of *explicit* provided by the Oxford Advanced Learner's Dictionary <https://www.oxfordlearnersdictionaries.com/definition/english/explicit?q=explicit> (accessed 30/11/2024): «clear and easy to understand, so that you have no doubt what is meant».

[27] On the impossibility of using verbs as compound-members in old Indo-Aryan, see Lowe (2015a: 269-273).

[28] To be specific, the possibility for a compound's left-hand member to be a genitive-marked word whose case ending has been zero-replaced is ensured by A 2.2.8: *ṣaṣṭhī* [*samāsaḥ* 2.1.3 *saha supā* 2.1.4 *vā* 2.1.18 *tatpuruṣaḥ* 2.1.22].

[29] Cf. for example Rizzi's (1986) study of null objects in English and Italian, where some irreducible contrasts are dealt with by lexically governed rules, i.e., rules that constitute exceptions to general grammatical principles.

It may be hard to pinpoint the exact reason behind the explicitness of Pāṇini's codification of compounding. As hinted above (see Section 3.1), Kiparsky (2009: 32, 39, and *passim*) submitted that all ingenious devices deployed by Pāṇini, including substitution, silent elements, rule-ordering and multiple levels of representation, follow merely from Pāṇini's consistent pursuit of maximum generalization (equivalently: simplicity). It may be possible that the explicit character of Pāṇini's codification of compounding, too, is to be attributed to his search for maximum generalization, as if it were the only possible way to insightfully – i.e., scientifically – inquire into linguistic phenomena[30]. Here I shall not pursue this hypothesis further.

In the next section I attempt a comparison of the two instances of codification examined in this study: the codification of long-distance agreement in generative grammar and of compounding in Pāṇini's grammar.

4. A common scientific thread

The codification operated by generative grammarians and the one operated by Pāṇini differ under many respects. First and foremost, language acquisition plays a pivotal role in the generative framework: according to generative grammarians, linguistic phenomena must be codified in the grammar in a way that makes sense of the «fact that all normal children acquire essentially comparable grammars of great complexity with remarkable rapidity […]» (Chomsky 1959: 57). To achieve this goal, generative grammarians adopt a universalistic perspective (see also Moro 2017: 84):

> […] the general features of grammatical structure are common to all languages and reflect certain fundamental properties of the mind. […] There are, then, certain language universals that set limits to the variety of human language. [footnote omitted] The study of the universal conditions that prescribe the form of any human language is "grammaire générale." Such universal conditions are not learned; rather, they provide the organizing principles that make language learning possible, that must exist if data are to lead to knowledge. By attributing such principles to the mind, as an innate property, it becomes possible to account for the quite obvious fact that the speaker of a language knows a great deal that he has not learned. (Chomsky 2009 [1966]: 98)

In short, in the generative framework any codification of linguistic phenomena in any natural language must satisfy universal conditions (which come down to the requirement that codification be expressible in geometrical terms according to Moro 2016: 121).

On the other hand, the *Aṣṭādhyāyī* may be characterized as a variationist and distributional grammar, i.e., one that accounts for diatopic, diastratic, diaphasic, and diamesic variants of old Indo-Aryan and for the frequency of occurrence of those variants (Kiparsky 1979; Deshpande 2019; Candotti and Pontillo 2022: 2). Thus, for example, A 2.2.8 (*ṣaṣṭhī* [*samāsaḥ* 2.1.3] [*saha supā* 2.1.4] [*vā* 2.1.18] [*tatpuruṣaḥ* 2.1.22]) provides for compounds like *aśva-śapha-* to be preferable (*vā*) over combinations of inflected words like *áśvasya śapháḥ* (see Mocci 2023: 287 n. 11 and the references cited therein). The universalistic perspective and the focus on language acquisition which are typical of

[30] Interestingly, the search for maximum generalization was later considered as a sort of model for all other sciences in ancient India, just as mathematics is a model for all other sciences in the modern era: see in this connection Staal (1965); Lowe (2024: 4).

generative grammar are completely alien to the *Aṣṭādhyāyī*: overall, the goal of Pāṇini's codification is not the identification of the *limits* of variation of natural languages which make language acquisition possible; rather, his goal is both prescriptive and descriptive (Kiparsky 2012: 327; Lowe 2024: 19). It is descriptive inasmuch as the *Aṣṭādhyāyī* was meant as a faithful description of a certain variety of old Indo-Aryan; it was also simultaneously prescriptive in that it was part of an editorial project targeted on the regularization of the Vedic canon (see Bronkhorst 1991: 87; Kiparsky 2012: 328-329; Candotti and Pontillo 2022: 2). Despite such sharp differences in scope and goals between generative grammar and the *Aṣṭādhyāyī*, some common thread indeed exists connecting the two grammars.

Thus, both the codification of long-distance agreement operated by generative grammarians and the codification of compounding operated by Pāṇini resulted as being *explicit*, in the sense that they specify the means (filters in the case of generative grammarians; operations in the case of Pāṇini) that license all well-formed tokens of long-distance agreement and compounding while simultaneously excluding all ill-formed ones. What is interesting for our purposes is that both these instances of codification are held in high regard in the current scientific community.

Thus, Pāṇini's model of compounding has been shown to be at least as empirically adequate as – and in some respects even more empirically adequate than – modern-day approaches: see Candotti and Pontillo (2019, 2022); Mocci and Pontillo (2019); Mocci (2022); (2024a); cf. also Lowe (2015b), who provides new evidence in support of Pāṇini's analysis of compound-members as inflected words. Similarly, even though formalism has changed, the fundamental aspects of the codification of long-distance agreement, namely the interplay of hierarchy and locality, have been retained in modern-day formal linguistics (Chomsky 2000: 123-124; 2001: 16-17), and constitute the core of recent neurolinguistic experiments in both humans and animals (Moro 2015; 2016; 2017: 244 n. 9). All in all, I submit that a major part of the reason that the two instances of codification examined in this study are held in high regard in the contemporary scientific community is to be found in the explicit nature of these codifications. This contention seems to be echoed by the following quote from Chomsky: *explicitness* in the technical sense used throughout essentially boils down to *rigorous formulation*, which is the most reliable means to push linguistics as an empirical science forward.

> The search for rigorous formulation in linguistics has a much more serious motivation than mere concern for logical niceties or the desire to purify well-established methods of linguistic analysis. Precisely constructed models for linguistic structure can play an important role, both negative and positive, in the process of discovery itself. By pushing a precise but inadequate formulation to an unacceptable conclusion, we can often expose the exact source of this inadequacy and, consequently, gain a deeper understanding of the linguistic data. More positively, a formalized theory may automatically provide solutions for many problems other than those for which it was explicitly designed. Obscure and intuition-bound notions can neither lead to absurd conclusions nor provide new and correct ones, and hence they fail to be useful in two important respects. (Chomsky 2002 [1957]: 5)

5. Concluding remarks

In this study I have been concerned with codification in two highly influential grammatical systems: modern generative grammar and Pāṇini's ancient *Aṣṭādhyāyī*. To be specific, I have examined the codification of long-distance agreement in generative grammar and the codification of compounding in Pāṇini's grammar. I have adopted the following working definition of codification: the operation of reducing a linguistic phenomenon to the interaction of grammatical rules.

In the case of generative grammar, grammatical rules are to be identified with so-called filters, i.e., precisely specified instructions that filter out impossible combinations of words, thereby also delimiting the boundaries of possible combinations of words. The filters involved in the codification of long-distance agreement are hierarchy (which bans establishing a relationship between two units that are identified by making reference to linear order) and locality (which instead bans establishing a relationship between two units that are too far removed).

When it comes to the *Aṣṭādhyāyī*, grammatical rules are to be identified with aphorisms and, more interestingly, with the operations enjoined by those aphorisms. Thus, Pāṇini deploys two operations in the codification of compounding, which are enjoined by A 2.1.4 and 2.4.71, to be considered jointly with 1.2.46. The operations at stake are the combination of inflected words and zero-replacement – no more than this is needed for Pāṇini to deal with the vast majority of old Indo-Aryan compounds. These operations are supplemented with a few specific rules to block some undesired outcomes such as compound-members that fulfill the function of partitive genitive.

Although the two instances of codification differ in goals and theoretical premises, they are connected by a common thread: they are both explicit, in the sense that they specify (rigorously formulate) the filters and operations needed to yield all well-formed tokens of (English) long-distance agreement and old Indo-Aryan compounds and only these. I have contended that the explicitness of these instances of codification is a major part of the reason that they are held as successful in the contemporary scientific community.

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