Pāṇinian Lexical Functional Grammar

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Abstract

In this paper I present an implementation in LFG of *kāraka* theory, the model of argument structure developed by the ancient Indian linguist Pāṇini in his grammar of Sanskrit, the *Aṣṭādhyāyī*. This implementation contributes to the goal of modelling and analysing Pāṇinian grammar in modern theoretical terms; from the perspective of LFG, it contributes an exploration of the capacity of LFG as a model of grammar, and more specifically speaks to the question of grammatical functions as primitives of the theory.

1 Introduction

The Indo-Aryan culture of first millennium BC northern India was the scene of the development of a highly advanced tradition of linguistic analysis, which remained the most sophisticated tradition of linguistics – far eclipsing the Western tradition – at least until the early 20th century.[†] The most important figure in that tradition is Pāṇini (c. 500–300 BC), whose grammar of Sanskrit, the *Aṣṭādhyāyī*, has been described as "one of the greatest monuments of human intelligence… an indispensable model for the description of languages" (Bloomfield 1929: 268); Pāṇini's influence can be traced in the development of modern Western linguistics in the 19th and 20th centuries, from Franz Bopp through figures like Leonard Bloomfield to the work of Paul Kiparsky (see Lowe 2024).

Pāṇini's model of argument structure, referred to here as *kāraka* theory, is a particularly advanced and widely lauded part of his grammar; it is notably similar to Fillmore's (1968) theory of Case Grammar, perhaps the earliest modern Western model of argument structure, and it influenced the early development of Lexical-Mapping Theory through the work of Ostler (1979). The goal of this paper is to present an implementation in LFG of the core of Pāṇini's argument structure system. The implementation has been tested in XLE and shown to work for one-, two-, and three-place predicates.

An average reader of the LFG proceedings might at this point ask the question: why? What value is there in modelling an ancient – and while no doubt sophisticated for its time, nonetheless necessarily limited – theory of argument structure in LFG when LFG already has well-developed models of argument structure?

There are two perspectives to consider. From the side of Pāṇinian studies, there is evident value in formalizing aspects of Pāṇinian grammar in modern theoretical terms, in order for example to test its robustness and investigate its similarities to and compatibility (or otherwise) with modern linguistic theory. This goal aligns also with the growing body of work seeking to adapt Pāṇinian notions and insights into computational linguistic work applied to Sanskrit and modern South Asian languages (see e.g. Kulkarni & Sharma 2019 and Kulkarni et al. 2020, with references).

But what about the LFG perspective? The goal of this paper is certainly not to argue that Pāṇini's theory of argument structure is in any meaningful sense 'better' than

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existing LFG approaches, whether for modelling Sanskrit specifically, or for modelling argument structure cross-linguistically. Nor does this paper seek to propose a Pāṇinian approach to argument structure in LFG as replacement of or improvement on existing LFG theories of argument structure. But as argued in Lowe (2024: 215), it is crucial for linguistic theory to keep questioning itself, for individual theories to keep learning from each other and to stretch and test themselves. Thus simply the act of implementing a distinctly non-LFG theory of argument structure in LFG has value in telling us something about the capacity of LFG as a theory, and about the benefits (or otherwise) of existing LFG approaches. In this particular case, moreover, there is one particular point of theoretical interest for LFG in implementing a Pāṇinian model of argument structure: the question of grammatical functions.

2 Grammatical functions

One key difference between Pāṇini's *kāraka* theory and existing LFG approaches to argument structure is that the former makes no reference whatsoever to a set of relations equivalent to LFG's grammatical functions (GFs). LFG differs from most contemporary syntactic frameworks in treating an inventory of GFs as one of the sets of primitives of the theory. The precise membership of the GF inventory may be debated: most questionable is the status of the clausal function COMP (Dalrymple & Lødrup 2000, Alsina et al. 2005, and more recently Belyaev et al. 2017, Laczkó 2021, Szűcs 2018, 2024); somewhat differently, SUBJ may be best understood as a conflation of two separate GFs, $\widehat{\text{GF}}$ and PIVOT (Falk 2006). But the assumption of an inventory itself remains almost unquestioned.

The only exception to this uniform acceptance of GFs within LFG is the proposal, by Patejuk & Przepiórkowski (2016) and Przepiórkowski (2016), to replace the inventory of GFs with an ordered list of dependents (DEPS). Patejuk & Przepiórkowski argue that at most SUBJ, OBJ and perhaps OBL need to be distinguished (echoing Alsina 1996); clausal functions, the θ index used to distinguish varieties of OBJ and OBL, and the distinction between arguments and adjuncts (Przepiórkowski 2016), are all unnecessary. While Patejuk & Przepiórkowski (2016) present a formalization which retains SUBJ and OBJ alongside the DEPS list, the formalizations offered by Przepiórkowski (2016: 571–572) go further in eliminating GFs entirely from the f-structure. The only author to engage substantively with Patejuk & Przepiórkowski's proposal is Kaplan (2017), who finds their arguments not "yet" convincing, and argues in favour of retaining an inventory of GFs, while recognizing the value of questioning such basics of the theory.

The assumption, or otherwise, of an inventory of GFs will naturally play an important role in any model of argument structure. While theories of argument structure in LFG necessarily focus on the mapping between underlying argument relations and GFs, the argument structure model of Kiparsky (1987; 1988; 1997; 2001; also presented in detail by Butt 2006: 100–111) is more flexible, capable of modelling the mapping between underlying argument relations and e.g. case marking, without reference to GFs, working on the assumption that GFs are not linguistic primitives.

Pāṇini's *kāraka* theory makes no reference to GFs: the mapping is between underlying argument relations and surface case relations. In fact, Pāṇini's grammar as a whole

lacks any notion of GFs. The absence of the notion of 'subject' in the *Aṣṭādhyāyī* has been widely discussed (e.g. Cardona 1974: 244–245, Kiparsky 2009, Keidan 2017); Keidan (2017) argues that one of Pāṇini's core argument structure notions, the *kartṛ*, is on some level akin to the notion of subject, but Lowe (2024: 130–135) shows that Pāṇini's *kartṛ* is in fact more abstract, being more similar to $\hat{\theta}$ or (as assumed in the present paper) the arg_1 of Kibort's (e.g. 2007) mapping theory.[1] Kiparsky (2009) goes as far as to argue that Pāṇini's grammar deals with some aspects of Sanskrit syntax all the better for entirely lacking the notion of subject. This reflects the observation (e.g. Hock 1986, 1987, 1990, 1991) that the standard tests for subjecthood, when applied to Sanskrit, tend to pick out the highest underlying argument of a predicate (i.e. $\hat{\theta}$ or arg_1) rather than anything that could be equated with the notion of subject.

A Pāṇinian LFG, then, must reckon without GFs. In implementing a Pāṇinian argument structure in an LFG framework, I am not necessarily seeking to argue that Patejuk & Przepiórkowski (2016) were right to argue against an inventory of GFs as primitives of the theory. Rather I am exploring, in a particular respect, the consequences of such an assumption; I show that it is at least possible to model argument structure alternations in LFG without the traditional reliance on GFs. This further shows that LFG's argument structure has, or at least could have, the same sort of flexibility that Kiparsky claims for his own argument structure model. Whether this is the right way to approach argument structure is a different question – an interesting one certainly, but not one I seek to take a position on in this paper.

3 Pāṇini's system: *kārakas*

In this section I provide a brief introduction to Pāṇini's *kāraka* theory; for more detailed expositions, see e.g. Cardona (1974), Kiparsky (2009: 48–56), Lowe (2024: 108–117).

Pāṇini's grammar is fundamentally generative: one begins with a meaning to be expressed, or at least with a set of lexical stems representing the lexical meaning to be expressed, and the grammar then proceeds through syntactic relations, morphology, and phonology to a detailed phonetic output. The *kāraka* relations play a key role in this system, representing the primary syntactic relations between a predicate and its arguments, relations that drive much of the morphology.

The *kārakas* are underlying grammatical argument relations defined on the basis of semantic roles. They are sometimes equated with the modern notion of semantic roles; in particular, the two most important *kāraka* roles, the *kartṛ* and *karman*, are often translated as 'agent' and 'patient' respectively. But such equations, and translations, are incorrect; there is no one-to-one relation between *kārakas* and semantic roles. For example, an argument with the semantic role of 'instrument' might take the *kāraka* role of *karaṇa* or *kartṛ*, depending on the construction. The *kārakas*, then, are fundamentally grammatical relations.

Key to Pāṇini's system is the requirement that each *kāraka* role must be 'grammatically marked' (Sanskrit *abhihita*) exactly once. The active finite verb suffix grammatically marks what is in some sense the highest *kāraka* relation, the *kartṛ*: not 'agent', but

[1] It is also similar to the notion of 'logical subject' (Jespersen 1924), for which see Mohanan (1990: 49–51) and Manning & Sag (1998: 113ff.).

often in practice resolving to the agent. The mediopassive finite verb suffix marks either the role of *karman* (not 'patient/theme', but often resolving to the patient or theme) or is understood to mark the verbal event (a way of avoiding it marking any *kāraka*). Non-nominative case suffixes grammatically mark particular *kāraka* roles; the nominative does not mark any *kāraka* role, and hence is the case suffix used when the role in question is marked by the verbal suffix. Very simply, this is how Pāṇini models the active-passive alternation: in the active the verbal suffix marks the *kartṛ*, so the *kartṛ* argument appears in the nominative; in the passive, the verbal suffix marks the *karman*, which then appears in the nominative, while the *kartṛ* receives different (instrumental) case marking. For example, let us suppose we want to derive the following sentence:

(1) caitro dātreṇa yavaṃ lunāti
C.NOM scythe.INS.SG barley.ACC.SG harvest.PRES.3SG
'Caitra harvests the barley with a scythe.'

Given the meaning to be expressed, 'Caitra harvests the barley with a scythe', we begin our derivation with the four lexical stems representing 'Caitra', 'harvest', 'barley' and 'scythe'. Various semantic features are also at play here, including e.g. the temporal reference of the verb (present time) and, importantly for our purposes, the semantic roles of the verb's arguments. This is represented in (2), with equivalent Sanskrit terminology in (3).

(2) *caitra*$_{[\text{agent}]}$ *dātra*$_{[\text{instrument}]}$ *yava*$_{[\text{patient}]}$ *lū*$_{[\text{present}]}$

(3) *caitra*$_{[\text{svatantra}]}$ *dātra*$_{[\text{sādhakatama}]}$ *yava*$_{[\text{īpsitatama}]}$ *lū*$_{[\text{vartamāna}]}$

Kāraka role labels are assigned to arguments based on their semantic roles, by rules such as the following:

(4) a. Aṣṭ. 1.4.54: *svatantraḥ kartā* 'The independent actor is labelled *kartṛ*.'
b. Aṣṭ. 1.4.49: *kartur īpsitatamaṃ karma* 'The participant most desired by the *kartṛ* is labelled *karman*.'
c. Aṣṭ. 1.4.42: *sādhakatamaṃ karaṇam* 'That which is the most effective means is labelled *karaṇa*.'

There are six *kāraka* roles, and thirty-three rules governing their assignment, but only these three concern us here.[2] On the basis of these rules (and a further rule attaching the verbal suffix *laṭ* to mark the present tense), we reach the following step in the derivation:

(5) *caitra*$_{[\text{kartṛ}]}$ *dātra*$_{[\text{karaṇa}]}$ *yava*$_{[\text{karman}]}$ *lū-laṭ*

Since we want to derive the active voice sentence in (1), the following rule applies; this will serve to replace *-laṭ* with an active voice person/number suffix.

(6) Aṣṭ. 1.3.78: *śeṣāt kartari parasmaipadam* 'Parasmaipada (active) affixes occur after the remaining roots [i.e. roots not treated in preceding rules] to mark the *kartṛ* role.'

[2]The kāraka labels are assigned in rules Aṣṭ. 1.4.23–1.4.55. The three not treated here are: *apādāna*, primarily representing the semantic roles of point of departure and source of fear; *sampradāna*, primarily representing the goal (beneficiary or recipient); and *adhikaraṇa*, primarily representing location.

The relevant rules for case assignment are given in (7). The accusative suffix is added to grammatically mark the *karman* role (7b), and the instrumental suffix is added to grammatically mark the *kartṛ* or *karaṇa* (7c), when they are not otherwise grammatically marked (7a). The nominative suffix does not grammatically mark any *kāraka* relation (7d).

(7) a. Aṣṭ. 2.3.1: *anabhihite* 'When not otherwise grammatically marked:'
b. Aṣṭ. 2.3.2: *karmaṇi dvitīyā* 'The accusative marks *karman*.'
c. Aṣṭ. 2.3.18: *kartṛkaraṇayos tṛtīyā* 'The instrumental marks *kartṛ* and *karaṇa*.'
d. Aṣṭ. 2.3.46: *prātipadikārthaliṅgaparimāṇavacanamātre prathamā* 'The nominative is used when only the meaning, gender, and number of a nominal stem are to be marked.'

Each *kāraka* role associated with an argument in the clause must be grammatically marked exactly once by some element in the clause. In the sentence under consideration, the finite verb marks the *kartṛ*, here the most agentive argument, so that argument receives nominative case. The *karman* and *karaṇa* receive accusative and instrumental respectively, since these case endings grammatically mark those roles. All *kāraka* roles in the sentence are therefore marked.

(8) *caitra*$_{[\text{kartṛ}]}$-*s*U *dātra*$_{[\text{karaṇa}]}$-Ṭ*ā*$_{[\checkmark\text{karaṇa}]}$ *yava*$_{[\text{karman}]}$-*am*$_{[\checkmark\text{karman}]}$ *lū*-Ś*nā*-*ti*P$_{[\checkmark\text{kartṛ}]}$

If we eliminate the *kāraka* roles, and the code letters (Skt. *anubandhas*, given in small caps) from this representation, it now looks very close to the desired output:

(9) *caitra-s dātra-ā yava-m lū-nā-ti*

Rules dealing with allomorphy and sandhi will then produce the final (for our purposes) sentence form (cf. 1):

(10) *caitro dātreṇa yavaṃ lunāti*

But the same underlying sentence form can equally derive the passive. If we return to (5), instead of applying the rule in (6), which adds active verbal suffixes to grammatically mark the *kartṛ*, we could alternatively apply the following rule, which specifies mediopassive verbal suffixes to grammatically mark either the *karman* or the *bhāva* 'verbal event'.

(11) Aṣṭ. 1.3.13: *bhāvakarmaṇoḥ* '(Ātmanepada (mediopassive) affixes occur) to mark the verbal event or the *karman* role.'

The same case assignment rules (7) apply, but if the finite verb suffix marks the *karman*, then this argument will be assigned nominative case, and the *kartṛ*, since it is not marked by the finite verb suffix, will be assigned instrumental case:

(12) *caitra*$_{[\text{kartṛ}]}$-Ṭ*ā*$_{[\checkmark\text{kartṛ}]}$ *dātra*$_{[\text{karaṇa}]}$-Ṭ*ā*$_{[\checkmark\text{karaṇa}]}$ *yava*$_{[\text{karman}]}$-*s*U *lū*-*ya*K-*ta*$_{[\checkmark\text{karman}]}$

Simplifying to

(13) *caitra-ā dātra-ā yava-s lū-ya-ta*

And with appropriate allomorphy and sandhi, the passive sentence:

(14) caitreṇa dātreṇa yavo lūyate
C.INS scythe.INS barley.NOM harvest.PASS.3SG
'The barley is harvested by Caitra with a scythe.'

The option for the mediopassive finite verb suffix to mark the 'verbal event' is Pāṇini's mechanism to license the passives of intransitives. In Sanskrit the passive is highly productive, and almost any verb can form a passive. So beside the active sentence in (15), it is equally possible to form the sentence in (16), which is semantically equivalent.

(15) caitraḥ svapiti
C.NOM sleep.ACT.3SG
'Caitra sleeps.'

(16) caitreṇa supyate
C.INS sleep.PASS.3SG
'(Lit.) it is slept by Caitra.' (I.e. 'Caitra sleeps.')

In the active sentence, there is only one argument, and so only one *kāraka* role, the *kartṛ*, marked by the active finite verb ending. In the passive sentence, there is no *karman* for the mediopassive ending to mark, so it is understood to mark the *bhāva* 'verbal event'. The *kartṛ* is then assigned instrumental case, just as in the derivation above.

Pāṇini's *kāraka* theory is also able to derive sentences with more complicated argument structures, including two types of causative, and the passives of those causatives. I give examples here, but do not include these in the grammar fragment developed below.[3]

(17) maitraś caitreṇa yavaṃ lāvayati
M.NOM C.INS barley.ACC harvest.CS.3SG
'Maitra makes Caitra harvest the barley.'

(18) maitraś caitraṃ vyākaraṇaṃ bodhayati
M.NOM C.ACC grammar.ACC understand.CS.3SG
'Maitra makes Caitra understand (i.e. teaches C.) grammar.'

(19) maitreṇa caitreṇa yavo lāvyate
M.INS C.INS barley.NOM harvest.PASS.CS.3SG
'The barley was made by Maitra to be harvested by Caitra.'

(20) maitreṇa caitro vyākaraṇaṃ bodhyate
M.INS C.NOM grammar.ACC understand.PASS.CS.3SG
'Caitra was made to understand (i.e. was taught) grammar by Maitra.'

4 Three models of argument structure

In this section I first introduce the LFG argument structure model of Kibort (e.g. 2007), mentioned above, and the Kibort-Findlay Mapping Theory (KFMT), the fully formal-

[3] For more on causatives and passives of causatives in Sanskrit, see Lowe et al. (2019, 2024) with earlier references.

ized and architecturally integrated implementation of that model; the implementation of Pāṇinian LFG is partly modelled on this. Then, I briefly introduce Kiparsky's linking theory, also introduced above, and then compare and contrast these models with Pāṇini's *kāraka* theory, revealing the main challenges and potential benefits of modelling Pāṇini's *kāraka* theory within LFG.[4]

4.1 LFG

Linking rules were first formulated within LFG (as "Association Principles") by Zaenen & Maling (1983), building on earlier work including that of Ostler (1979). The first comprehensive theory of linking within LFG, *Lexical Mapping Theory* (LMT), was advanced by Bresnan & Kanerva (1989), and further developed by Bresnan & Zaenen (1990), Zaenen (1993), and Kibort (2001, 2004, 2007) among others. The model of Kibort (2007) was adopted by Dalrymple et al. (2019), and formalized within a connected s-structure model of LFG by Findlay (2016), a formalization known as the Kibort-Findlay Mapping Theory (KFMT)

Kibort (2007) proposes a universal "valency template" for all non-derived predicates:

(21)

⟨	arg_1	arg_2	arg_3	arg_4	…	arg_n ⟩
	[−O/−R]	[−R]	[+O]	[−O]		[−O]

Verbs select one or more argument slots together with default feature specification. Argument slots link to grammatical functions according to the hierarchy of grammatical functions:[5] arg_1 (if selected) links to the highest available grammatical function, then arg_2 (if selected) links to the highest remaining grammatical function, and so on.

What crucially distinguishes Kibort's model from earlier LFG mapping theories is the separation of semantic roles from the argument structure. Whereas in earlier work predicates are represented as selecting for agents, patients, etc., which then map via the ±O/R features to grammatical functions, Kibort explicitly keeps semantic roles separate from the grammatical system of argument structure, by positing the level of 'arg' relations between semantic roles and grammatical functions. So, predicates select for zero or more argument slots from the universal valency template; these slots are related on the one hand to semantic roles, and on the other hand (via the linking principles) to grammatical functions:

(22)

			(agent)	(patient)
	harvest	⟨	arg_1	arg_2 ⟩
intrinsic:			[−O]	[−R]
			SUBJ	OBJ

This intermediate level of arg_x relations can be directly compared with Pāṇini's *kāraka* roles. Both are the base roles in the grammatical argument structure system, associated with but distinct from the semantic roles/relations between a predicate and its arguments. In the Pāṇinian argument structure model developed below, the *kārakas* are

[4]For a more extensive comparison of these three approaches, see Lowe (2024: 108–128).

[5]Standardly SUBJ > OBJ , OBL_θ > OBJ_θ (Bresnan & Moshi 1990); but according to Her (2013): SUBJ > OBJ > OBL_θ > OBJ_θ.

treated as directly equivalent to the s-structure ARGx roles which are the KFMT implementation of Kibort's arg$_x$ relations.

4.2 Kiparsky's linking theory

The linking theory developed by Kiparsky (1987, 1988, 1997, 2001), which again builds on the proposals of Ostler (1979), explicitly avoids the notion of a set of distinct semantic roles, depending rather on the idea that the semantic arguments of a predicate are best understood in terms of a spectrum between Dowty's (1991) 'Proto-Roles' of Proto-Agent and Proto-Patient. In Kiparsky's theory, the arguments of a predicate are ordered according to such a spectrum, and based on this ordering two syntactic features are assigned: ±H(ighest)R(ole) and ±L(owest)R(ole). For example, given a preliminary version of the Sanskrit sentence 'Devadatta gives the cow to Yajñadatta', with case-marking yet to be determined, we would have the following assignment:

(23)

devadatta	yajñadatta	go	dadāti
D.	Y.	cow	gives
[+HR]	[ ]	[+LR]	

'Devadatta gives the cow to Yajñadatta.'

Devadatta, as the giver or 'agent', is the most Proto-Agentive argument, so receives the feature [+HR]. The cow, as the theme, is the most Proto-Patientive, so receives [+LR]. Yajñadatta as the beneficiary is intermediate between the two in terms of Proto-Agent and Proto-Patient properties, so receives no specification.

In contrast with the LFG model presented above, but in agreement with Pāṇini's *kāraka* theory, Kiparsky's model does not depend on grammatical functions like subject and object: it is possible to state relations directly between the underlying syntactic features [+HR] and [+LR] and case marking, if that is the most relevant surface marking of argument relations in the language in question. So, Kiparsky assumes default relations between case and HR/LR features such as:

(24)
a. nominative = [ ]
b. accusative = [−HR]
c. dative = [−HR, −LR]

Nominative is the least marked case, and is in principle compatible with any argument. Case assignment proceeds according to a principle of 'Specificity', a form of the Elsewhere / Pāṇini's Principle: more specific assignments override less specific assignments. So for (23), granted the defaults in (24), there is only one option for Devadatta, the nominative, and likewise for Yajñadatta, only the dative is possible.[6] The cow could be assigned either nominative or accusative, since both are compatible with its [+LR] specification; it is assigned accusative because this is the more specific assignment. We therefore obtain the correct case marking:

[6]Of course there are other cases, and the presentation is simplified here.

(25) devadatto yajñadattāya gām dadāti
D.NOM Y.DAT cow.ACC gives
[+HR] [ ] [+LR]
'Devadatta gives the cow to Yajñadatta.'

As we have already noted, subject and object play no role here. They could, but they need not: Kiparsky's model is intentionally underspecified in this respect, so that the generalizations in (24) could be reformulated e.g. in terms of structural position, or grammatical function, depending either on the theory assumed or on the most relevant properties of the language concerned.

4.3 Comparisons

The major difference between Pāṇini's, Kibort's and Kiparsky's models has already been discussed: While the LFG model necessarily treats the mapping between underlying argument relations and GFs, Pāṇini's model focuses on the mapping between underlying relations and case assignment, while Kiparsky's system has the flexibility to cover either mapping.

The three models also differ in their approach to the passive. Kibort (2007) assumes a demotional approach to the passive: the passive operation 'demotes' the highest argument of a predicate, so that it is not realized as the highest GF, but can only be realized as an oblique argument. Specifically, she proposes that the passive operation adds the feature [+R] to the arg_1:

(26)

		(agent)	(patient)
	harvest ⟨	arg_1	arg_2 ⟩
intrinsic:		[−O]	[−R]
passive		[+R]	
		OBL_θ	SUBJ

Kiparsky understands passivization rather in suppressional terms: the passive operation effectively removes the highest argument from the argument frame of the predicate, at least for linking purposes. Under a suppressional approach to the passive, the passive agent, if expressed, must be treated as an adjunct. In Kiparsky's model, in the passive the [+HR] argument is prevented from linking. Kiparsky then assumes a structural requirement for a [+HR] role, introduced when necessary by a process of 'agreement'. For example, for the sentence 'The cow is given by Devadatta':

(27)

	devadatta	*go*	*dīyate*
	[+HR]	[+LR]	
passive:	∅	|	
'agreement':		[+HR]	

With the original [+HR] argument prevented from linking, the remaining argument, though originally [+LR] must be reassigned to [+HR]. Thus the only possible case assignment in this passive sentence will see the cow surfacing as nominative:

(28) devadattena gaur dīyate
D.INS cow.NOM give.PASS
∅ [+HR]
'The cow is given by Devadatta.'

Suppressional approaches to the passive are also found in LFG, and could be adopted even within Kibort's model. For Pāṇini's approach to the passive, it is not clear that either of the terms 'demotional' or 'suppressional' are appropriate, but the demotional view of the passive is certainly closer to Pāṇini's: there is no suppression or elimination of the *kartṛ* argument in the passive.

In fact, in Pāṇini's approach to the passive, there is no change whatsoever to the underlying relations between a predicate and its arguments, relative to the active. This represents a more significant difference which sets Pāṇini's model apart from all (to my knowledge) modern approaches to the passive. So, in all modern models of argument structure, whether demotional or suppressional, the passive argument structure is in some way derived from that of the active. Or, more precisely, the base argument structure assumed for any predicate corresponds directly to what surfaces in the active voice, while some change – the elimination of an argument, or an augmented specification for one argument – is required for the passive. In argument structure terms, then, the active is always more basic, and the passive derived.

While, then, lexical non-derivational theories tend to refer to the passive 'alternation', rather than to a passive 'operation' or 'derivation', this is never a true alternation in the sense of an alternation of equals. In contrast, Pāṇini's approach to the passive does treat active and passive as true, equal, alternants of each other. The underlying argument relations remain exactly the same between active and passive; the difference between active and passive comes down solely to the free choice between active and mediopassive verb endings, and everything else follows automatically from this, with no additional processes required for the passive.

Cross-linguistically, it is not unreasonable to model argument structure in such a way that the active is derived more directly, while the passive involves additional mechanisms; this reflects, for example, the fact that the passive voice is more restricted than the active, both in terms of its occurrence and productivity across and within languages, and the fact that the passive is usually associated with more extensive morphological marking. Such arguments can in fact be applied to Sanskrit. However, for Pāṇini there were advantages to modelling the active-passive alternation with real equality: in particular, it gave him a simple way of dealing with the ergative.[7] Such considerations go beyond the scope of the present paper, but once again by implementing a Pāṇinian model of argument structure in LFG, we can at least explore the value of a treatment of the passive which is uniquely distinct from all modern approaches to the passive.

5 Pāṇinian LFG

In this section I present the toy grammar developed and implemented in XLE as a proof-of-concept, as it were, for a 'Pāṇinian' LFG. The aim is merely to demonstrate

[7] On the ergative in Sanskrit, see Lowe et al. (2024: 34–38).

the viability of the approach; its coverage and completeness remain to be expanded in future work.

5.1 The *kārakas*

In modelling Pāṇini's *kāraka* theory in LFG, I start from the identification, argued for above, that Pāṇini's *kārakas* correspond directly to the arg_x roles of Kibortian argument structure. For the purposes of the present implementation, I identify the three *kārakas* in question with three of Kibort's arg_x roles as shown in (29).[8]

(29) a. *kartṛ* = arg_1
b. *karman* = arg_2
c. *karaṇa* = arg_4

In KFMT (Findlay 2016), arg_x roles are features at s-structure: ARG1, ARG2, etc. For Pāṇinian LFG, then, the *kārakas* are modelled as s-structure features.

In standard KFMT, constraints are stated on the relation between the s-structure features ARG1, ARG2, etc., and corresponding f-structure features; for example, the value of ARG1 at s-structure can be projected from either the f-structure SUBJ or OBL_θ.[9] But as discussed above, Pāṇini's system makes no reference to grammatical functions: rather than modelling the mapping between underlying argument positions and GFs, it models the mapping between underlying argument positions and case.

For a more faithful implementation of Pāṇini's grammar within LFG, then, we must avoid grammatical functions. In the spirit of Patejuk & Przepiórkowski (2016), all arguments of a predicate are treated as members of a single set, DEPS, at f-structure. Patejuk & Przepiórkowski (2016) propose that DEPS takes as its value an ordered set, but for the present purposes it is sufficient to treat the Pāṇinian DEPS as taking a standard unordered set as its value.

5.2 C-structure

Sanskrit is a discourse-configurational language with considerable freedom for discontinuous constituents. The default, or at least most common, word order is SOV, and the left periphery is associated with topicalization. The evidence suggests a relatively flat phrasal structure for Sanskrit, with the exocentric clausal cateogry S playing a significant role. Lowe (2015a: 37–46) discusses the evidence for phrasal categories and other hierarchical relations in Sanskrit phrase structure, and concludes that while there is evidence for phrases (XPs), including VP, there is no clear evidence for intermediate (X') categories or for a hierarchical left periphery.

In any case, for the present implementation the c-structure is relatively unimportant, and for simplicity I follow Lowe (2015a) in modelling Sanskrit c-structure as entirely flat.[10] I therefore assume the following simple phrase structure rules:

[8] Kibort's arg_3 is not relevant for our purposes and may not be required for Sanskrit.

[9] This corresponds to the inherent [−O] feature of Kibort's arg_1; cf. Findlay (2016: 318, ex. 50a).

[10] As in Lowe (2015a), I accept the existence of VPs in Sanskrit containing the verb and optionally one or more arguments, but for the purposes of this toy grammar I treat all arguments as VP-external, to avoid proliferating multiple parses.

(30) a. $S \rightarrow \underset{@ARG}{NP^*}\ VP$

b. $VP \rightarrow \underset{\uparrow=\downarrow}{V^0}$

c. $NP \rightarrow \underset{\uparrow=\downarrow}{N^0}$

d. $V^0 \rightarrow \underset{\uparrow=\downarrow}{\widehat{V}}\ \underset{\uparrow=\downarrow}{\widehat{Vsuff}}$

e. $N^0 \rightarrow \underset{\uparrow=\downarrow}{\widehat{N}}\ \underset{\uparrow=\downarrow}{\widehat{Nsuff}}$

Since the contribution of suffixes is crucially distinguished from that of their stems in the Pāṇinian system, I include what are to be understood as sub-lexical nodes, $\widehat{V}$, $\widehat{N}$, $\widehat{Vsuff}$ and $\widehat{Nsuff}$ as non-projecting categories.[11]

The template ARG, called by NP arguments in (30a), is defined in (31). It specifies the corresponding f-structure as a member of the clause's DEPS set; it further specifies the corresponding s-structure as the value of a KĀRAKA feature in the clausal s-structure. The metavariable KĀRAKA is a disjunction over possible s-structure roles (32): KARTṚ, KARMAN, KARAṆA, etc.[12] Thus, every argument of a clausal predicate will appear in the DEPS set at f-structure, and will appear as the value of some KĀRAKA feature at s-structure.

(31) $\text{ARG} \equiv \quad \downarrow \in (\uparrow \text{DEPS})$
$(\uparrow_\sigma \text{KĀRAKA}) = \downarrow_\sigma$

(32) $\text{KĀRAKA} \equiv \{\ \text{KARTṚ} \mid \text{KARMAN} \mid \text{KARAṆA} \ldots\ \}$

5.3 Lexicon

Verbal stems contribute merely their PRED value and a corresponding feature for the s-structure. The s-structure feature BHĀVA roughly corresponds to the EV or EVENT feature in standard s-structures. Note that there is no subcategorization in the PRED value, since there are no distinct GFs in the f-structure; as shown by Asudeh & Giorgolo (2012), subcategorization can be constrained in the s-structure.

(33) a. *lū* $\widehat{V}$
$(\uparrow \text{PRED}) =$ 'harvest'
$(\uparrow_\sigma \text{BHĀVA SEM}) = \text{HARVEST}$

b. *svap* $\widehat{V}$
$(\uparrow \text{PRED}) =$ 'sleep'
$(\uparrow_\sigma \text{BHĀVA SEM}) = \text{SLEEP}$

Likewise nominal stems contribute nothing significant beyond their PRED value and corresponding s-structure feature:

[11] Cf. the similar but distinct use of non-projecting categories for stem forms of nouns in Sanskrit compounds by Lowe (2015b). Note further that the use of non-projecting categories would be a somewhat more LFG-faithful way of representing sublexical nodes in L_RFG.

[12] This is equivalent, in standard KFMT, to a metavariable over s-structure ARGx roles, e.g. $\text{ARGX} \equiv \{$ ARG1 | ARG2 | ARG3 ... $\}$.

(34) *caitra* = $\widehat{\text{N}}$
$(\uparrow \text{PRED}) = \text{‘Caitra’}$
$(\uparrow_\sigma \text{SEM}) = \text{CAITRA}$

In Pāṇini's system, the contributions of nominal and verbal suffixes are crucial. I define the lexical entry in (35) for the 3sg. active finite verb suffix. The second f-description in the lexical entry specifies the feature-value pair MRK VSUFF as appearing within the KARTṚ s-structure. This models the Pāṇinian constraint that the active finite verb suffix grammatically marks the *kartṛ* role. The next three lines in (35) state constraints on an f-structure labelled %KR: the s-structure projected from %KR is identified with the value of the KARTṚ feature in the clausal s-structure; and appropriate person/number features are specified. The somewhat roundabout use of a local name is required by the fact that all arguments appear in the unordered DEPS set at f-structure. The following two lines provide alternative definitions of %KR. The first of these applies if there is an explicit *kartṛ* in the clause: %KR is defined as some member of the DEPS set. But since constraints involving local names cannot themselves construct an f-structure for the name to apply to, we require a different formulation when there is no explicit *kartṛ*, that is in the context of ‘pro-drop’. For that case, I make use of $\downarrow$ inside the lexical entry to effectively construct an f-structure inside the DEPS set which can serve for the pro-dropped *kartṛ*.

(35) *-ti* $\widehat{\text{Vsuff}}$
$(\uparrow \text{VOICE}) = \text{ACTIVE}$
$(\uparrow_\sigma \text{KARTṚ MRK}) = \text{VSUFF}$
$\%\text{KR}_\sigma = (\uparrow_\sigma \text{KARTṚ})$
$(\%\text{KR NUM}) = \text{SG}$
$(\%\text{KR PERS}) = 3$
$\{ (\uparrow \text{DEPS} \in) = \%\text{KR} \quad |$
$\%\text{KR} = \downarrow$
$\downarrow \in (\uparrow \text{DEPS})$
$(\%\text{KR}_\sigma \text{SEM}) = \text{PRO}$
$(\%\text{KR PRED} = \text{‘pro’}) \}$

The passive use of the 3sg. mediopassive finite verb suffix (36) is mostly equivalent, with the change of KARMAN for KARTṚ, modelling the Pāṇinian constraint that the mediopassive finite verb suffix grammatically marks the *karman* role.[13] With the passive there is an additional possibility, however: in the absence of a *karman* (i.e. with an intransitive verb, or with a transitive verb used intransitively), the mediopassive suffix may grammatically mark the BHĀVA; as noted above, this is Pāṇini's method for licensing the impersonal passive. This possibility is defined in the final two lines of (36).

[13]For simplicity I ignore the middle voice uses of the mediopassive; they would simply require additional disjunctions in (36).

(36) *-ta* $\widehat{\text{Vsuff}}$

$(\uparrow \text{VOICE}) = \text{PASSIVE}$
$\{ (\uparrow_\sigma \text{KARMAN MRK}) = \text{VSUFF}$
$\%\text{KR}_\sigma = (\uparrow_\sigma \text{KARMAN})$
$(\%\text{KR NUM}) = \text{SG}$
$(\%\text{KR PERS}) = 3$
$\{ (\uparrow \text{DEPS} \in) = \%\text{KR} \mid$
$\%\text{KR} = \downarrow$
$\downarrow \in (\uparrow \text{DEPS})$
$(\%\text{KR}_\sigma \text{ SEM}) = \text{PRO}$
$(\%\text{KR PRED} = \text{‘pro’}) \} \mid$
$(\uparrow_\sigma \text{BHĀVA MRK}) = \text{VSUFF}$
$\neg(\uparrow_\sigma \text{KARMAN}) \}$

On the other side of the coin are the case suffixes. Recall that in Pāṇini's system the nominative case ending does not grammatically mark any *kāraka*, while the other cases do. Therefore, the argument suffixed with the nominative case must be the argument whose *kāraka* role is grammatically marked by the verbal suffix. This constraint is formulated in the fourth line of (37a). The other cases are, of course, not compatible with an argument which is grammatically marked by the verbal suffix; this is ensured by the distinct value NSUFF for the feature MRK specified in (37b–c). The final lines of (37b–c) specify the KĀRAKA roles that the suffixed nouns must or may correspond to at s-structure. Note that in this system the case suffixes are constructive (Nordlinger 1998, 2000), but at the level of s-structure rather than f-structure.

(37) a. *-s*U $\widehat{\text{Nsuff}}$

$(\uparrow \text{CASE}) = \text{NOM}$
$(\uparrow \text{NUM}) = \text{SG}$
$(\uparrow_\sigma \text{MRK}) =_c \text{VSUFF}$

b. *-am* $\widehat{\text{Nsuff}}$

$(\uparrow \text{CASE}) = \text{ACC}$
$(\uparrow \text{NUM}) = \text{SG}$
$(\uparrow_\sigma \text{MRK}) = \text{NSUFF}$
$(\text{KARMAN} \uparrow_\sigma)$

c. *-ṭā* $\widehat{\text{Nsuff}}$

$(\uparrow \text{CASE}) = \text{INS}$
$(\uparrow \text{NUM}) = \text{SG}$
$(\uparrow_\sigma \text{MRK}) = \text{NSUFF}$
$\{(\text{KARTṚ} \uparrow_\sigma) \mid (\text{KARAṆA} \uparrow_\sigma) \}$

6 Examples

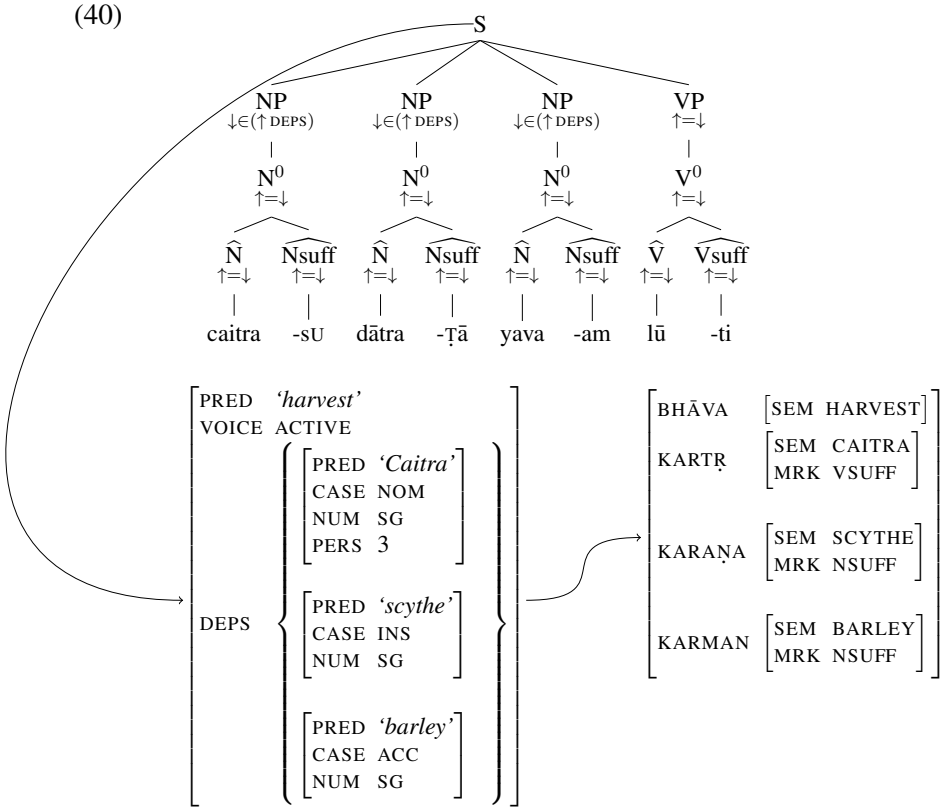
In (40) I give the c-structure, f-structure and s-structure for the sentence in (38)=(1). For the corresponding passive sentence in (39)=(14), the c-structure, f-structure and s-structure are given in (41). Note that due to the need to distinguish the contributions of suffixes from stems (and since I have not implemented a morphological parser), the

grammar effectively models an underlying version of the sentence (so 38 is closer to 8 than to 1).

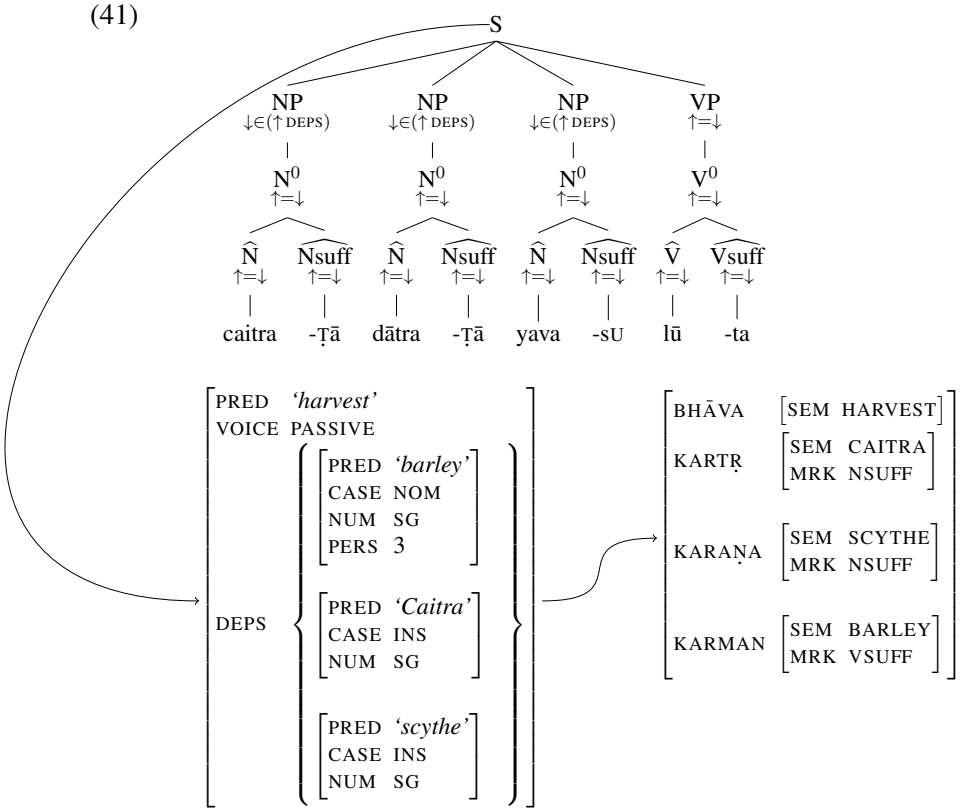
(38) caitro dātreṇa yavaṃ lunāti
C.NOM scythe.INS.SG barley.ACC.SG harvest.PRES.3SG
'Caitra harvests the barley with a scythe.'

(39) caitreṇa dātreṇa yavo lūyate
C.INS scythe.INS.SG barley.NOM.SG harvest.PASS.PRES.3SG
'The barley is harvested by Caitra with a scythe.'

(40)



(41)



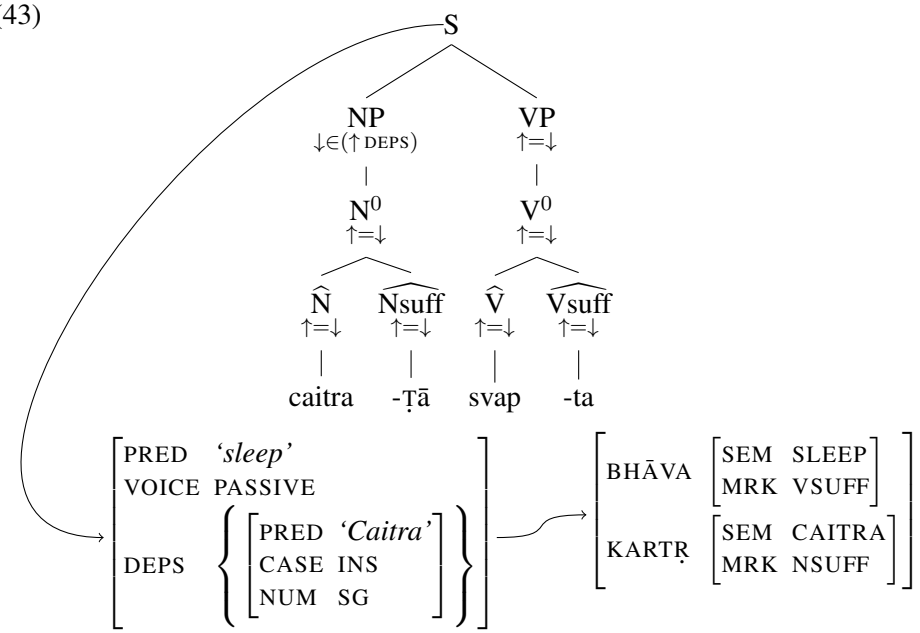
In (40), the three arguments of the verb all appear in the DEPS set in the f-structure, but their *kāraka* roles are distinguished in the s-structure; since the active finite verb ending grammatically marks the *kartṛ* role, the *kartṛ* argument (Caitra) necessarily takes nominative case and has the feature-value pair MRK VSUFF in the s-structure.

In (41) the only difference is that the finite verbal suffix is mediopassive; used as a passive here, it grammatically marks the *karman*, resulting in the MRK VSUFF feature in the corresponding s-structure. The *karman*, the barley, therefore receives nominative case, while the *kartṛ* and *karaṇa* both receive instrumental case, which supplies the MRK NSUFF feature in the corresponding s-structures.

For the passive of an intransitive verb, as in (42)=(16), the c-, f-, and s-structure are illustrated in (43).

(42) caitreṇa supyate
C.INS sleep.PASS.3SG
'(Lit.) it is slept by Caitra.' (I.e. 'Caitra sleeps.')

(43)



As there is no *karman*, the mediopassive finite verb suffix grammatically marks the *bhāva*, the verbal event; the sole argument, the *kartṛ*, is grammatically marked by the instrumental case suffix.

7 A PCASE-style alternative

An anonymous reviewer of the abstract suggested an apparently simpler alternative to the model developed above, involving a formulation similar to that used for PCASE in Kaplan & Bresnan (1982). Rather than the constraints in (31), the annotation on NP arguments would be:

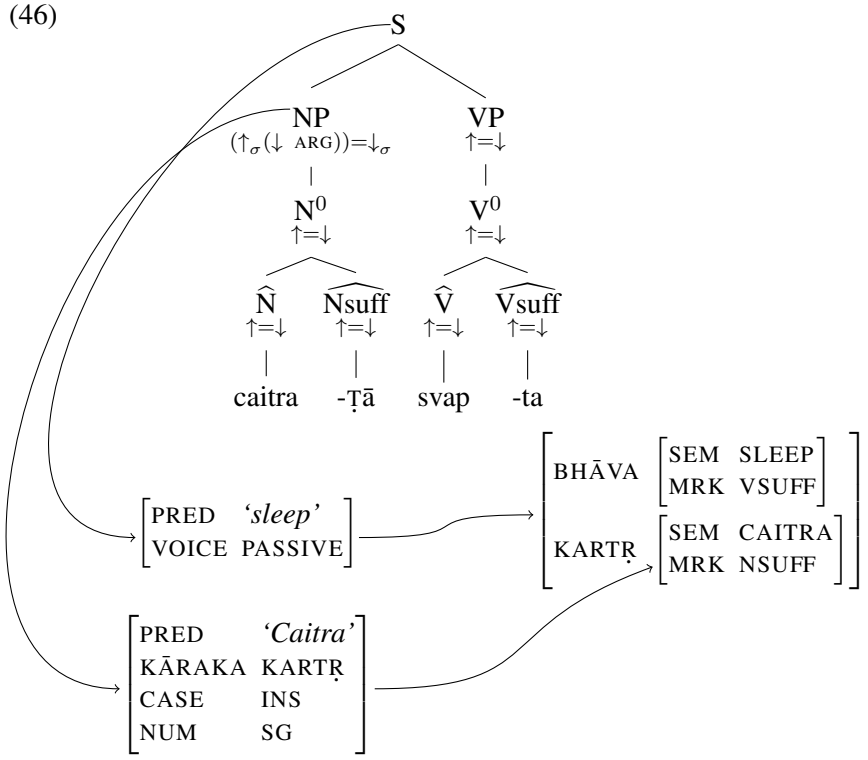
(44) $(\uparrow_\sigma(\downarrow \text{KĀRAKA})) = \downarrow_\sigma$

The value of $(\downarrow \text{KĀRAKA})$ would need to be specified for the f-structure of each argument. For example, instead of the constructive case style constraints in the last line of (37), the nominal suffix -ṭ*ā* would instead have the following constraint:

(45) $\{\ (\uparrow \text{KĀRAKA}) = \text{KARTṚ} \mid (\uparrow \text{KĀRAKA}) = \text{KARAṆA}\ \}$

The effect of this would be to construct the same s-structure relations as in the model above using an f-structure feature KĀRAKA whose value is the name of the corresponding s-structure feature for that f-structure. The major difference is that this approach would produce disconnected f-structures: the f-structures of the verb's arguments are not embedded within the f-structure projected by the verb. This would eliminate the need for the DEPS set in the f-structure of the verb, an alternative and perhaps purer way to represent the absence of grammatical functions. So, instead of (43), this approach would produce the following:

(46)



However, there is a implementational difficulty with this approach. It is necessary for the verbal suffix to state constraints on the f-structure of its *kartṛ*, as in (35) and (36). We could in theory do this by defining %KR via the inverse projection from s-structure, for example (for the active verb suffix):

(47) $\%\text{KR} \in (\uparrow_\sigma \text{ KARTṚ})_{\sigma^{-1}}$

But this can only work if the f-structure for the *kartṛ* contains the feature-value pair KĀRAKA KARTṚ, since otherwise that f-structure cannot project (via 44) to the relevant s-structure. And it does not appear to be possible to specify that on the verb suffix; at least, it cannot be implemented in XLE.[14]

In cases of pro-drop, the problem can be overcome by using ↓ in the lexical entry to create an f-structure for the *kartṛ* without going via s-structure. However, when there is an explicit *kartṛ* argument, ↓ in the lexical entry does not help, because there is no way to unify the f-structure projected by the *kartṛ* and the f-structure ↓ (since the function σ is not injective, both might in theory independently project to $(\uparrow_\sigma \text{ KARTṚ})$).

The problem arises due to the absence of a *kāraka* specification in the lexical entry for the nominative suffix (cf. 37a), and can be resolved by adding such a specification, since then the f-structure for the *kartṛ* is directly defined as projecting to $(\uparrow_\sigma \text{ KARTṚ})$. However, this goes directly against Pāṇini's approach, where the nominative is explicitly not associated with any *kāraka*. Such an approach would therefore be distinctly less Pāṇinian than the approach developed in §5, despite the apparent advantage of avoiding

[14]Specifically, the constraint $\%\text{KR}_\sigma = (\uparrow_\sigma \text{ KARTṚ})$, theoretically equivalent to (47), does not license the identification of %KR with an f-structure that could project to $(\uparrow_\sigma \text{ KARTṚ})$ if the identification were accepted.

the need for DEPS.

8 Conclusion

In this paper I have presented an implementation of the core, at least, of Pāṇini's *kāraka* theory in LFG. I hope to have shown that this 'Pāṇinian LFG' quite faithfully represents the key aspects of Pāṇini's system, despite the fundamental differences between the two theories. Perhaps the most significant difference is the lack of anything corresponding to GFs in Pāṇini's system. In implementing a Pāṇinian LFG, I have demonstrated that it is possible to model argument structure in LFG without reference to GFs. As discussed in §§1–2, my goal here has not been to argue that such an approach to argument structure is necessarily better than existing LFG approaches, nor necessarily to advocate the reduction or elimination of GFs from LFG as proposed by Patejuk & Przepiórkowski (2016). But I hope to have shown, at least, that if one were to accept the arguments of Patejuk & Przepiórkowski (2016), it would still be perfectly possible to model argument structure alternations. This also gives LFG the sort of flexibility in modelling argument structure that we observed above in Kiparsky's mapping theory. While it is undeniably the case that GFs play a key role in the argument structure alternations of some languages, e.g. English, it may be that in some languages, perhaps including Sanskrit, GFs are not implicated in argument structure, which concerns rather the mapping between underlying arguments and e.g. case marking. It is to the advantage of LFG that it has the flexibility to deal with such cross-linguistic variation.

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