Chapter 20

Meaning in LFG

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20.1 Introduction

This chapter presents a new view of semantics in Lexical Functional Grammar (LFG: Kaplan and Bresnan 1982; Bresnan et al. 2016; Dalrymple et al. 2019).[1] Or, rather, it argues that an old view, that first espoused by Dalrymple et al. (1993b), had the right idea, and that such a view can be suitably developed so as to properly integrate meaning into the LFG architecture. This gives semantic structure a proper role in the projection architecture, and opens up new analytical possibilities. I begin in Section 20.2 with an overview of what I take to be the overarching LFG philosophy, and present the projection architecture. In Section 20.3, we turn to the question of how meaning is represented in LFG, and in particular the role of semantic structure. In Section 20.4, I give my formal proposals, which involve adding a new attribute MNG to semantic structure to encode meanings, and dividing the expressions in a functional description into two types: constraints and constructors. Section 20.5 discusses two applications of the new approach, in terms of the analysis of idioms and the theory of information structure. Finally, Section 20.6 concludes.

20.2 Background

20.2.1 Constraint-based grammar

The task of the human language faculty is, at least, to establish a (bidirectional) mapping between form and meaning. When human beings are exposed to language, it is through a signal – acoustic, visual, or tactile – that must then be *interpreted* in order to arrive at the meaning which it expresses. And similarly in the opposite direction: in order to express a thought through language, human beings must encode it in an externalisable form, such as speech, sign, or writing. What is more, this mapping does not seem to be direct: there is ample evidence for the psychological reality of intermediate levels of structure, corresponding to constituency, functional information, etc. (Fodor et al. 1974; Bock and Levelt 1994).

Linguistic theories differ in what portion of the mapping from form to meaning they focus on. The linguist's version of the physicist's 'theory of everything' would give a unified account of the mapping all the way from the raw sensory input to the neurological processes underlying whatever mental representations are taken to be the output of linguistic parsing (at least 'meaning', writ large), and *vice versa*. In practice, of course, theories are (sensibly) much more selective in their domains of application. Theories of syntax and semantics, of the sort exemplified in this chapter, for example, will take the *string* as the input to comprehension, assuming a large amount of phonological processing to have already taken place. And on the output side, such theories abstract away from specific neurological implementations, and instead represent the result of linguistic processing as some (perhaps singleton) set of mathematical objects standing in for, or in some sense expressing the contents of, the mental representations.

[1] Mary Dalrymple has been one of the constants in my academic life – over the years, she has been a teacher, supervisor, mentor, and colleague – and it's safe to say that no-one has had a bigger impact on my development as a scholar. It is therefore a great pleasure to be able to contribute to this Festschrift in her honour, in part as a thank you for all that I have gained from our relationship, and especially for her boundless generosity with her time. Her ideas and influence can be clearly felt in this chapter, although I am sure she will not agree with all I have to say (and of course any errors are mine alone). I would also like to thank Ash Asudeh and an anonymous reviewer, whose comments have greatly improved the present work, although once again they bear no blame for any remaining issues.

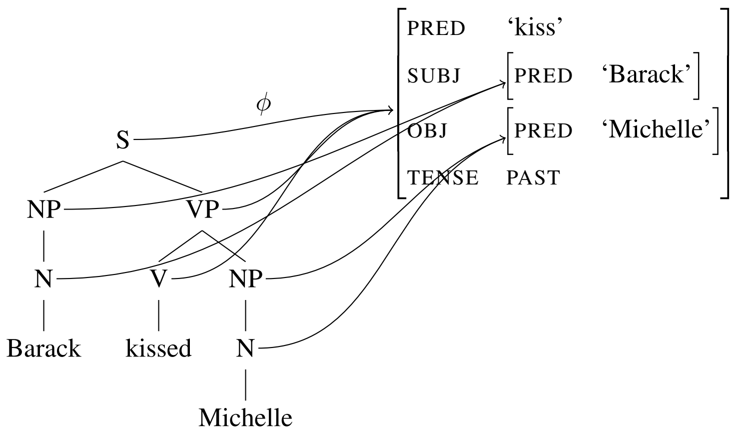

Figure 20.1: C- and f-structures for *Barack kissed Michelle*

There are at least two ways of viewing the mapping from the string to these formal representations: as *derivational*, or as *constraint-based* (Kaplan 1989a, 1995: 11). On the derivational view, popular within what Culicover and Jackendoff (2005) call 'Mainstream Generative Grammar', i.e. work in the tradition of Noam Chomsky (e.g. Chomsky 1957, 1965, 1981, 1995, i.a.), linguistic analysis consists in performing a number of transformations on the input until we arrive at a target output. On the constraint-based view, we obtain from the string a *description* in some formal language, and comprehension consists in finding the minimal objects licensed by the theory which satisfy all the *constraints* which make up this description. Production simply works in reverse, finding a string which encodes a description which picks out the objects we wish to 'express'.[2] There are a number of attractive properties of the constraint-based approach (on which see e.g. Pollard and Sag 1994: Introduction; Pullum and Scholz 2001; Pullum 2013), including its greater ability to handle the phenomenon of gradient grammaticality and the incrementality of linguistic processing. This has led to its proving popular with theories dedicated to both the computational tractability and psychological plausibility of linguistic theory, e.g. Head-driven Phrase Structure Grammar (HPSG: Pollard and Sag 1994) or LFG.

In LFG, lexical entries include a set of expressions which describe their contribution to, and the constraints they impose on, the various levels of linguistic structure. When we analyse a sentence, we gather up all of the expressions associated with the words it contains, along with any which are contributed by the phrasal configuration itself, into what is called a *functional description*, or f-description. In order to obtain an analysis for the sentence, we find the minimal structures which satisfy the f-description. But which structures should we be describing?

20.2.2 The projection architecture

From the beginning, LFG has recognised two distinct levels of syntactic analysis: c-structure and f-structure (Kaplan and Bresnan 1982). The former represents constituency, category information, and the linear order of words in a traditional phrase structure tree. The latter represents more abstract syntactic information such as grammatical functions, tense, aspect, mood, various kinds of dependencies, etc. in an attribute-value matrix, or AVM. The two levels of analysis are connected by a *projection function*, called ϕ, which maps c-structure nodes to f-structures. As an example, Figure 20.1 shows (simplified) c- and f-structures for the sentence *Barack kissed Michelle*. Lexical entries and phrase structure rules are annotated with descriptions of the ϕ mapping, using the symbols $\downarrow$ to refer to the f-structure projected from the node which bears the annotation, and $\uparrow$ to refer to the f-structure projected from that node's c-structure mother.[3] For example, we can annotate the initial c-structure rule for English as in (1), to show that the leftmost NP is the subject at f-structure:

(1) $$\mathrm{S} \quad \rightarrow \quad \underset{(\uparrow \textsc{subj}) = \downarrow}{\mathrm{NP}} \qquad \underset{\uparrow = \downarrow}{\mathrm{VP}}$$

The constraint on the NP says that its f-structure, '$\downarrow$', is the value of the clausal f-structure's SUBJ attribute, '($\uparrow$ SUBJ)'. The constraint on the VP says that its f-structure, '$\downarrow$', is the same as the clausal f-structure corre-

[2]Many other monikers have appeared in the literature for the derivational and constraint-based approaches. Kaplan (1995: 11) calls the former the *constructive* or *procedural* approach, and the latter the *descriptive*, *declarative*, or *model-based* approach. Pullum and Scholz (2001) call them *generative-enumerative* and *model-theoretic*, respectively.

[3]That is, we define $\downarrow$ as $\phi(*)$ and $\uparrow$ as $\phi(\mathcal{M}(*))$, where $*$ is the node which bears the annotation, and $\mathcal{M}$ is the c-structure mother function.

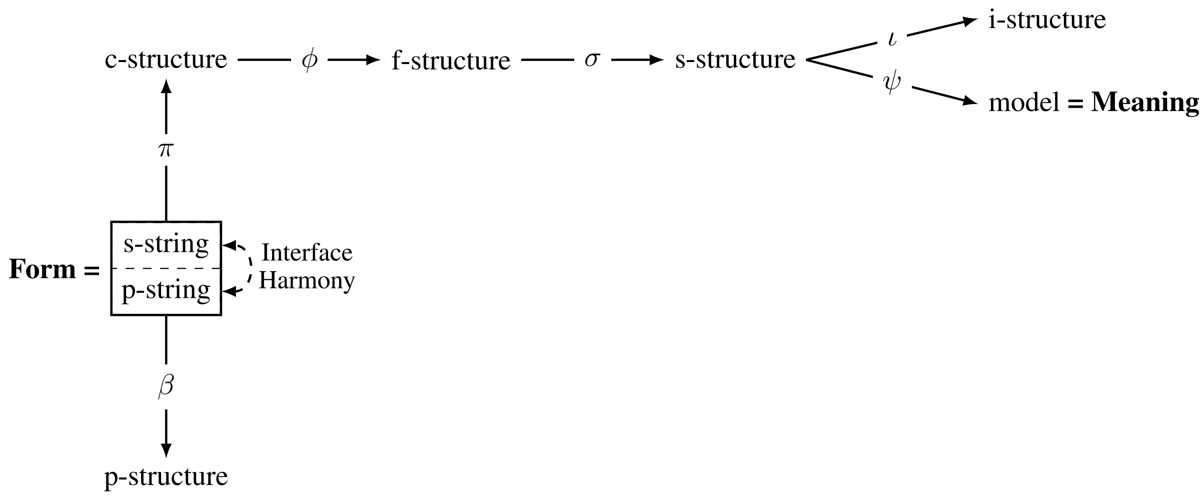

Figure 20.2: The projection architecture. On the division of the string into the s-string and p-string, and on p-structure, see Dalrymple and Mycock (2011) and Mycock and Lowe (2013). The path from f-structure to the model will be discussed in detail in this chapter. On i-structure, see Dalrymple and Nikolaeva (2011). I have chosen to omit m-structure, since there is no clear consensus on the place of morphology in the LFG architecture: Butt et al. (1996) suggest that m-structure should be projected from c-structure, Frank and Zaenen (2000, 2004) instead argue it should be projected from f-structure, and Dalrymple et al. (2019) do without this level of representation altogether, instead building on the quite different view of the morphology-syntax interface proposed by Dalrymple (2015a)

sponding to the S, '$\uparrow$'.

The lexical entry for *kissed* will include the following two constraints:

(2) kissed V $(\uparrow \textsc{pred}) = \text{`kiss'}$
$(\uparrow \textsc{tense}) = \textsc{past}$

These say that the f-structure corresponding to the pre-terminal node which dominates *kissed* has at least the attributes PRED and TENSE, with the values 'kiss' and PAST respectively.[4]

Later LFG work has expanded the number of different levels of representation – the different 'structures' – that are assumed, going beyond the two levels of syntax to accommodate prosody, semantics, and more. Figure 20.2 gives a contemporary view of the so-called *projection architecture*, showing the different levels of structure and the projection functions which map between them. All of these different structures are taken to have "their own primitives and organizing principles, and therefore their own internal structure and formal representation" (Dalrymple et al. 2019: 265) – that is, LFG takes a highly modular view of the grammar. Each structure represents a different plane of linguistic analysis; such structures are independent but mutually constraining. And although each of these levels may be linguistically relevant and allow important generalisations to be expressed, if all we are interested in is the mapping from form to meaning, they are formally dispensable (Kaplan 1987; Asudeh 2006). We can define a single, new function taking us directly from the (s-)string to the meaning, which is just the composition of the relevant projection functions – in the present architecture, this would be $\psi \circ \sigma \circ \phi \circ \pi$.

20.2.3 Co-description and description by analysis

The relationship between different levels of structure can be approached in two different ways. The most common technique in LFG, and the one I will adopt here, is called *co-description*. This involves describing multiple structures simultaneously. In other words, lexical entries and annotated phrase structure rules can contain information about all different levels of representation, and these constraints are present all at once. In terms of notation, it is common to use a subscripting convention to represent the application of further projection functions beyond ϕ, so that, for example, $\uparrow_{\sigma\iota} \equiv \iota(\sigma(\phi(*)))$. The co-description view, it seems to me, most directly captures the spirit of the constraint-based approach to linguistic analysis. In this view, a single set of constraints is obtained

[4] As Dalrymple et al. (2019: 410–411) point out, under a view of the projection architecture which disconnects the string from the c-structure (Dalrymple and Mycock 2011), as in Figure 20.2, so that the latter is a projection from the former (instead of the string being read off the terminal nodes of the c-structure tree), the symbol $\uparrow$ has a different meaning when it appears in lexical entries. Rather than $\phi(\mathcal{M}(*))$, it should be read as $\phi(\pi(\bullet))$, where $\bullet$ is the s-string unit corresponding to the lexical entry, and π is the projection function from the s-string to the c-structure.

from the string, and linguistic analysis involves simply finding the minimal structure at each and every level of representation which satisfies the constraints that apply to it.

The alternative is so-called *description by analysis*, where we obtain a description of one structure by inspecting and analysing another. For example, it might be that every time the attribute-value pair $\langle \text{TENSE}, \text{PAST} \rangle$ appears at f-structure, an appropriate past-tense meaning is also introduced at semantic structure. In this case, it would seem redundant to have to specify both of these things each time, since the latter can be inferred from the former. We could therefore construct the s-structure by inspecting the f-structure, without needing an additional constraint to be included in a verb's lexical entry. Although this seems appealing, it ignores the fact that there are frequently mismatches between levels (in this example, the pair $\langle \text{TENSE}, \text{PAST} \rangle$ might be present at f-structure for 'sequence-of-tense' reasons, and have no semantic import), and it also does not capture the constraint-based view that our grammatical theory should be, at least in principle, "process neutral" (Pollard and Sag 1994: 13): by introducing an inherent directionality into parsing, description-by-analysis approaches begin to look rather more derivational.[5]

In what follows, I will take it as given that a co-descriptive approach is to be preferred.[6] In the next section, we examine various proposals for accommodating meaning into the projection architecture, and discuss some of the shortcomings associated with these approaches. In Section 20.4, I will present a properly co-descriptive account of meaning in the LFG architecture.

20.3 Meaning in the projection architecture

In this chapter, I am interested in the portion of the projection architecture which leads from f-structure to the model. In particular, we must ask about the role of s-structure. Lowe (2014: 404) is partially right in saying that "[s]emantic structures have been as it were the poor relation in LFG's projection architecture". They have certainly had a mixed history, but that is not to say they have been ignored. There are essentially two phases in their history: pre- and post-glue. Before the introduction of glue semantics to LFG by Dalrymple et al. (1993b) (see below), semantic structure was taken to encode the predicate-argument structure of a sentence. Afterwards, its role becomes rather less clear: although the glue approach is standardly taken to rely on an s-structure 'scaffolding',[7] the structures themselves often contain very little information, and are not really 'semantic' in any meaningful way.

20.3.1 Pre-glue

Halvorsen (1982, 1983) was the first to make use of semantic structures. In his approach, s-structures are AVMs, like f-structures, and they directly encode the meaning contributions relevant to computing the meaning of the sentence as a whole. For example, the semantic structure for *John was flattered by Mary* is (3) (Halvorsen 1983: 570):[8]

(3) $$\begin{bmatrix} \text{PREDICATE} & \mathbf{flatter} \\ \text{ARG1} & \lambda P.P(\mathbf{mary}) \\ \text{ARG2} & \lambda P.P(\mathbf{john}) \end{bmatrix}$$

These semantic structures are then converted into an expression of intensional logic, which we can see as the analogue of the ψ mapping from the s-structure to the model (although Halvorsen does not discuss it in these terms, since the projection architecture had not yet been developed in its current form).

For Halvorsen (1983), s-structures are obtained by applying a translation algorithm to f-structures, and thus his analysis is clearly couched in terms of description by analysis. A co-description-based alternative is proposed by Halvorsen and Kaplan (1988). They make use of co-description to construct a semantic structure alongside the f-structure, seeing them both as projected from c-structure.[9] These semantic structures once again encode the predicate-argument structure of the meaning, albeit in a slightly different form. (4) is Halvorsen and Kaplan's (1988) semantic structure for *John ran slowly*:

[5] Kaplan (*apud* Dalrymple et al. 2019: 267) also speculates that description by analysis may be more powerful than co-description; this would be another reason to prefer the latter, since we want the most constrained theory possible.

[6] For this reason, I will not discuss the description-by-analysis proposals of Andrews (2007, 2008, 2010b), although these offer a very interesting alternative view of the issues.

[7] The 'first-order glue' proposed by Kokkonidis (2008) offers an alternative which does not rely on s-structure in this way, but it has had only moderate take-up among LFG practitioners: see e.g. Bary and Haug (2011) or Findlay (2019) for examples.

[8] I have simplified and modified Halvorsen's representation slightly for the sake of exposition and in order to harmonise notation in this chapter. The conventions I use are the following: $\mathbf{boldface}$ for predicates and individual constants, Roman type for connectives, brackets, etc., and $italics$ for variables.

[9] Butt (1995: 130) criticises this organisation of the grammar as inadequate for the analysis of complex predicates. (See also discussion in Appendix A of Andrews and Manning 1999.) Later work assumes that s-structure is projected from f-structure instead, as depicted in Figure 20.2.

$$\dfrac{\dfrac{b_\sigma = \mathbf{barack} \quad m_\sigma = \mathbf{michelle}}{b_\sigma = \mathbf{barack} \otimes m_\sigma = \mathbf{michelle}}\otimes_{\mathcal{I}} \quad \dfrac{\forall X,Y.b_\sigma = X \otimes m_\sigma = Y \multimap k_\sigma = \mathbf{kiss}(X,Y)}{b_\sigma = \mathbf{barack} \otimes m_\sigma = \mathbf{michelle} \multimap k_\sigma = \mathbf{kiss}(\mathbf{barack},\mathbf{michelle})}\mathcal{UI}[\mathbf{barack}/X, \mathbf{michelle}/Y]}{k_\sigma = \mathbf{kiss}(\mathbf{barack},\mathbf{michelle})}\multimap_{\mathcal{E}}$$

Figure 20.3: Glue proof for *Barack kissed Michelle* using 'old glue'-style meaning constructors

(4) $$\begin{bmatrix} \textsc{pred} & \begin{bmatrix} \textsc{rel} & \textsc{ran} \\ \textsc{mod} & \textsc{slowly} \end{bmatrix} \\ \textsc{arg}1 & \textsc{John} \end{bmatrix}$$

Although Halvorsen and Kaplan do not give an explicit algorithm for doing so, it is clear to see how this could also be converted into a formula of intensional logic or some other formal system which has a well-established model-theoretic interpretation.

20.3.2 Post-glue

The advent of glue semantics radically changed the role of semantic structure. In glue semantics, the meaning contribution of a lexical item or phrasal configuration is given in the form of a *meaning constructor*, a pairing of an expression in some meaning language with a term in linear logic. The nature of this 'pairing' has varied over the years, as we will see. Semantic composition then proceeds as logical deduction, guided by the linear logic term. The fact that linear logic lacks the sub-structural rules of Weakening and Contraction (Girard 1987) makes the logic *resource sensitive*: each premise must be used exactly once in a proof.[10]

In so-called 'old glue', meaning constructors are expressions in linear logic whose propositional atoms are pairings of semantic structures with meanings. In the earliest version of 'old glue', presented in Dalrymple et al. (1993b), the relationship between semantic structures and meanings was one of equality. Thus, (minimal) lexical entries for *Barack*, *Michelle*, and *kissed* would be as follows:

(5) Barack N $(\uparrow \textsc{pred}) = \text{'Barack'}$
$\uparrow_\sigma = \mathbf{barack}$

(6) Michelle N $(\uparrow \textsc{pred}) = \text{'Michelle'}$
$\uparrow_\sigma = \mathbf{michelle}$

(7) kissed V $(\uparrow \textsc{pred}) = \text{'kiss'}$
$\forall X, Y.(\uparrow \textsc{subj})_\sigma = X \otimes (\uparrow \textsc{obj})_\sigma = Y \multimap \uparrow_\sigma = \mathbf{kiss}(X, Y)$

The lexical entries for the nouns simply equate their semantic structure with the appropriate constant in the meaning language. Thus, it is perhaps a little misleading to call these semantic contributions meaning *constructors*: they simply give meaning assignments without any compositional work. The meaning contribution of *kissed*, though, explicitly *constructs* a meaning for the clause, building it out of the meanings of its subject and object. In words, it says that if a meaning X can be found for the subject, and a meaning Y can be found for the object, then the meaning of the whole sentence is $\mathbf{kiss}(X, Y)$. Assuming the f-structure labels in (8), Figure 20.3 shows how this deduction proceeds.

(8) $$k\begin{bmatrix} \textsc{pred} & \text{'kiss'} \\ \textsc{subj} & b\begin{bmatrix} \textsc{pred} & \text{'Barack'} \end{bmatrix} \\ \textsc{obj} & m\begin{bmatrix} \textsc{pred} & \text{'Michelle'} \end{bmatrix} \end{bmatrix}$$

The aim of the proof is to reach a meaning for the outer, clausal f-structure, k. In fact, this is all that survives the proof, since the rule of linear implication elimination 'uses up' the antecedent in order to derive the consequent. That is, from A and $A \multimap B$, we can prove B, but not $A \otimes B$. So at the end of the deduction in Figure 20.3, the only constraint on semantic structures which the f-description for the sentence contains is $k_\sigma = \mathbf{kiss}(\mathbf{barack}, \mathbf{michelle})$; the projection function σ is simply undefined for b and m. Notice that this makes semantic structure very different from in the Halvorsen/Halvorsen and Kaplan proposals, where the final s-structure for the sentence encodes the meaning of the predicate and its arguments, but not the whole sentence; here we have

[10]For reasons of space, I will not give a detailed introduction to glue semantics or linear logic here. For a straightforward introduction to the modern theory, see Asudeh (2012: ch. 4) or Dalrymple et al. (2019: ch. 8). Dalrymple (1999) offers a good overview of some of the foundational work from the 1990s.

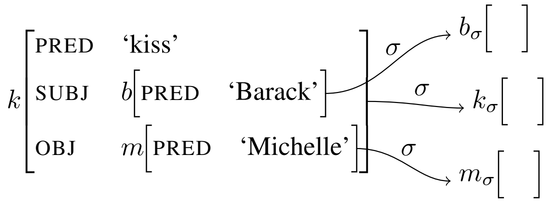

Figure 20.4: F- and s-structures for *Barack kissed Michelle* with 'empty' s-structures

the reverse: the s-structure simply *is* the meaning of the whole sentence, and records nothing about the meanings of its parts.

In later versions of 'old glue', e.g. Dalrymple et al. (1993a), Dalrymple et al. (1996), and most of the papers in Dalrymple (1999), meanings and semantic structures are no longer identified, but merely "put in correspondence" by means of the "otherwise uninterpreted binary predicate symbol" $\rightsquigarrow$ (Dalrymple et al. 1999b: 11). This has essentially the same effect as equality in terms of meaning deduction, but it also has the profoundly negative consequence of severing meaning from the architecture of the grammar: meanings are no longer represented at s-structure, but merely stand in some unspecified correspondence with such structures. This also leaves the nature of semantic structure quite mysterious. At least before, we knew what a semantic structure was: it was a meaning. Now we just know that semantic structures can be put in correspondence with meanings, but know nothing about their actual properties. This move is what has led to the situation bemoaned by Lowe in the comment quoted above, whereby semantic structures are neglected as an independent level of representation. It also leads to the commonly seen and occasionally remarked upon situation where semantic structures are represented as totally empty AVMs. Figure 20.4 shows the disconnected, (superficially) empty s-structures projected from the f-structure for *Barack kissed Michelle* commonly assumed in glue analyses of this sort.

Dalrymple et al. (1999b: 10) comment on this state of affairs in the introduction to Dalrymple (1999):

> For the purposes of this book, it is not necessary to specify the exact nature of semantic structures. We require only that, like f-structures, semantic structures may have several attributes associated with them. A semantic structure attribute takes as its value a semantic structure. Semantic structures may contain other, undetermined information: for instance, information about selectional restrictions. In this volume, when semantic structures are presented, some of that information may be elided. Therefore the reader should not infer that two semantic structures which are depicted with identical attributes and values are identical.

But the only semantic structure attributes mentioned in that book are VAR and RESTR, used in the analysis of quantifiers, and ANT, used in the analysis of anaphora, and they themselves end up with 'empty' AVMs as their values.[11] As the final sentence of this quotation highlights, given a standard set-theoretic interpretation of AVMs, two empty AVMs are identical, which means that, as presented, all of the s-structures in Figure 20.4 are in fact one and the same – clearly not what is intended. In order that we not infer this, there must be something that distinguishes the s-structures, but there have been very few proposals as to what this "elided" information might be (three such proposals will be discussed below). Recall too that structures in the projection architecture are supposed to be independent levels of linguistic structure, with "their own primitives and organizing principles, and therefore their own internal structure and formal representation" (Dalrymple et al. 2019: 265). That is, there ought to be interesting things to say about s-structure which are not dependent on its interactions with other levels of structure. But on the view presented in Dalrymple (1999), s-structure is a severely deficient kind of structure: parasitic on the meanings which it stands in correspondence with, devoid of any real content or its own "primitives", and with only a very limited kind of internal structure (aside from the VAR, RESTR, and ANT attributes, semantic structures are usually presented as disconnected and with no relation between the different s-structures of a clause). So, there are two challenges facing any theory of s-structure: how do we distinguish otherwise identical s-structures which we nevertheless want to keep apart, and how do we add some content to s-structures so that they are a legitimate level of representation in the projection architecture?

In the post-glue era, there have been three main proposals for what content to add to s-structure. Firstly, there are the information structure-based features of Dalrymple and Nikolaeva (2011). Secondly, there is the use of the INDEX feature by Dalrymple et al. (2018). Thirdly, there are the connected semantic structures advocated by Asudeh and Giorgolo (2012) and others (e.g. Asudeh et al. 2014; Lowe 2015; Findlay 2016; Lovestrand 2018). We will consider each of these in turn.

[11]The one exception would be where the value of ANT is the semantic structure of a common noun which itself contains VAR and RESTR attributes.

Semantic structure as the interface with information structure

Dalrymple and Nikolaeva (2011) (based on an insight of Mycock 2009) claim that information structure, "a level of sentence grammar where propositions, as conceptual states of affairs, are structured in accordance with the informational value of sentence elements and contextual factors" (Dalrymple and Nikolaeva 2011: 14; see also e.g. Lambrecht 1994; Erteschik-Shir 2007), should be projected from s-structure (this is represented in Figure 20.2), and that therefore a number of features relevant to i-structure should be present at s-structure. In particular, they advocate moving various information-structural features proposed by Liao (2010) in her analysis of empty pronouns in Mandarin Chinese from f-structure to s-structure. These features describe the relative "activation and accessibility of discourse referents" (Dalrymple and Nikolaeva 2011: 78), such as their STATUS (IDENTIFIABLE or UNIDENTIFIABLE), level of ACTiVation (ACTIVE, ACCESSIBLE, or INACTIVE), and whether or not they are pragmatically ANCHORED. In addition, Dalrymple and Nikolaeva (2011) also propose a feature DF, which takes as its value various i-structure roles, such as TOPIC or FOCUS. This encodes the contextually-given information-structural role of the meaning contribution corresponding to the semantic structure. Finally, the authors also advocate that "[s]emantic features determining topic-worthiness [. . .], including animacy, humanness, definiteness, and specificity" ought also to be represented at s-structure (Dalrymple and Nikolaeva 2011: 79).

How far do these additions resolve the problems highlighted above? Certainly we now have some idea what the putatively "elided" content of s-structure is. But how much are these its *own* primitives? Dalrymple and Nikolaeva (2011) are right that information-structural information should not be encoded at f-structure, which is a level of *syntactic* representation, but one might wonder why s-structure is any better a location for them: if they are genuinely *information-structural* features, why not represent them at i-structure? Whether or not a discourse referent is accessible is not part of its *meaning*, i.e. its semantics; rather, it is part of how that meaning is integrated into the discourse – exactly the domain of i-structure. By contrast, genuinely semantic features like humanness, animacy, or definiteness do seem much more appropriate as s-structure features, since these are aspects of meaning.

As for our other concern, although s-structures might be distinguishable by having different values for STATUS, ACTV, etc., we still cannot guarantee the uniqueness of two s-structures projected from distinct f-structures: if two HUMAN, ANIMATE nouns in a sentence happen to both be IDENTIFIABLE and ACTIVE, for example, then they could well have identical s-structures. In sum, Dalrymple and Nikolaeva's (2011) additions to s-structure help in some ways to make it more contentful, but do not solve the problem of unwanted identity.

The feature INDEX

The second of our proposals does offer a partial solution to this problem, however. Dalrymple et al. (2018), who develop a means of integrating LFG's binding theory into the dynamic semantic theory of PCDRT (Haug 2014), propose that each semantic structure which introduces a discourse referent should contain a feature INDEX, the value of which is represented by a unique integer. This, by definition, successfully ensures s-structure distinctiveness. We might wonder, though, how general a solution this is: should all s-structures contain an INDEX attribute? Dalrymple et al. (2018) only give examples with s-structures corresponding to nominal expressions, since these are the most canonical of anaphoric antecedents. But to the extent that other kinds of expressions can also serve as antecedents to anaphors, we might expect that their s-structures too should contain an INDEX feature:[12]

(9) Mary thinks [that John has cancer]$_i$. It would be terrible if this$_i$ were true.

It seems likely, however, that not all s-structures will correspond to potential anaphoric antecedents (those of certain modifiers, for example, or those which correspond to grammatical meanings like tense, aspect, etc., as discussed below and in Lowe 2014), and so there would be no independent motivation for assigning them an INDEX feature. Instead, such a move would be purely *ad hoc*, done for the sole purpose of having a means of differentiating s-structures.

Connected semantic structures

The third proposal is something of a return to the pre-glue, Halvorsen-style connected s-structures, which represent the predicate-argument structure of a clause. On this view, the s-structure for a sentence like *Barack kissed Michelle* would look like (10):

[12] I thank a reviewer for this observation and for providing the example in (9).

(10) $\begin{bmatrix} \textsc{rel} & \text{kiss} \\ \textsc{arg1} & \begin{bmatrix} \textsc{rel} & \text{Barack} \end{bmatrix} \\ \textsc{arg2} & \begin{bmatrix} \textsc{rel} & \text{Michelle} \end{bmatrix} \end{bmatrix}$

This very much mirrors the layout of the f-structure, but there is not a one-to-one correspondence between f-structures and s-structures, since different f-structures might end up with the same s-structure correspondent, allowing for the possibility of different mappings between grammatical functions and ARG attributes. For example, the passive *Michelle was kissed by Barack* would have a different f-structure from the active voice *Barack kissed Michelle*, as shown in (11), but both f-structures correspond to the same s-structure, that shown in (10).

(11) a. *Barack kissed Michelle.*

$\begin{bmatrix} \textsc{pred} & \text{`kiss'} \\ \textsc{subj} & \begin{bmatrix} \textsc{pred} & \text{`Barack'} \end{bmatrix} \\ \textsc{obj} & \begin{bmatrix} \textsc{pred} & \text{`Michelle'} \end{bmatrix} \end{bmatrix}$

b. *Michelle was kissed by Barack.*

$\begin{bmatrix} \textsc{pred} & \text{`kiss'} \\ \textsc{subj} & \begin{bmatrix} \textsc{pred} & \text{`Michelle'} \end{bmatrix} \\ \textsc{obl}_{\textsc{agent}} & \begin{bmatrix} \textsc{pred} & \text{`Barack'} \end{bmatrix} \\ \textsc{voice} & \textsc{passive} \end{bmatrix}$

The REL attribute was (re)introduced by Asudeh et al. (2008, 2013), in part due to the event semantics they use, which enables them to separate the valency frame of a verb from the core, event-denoting RELation it expresses. That is, by adding a type for events to our semantic ontology, we can have meaning constructors for verbs like (12), which will then combine with valency frame constructors like (13) to give the standard, compositional meaning constructor:[13]

(12) $\forall E.(\uparrow_\sigma \textsc{event}) \rightsquigarrow E \multimap \uparrow_\sigma \rightsquigarrow \mathbf{yawn}(E)$

(13) $\forall E, P, X, Y.[(\uparrow_\sigma \textsc{event}) \rightsquigarrow E \multimap \uparrow_\sigma \rightsquigarrow P(E)] \multimap$
$(\uparrow \textsc{subj})_\sigma \rightsquigarrow X \multimap (\uparrow \textsc{obj})_\sigma \rightsquigarrow Y \multimap \uparrow_\sigma \rightsquigarrow \exists e.P(e) \wedge \mathbf{agent}(e) = X \wedge \mathbf{patient}(e) = Y$

We can of course have different valency frame meaning constructors for different kinds of verb, and we can also have different ones for the same verb, representing voice alternations or morphosemantic alternations like dative shift. In this way, we can capture some notion of constructional meaning even in a strictly lexicalist account (Asudeh et al. 2013).[14]

Notice that since ($\uparrow_\sigma$ EVENT) is only ever mentioned in the antecedent of a conditional, and any atomic ('$\rightsquigarrow$') statement involving it is never directly consumed or produced, we do not need to actually assume an attribute EVENT at s-structure. If we wanted to describe in more detail the nature of the event in question by proposing new s-structure attributes (like COMPLETED, EXTENDED, etc.), then of course we are free to do so. But if not, there is no need for the attribute to actually exist, provided that any atomic statement involving it is never consumed or produced: that is, the truth of any atomic statement involving it is never actually checked directly.

Given the approach outlined here, we once again have some actual content and structure in our s-structures. The s-structures for a clause are now connected, the arguments embedded within the clausal structure; and there are no more empty s-structures, since they all contain at least a REL attribute. What is more, we are free to adopt whichever of Dalrymple and Nikolaeva's (2011) s-structure features we would like to as well. However, we might note that, as with the original pre-glue proposals, we do not represent the meaning of the outer s-structure anywhere. That is, although we might conclude that k_σ is 'in correspondence' with the meaning of the clause, this does not figure in the semantic structure.

Whether or not we solve the distinctiveness problem rather depends on the interpretation of the REL feature. The values of PRED at f-structure are taken to be *uniquely instantiated*, so that two apparently 'identical' PRED values are in fact non-unifiable. If we assume the same for REL values, then we solve the indistinguishability issue. But, as Lovestrand (2018: 171) notes, the exact character of REL values is "relatively unexplored in the literature". Are they really just unanalysed atomic symbols? If so, then REL seems to merely be recapitulating the role of PRED at f-structure. In Section 20.4, I will propose that we replace the attribute REL with MNG, whose value is the actual meaning which the s-structure was previously said merely to stand in correspondence with. This does not solve the distinctiveness issue (since meanings are not uniquely instantiated), but does give the semantic structure some meaningful content, and furnishes it with different primitives from f-structure: at s-structure, but not f-structure, expressions in some meaning language can be values of (certain) attributes.

[13] I continue to give these meaning constructors in the old glue style for the time being. We will discuss the new glue format in Section 20.3.3.

[14] Although see Müller (2018) for some scepticism towards attaching such meaning constructors to phrasal configurations.

20.3.3 New glue

So far, I have presented all meaning constructors in the 'old glue' style, even when the original authors did not. In fact, almost all contemporary work in glue semantics uses the so-called 'new glue' style, introduced by Dalrymple et al. (1999a). These authors demonstrate that a 'core fragment' of linear logic satisfying certain conditions is equivalent to typed linear lambda calculus, and so is also very similar to categorial grammar approaches. This core fragment is sufficient to account for many linguistic phenomena, and its use of the lambda calculus rather than quantification over meaning terms makes it more similar to much mainstream work in theoretical semantics, thus making it more transparent for many practitioners. On this view, meaning constructors have the following form, where M is an expression in some meaning language, and G is a linear logic expression where the atomic propositions are semantic structures:

(14) $M : G$

We can also assign the semantic structures a type; usually just the base types e (for entities) and t (for truth values/ propositions) are assumed. Operations in the lambda calculus are connected to proof rules in the linear logic by the *Curry-Howard Isomorphism* (Curry and Feys 1958; Howard 1980) – most significantly, functional application corresponds to implication elimination, and lambda abstraction to implication introduction. In this approach, the meaning constructors from (5)–(7) would become the following:

(15) $\mathbf{barack} : \uparrow_{\sigma\langle e\rangle}$

(16) $\mathbf{michelle} : \uparrow_{\sigma\langle e\rangle}$

(17) $\lambda x \lambda y.\mathbf{kiss}(x, y) : (\uparrow \text{SUBJ})_{\sigma\langle e\rangle} \multimap (\uparrow \text{OBJ})_{\sigma\langle e\rangle} \multimap \uparrow_{\sigma\langle t\rangle}$

It is common to suppress the types on the semantic structures, since these can be inferred from the meaning side.

This notation is certainly advantageous from the semantic point of view, but it does somewhat obscure the role of meaning constructors in the LFG architecture. An expression of the form given in (17) is not transparently a constraint; that is, it is not obviously something which can be true or false of a structure, which is the sort of thing a constraint-based theory needs grammatical analysis to produce. The original notation made it much clearer that these were constraints, sometimes of an implicational character. A statement like $\uparrow_\sigma \rightsquigarrow \mathbf{barack}$ is a true-or-false statement: either the s-structure $\uparrow_\sigma$ can be put in correspondence with the meaning $\mathbf{barack}$ or it can't. We might be tempted to interpret $\mathbf{barack} : \uparrow_\sigma$ in the same way, therefore. But we can't read the colon as meaning $\rightsquigarrow$ (or, rather, $\leftsquigarrow$), since this isn't what it means in (17). (17) does not say that the meaning $\lambda x \lambda y.\mathbf{kiss}(x, y)$ is in correspondence with an implication over s-structures (what would this mean anyway?). Instead, (17) is equivalent to (7), where there are three instances of $\rightsquigarrow$; this is just an implicational constraint, telling us that *if* we can find resources for the subject and object, *then* we can derive a true-or-false statement about the meaning of the clause. But this fact is somewhat obscured by the notation in (17).

Glue practitioners claim, quite rightly, that meaning constructors have the same status as any other piece of functional description, and therefore can appear wherever other kinds of functional description can appear: in lexical entries, on annotated phrase structure rules, in templates, etc. But given the new glue format, they look like very different kinds of animals, and it is not at all clear to the uninitiated how they are supposed to be interpreted as *constraints* in the same way as a defining equation like $(\uparrow \text{NUM}) = \text{SG}$. I suspect this is part of the reason why "a great many practitioners of LFG syntax profess not to understand [glue semantics]" (Andrews 2010c: 1). It seems to me that the old glue format was actually more perspicuous in this respect: once we admit linear logic into the language of f-descriptions, these kinds of meaning constructors make immediate sense as constraint-building expressions. We will return to this below.

20.3.4 Summary

There is no obvious consensus on the status of meaning in the architecture of LFG. Semantic structure was originally intended to be where meaning was represented, but as the glue semantics program developed, this level of representation became increasingly bloodless – disconnected and devoid of any real substance. Recent work has attempted to inject some life back into s-structure, but some of this has been ill-advised (e.g. incorporating information structural features into s-structure). In the next section, I introduce my own proposals, which share much in common with the more recent connected s-structure strand of research, but add a little more substance by representing meaning directly at s-structure. I also integrate meaning constructors into the description language of LFG more directly, by eschewing the new glue formulation, and allowing any piece of the f-description to make use of linear implication.

$$
\begin{array}{rcl}
\langle \text{f-expression} \rangle & ::= & \langle \text{constraint} \rangle | \langle \text{constructor} \rangle \\
\langle \text{constraint} \rangle & ::= & \langle \text{attr} \rangle = \langle \text{val} \rangle \\
& & | \langle \text{attr} \rangle =_c \langle \text{val} \rangle \\
& & | \langle \text{attr} \rangle \neq \langle \text{val} \rangle \\
& & | \langle \text{attr} \rangle \\
& & | \neg \langle \text{attr} \rangle \\
\langle \text{constructor} \rangle & ::= & \langle \text{constraint} \rangle \multimap \langle \text{constraint} \rangle \\
& & | \langle \text{constructor} \rangle \multimap \langle \text{constructor} \rangle \\
& & | \langle \text{constructor} \rangle \multimap \langle \text{constraint} \rangle
\end{array}
$$

Figure 20.5: The syntax of f-expressions

20.4 Proposal

I believe Dalrymple et al. (1993b) had the right intuition when they identified semantic structures with meanings, using equality statements in the f-description. This anchored meanings within the LFG architecture, rather than leaving them disconnected, as in later approaches. However, I also want to allow for the presence of relevant semantic features like HUMAN, ANIMATE, or DEFINITE at s-structure, as well as admitting some internal structure, so we cannot straightforwardly identify s-structures and meanings. Instead, we introduce a distinguished attribute, MNG (for 'meaning'), the value of which *can* be identified with a meaning. Thus, instead of the meaning contribution from (5), repeated here as (18), we will have (19):

(18) $\uparrow_\sigma = \mathbf{barack}$

(19) $(\uparrow_\sigma \text{ MNG}) = \mathbf{barack}$

Since these are just normal constraints like any other piece of functional description, I will not use the term 'meaning constructor' to refer to them. That will be reserved for expressions which contain the linear implication $\multimap$, seen as instructions for how to derive a particular meaning constraint. We will discuss how this will work for meanings in more detail in Section 20.4.2, but in fact once we allow expressions of this form into the f-description, there is no need to limit them to constraints over meanings. Instead, we can generalise the notion of meaning constructor to a broader kind of expression, simply called a 'constructor'. In Section 20.4.1, I give a new syntax for expressions contained in functional descriptions, and show how constructors can be used to model certain kinds of constraining equations. Section 20.4.2 discusses how this distinction extends to meaning contributions. Section 20.4.3 shows how this new approach works for our simple running example, and Sections 20.4.4 and 20.4.5 extend the analysis to quantifiers and modification, respectively, showing that the basic glue insights are preserved unchanged.

20.4.1 Two kinds of constraint

A functional description is made up of a set of expressions; let us call them *functional expressions*, or *f-expressions*. I propose that these be divided into two types: *constraints*, which are statements that must be satisfied by the structures which represent a parse of the sentence; and *constructors*, which are complex expressions built up from constraints and linear implication that allow us to derive other constraints. The formal syntax is given in Backus-Naur form in Figure 20.5. I don't define $\langle$attr$\rangle$ or $\langle$val$\rangle$ explicitly, but, informally, $\langle$attr$\rangle$ is (a path to) some object in the projection architecture of which a property can be ascribed (e.g. a c-structure node, f-structure attribute, etc.), while $\langle$val$\rangle$ is something which can be identified with that object, either another object, or an atomic symbol like $+$ or $-$ which can serve as its value. Truth and falsity, 1 and 0, are also possible constraints – the former trivially satisifed, the latter impossible to satisfy – though they are not generally mentioned in discussions of constraints in LFG, and so I have not included them in Figure 20.5. They will be important for my proposals below relating to constraining equations, however.

We will say that only constructors are subject to the resource sensitivity limitations of linear logic. Formally, we can think of this as meaning that each constraint (including one derivable from a constructor) is prefixed with the 'of course' modal operator of linear logic, !. We also require that an f-description be reducible to a set consisting purely of constraints, with no constructors left. If it is not, then the sentence is ill-formed in some way. These requirements together mean that each constructor must be used exactly once, but that constraints remain simply statements which can be true or false, and are not used up when they provide the antecedent to a linear logic implication. We will see in the next section how this does not imperil the resource-sensitive approach to meaning composition.

$$
\begin{array}{rcl}
\langle\text{f-expression}\rangle & ::= & \langle\text{constraint}\rangle | \langle\text{constructor}\rangle \\
\langle\text{constraint}\rangle & ::= & \langle\text{attr}\rangle = \langle\text{val}\rangle \\
 & & |\exists V.\langle\text{attr}\rangle = V \\
 & & |\langle\text{constraint}\rangle \supset \langle\text{constraint}\rangle \\
\langle\text{constructor}\rangle & ::= & \langle\text{constraint}\rangle \multimap \langle\text{constraint}\rangle \\
 & & |\langle\text{constructor}\rangle \multimap \langle\text{constructor}\rangle \\
 & & |\langle\text{constructor}\rangle \multimap \langle\text{constraint}\rangle
\end{array}
$$

Figure 20.6: An alternative syntax for f-expressions

Table 20.1: Different kinds of constraining equation and their interpretations

Standard form	Interpretation
$\langle\text{attr}\rangle =_c \langle\text{val}\rangle$	$(\langle\text{attr}\rangle = \langle\text{val}\rangle) \multimap 1$
$\langle\text{attr}\rangle \neq \langle\text{val}\rangle$	$(\langle\text{attr}\rangle = \langle\text{val}\rangle) \supset 0$
$\langle\text{attr}\rangle$	$(\exists v.\langle\text{attr}\rangle = v) \multimap 1$
$\neg\langle\text{attr}\rangle$	$(\exists v.\langle\text{attr}\rangle = v) \supset 0$

One immediate consequence of allowing constructors over any kind of constraint, rather than just meaning statements, is that we have a direct way of encoding so-called *constraining equations* (Kaplan and Bresnan 1982: 207ff.), rather than having to rely on a two-step constraint satisfaction process (this idea goes back to Saraswat 1999: 311f.). We recast positive constraining equations as constructors that imply truth (represented as 1) if an attribute has a particular/any value. Negative constraining equations instead imply falsity (represented as 0), although they do so using a material (non-linear) conditional, $\supset$, instead (since they should *prohibit* the presence of their antecedent, rather than require it the way a constructor does). These changes result in a more compact syntax for f-expressions, shown in Figure 20.6. The new interpretation of constraining equations of various kinds is shown in Table 20.1. For the positive constraining equations, since the constructor must be used up, it ensures that its antecedent must be true, although it does not by itself make it true – exactly the import of a positive constraining equation. In the case of the negative constraining equations, if the situation they prohibit is true, falsity (represented by 0) is introduced into the f-description, and no parse will be possible. But if it is false, then the constraint containing $\supset$ is true, and the validity of the f-description is preserved.[15]

20.4.2 Meaning constraints vs. meaning constructors

Given the general distinction between constraints and constructors, we can divide up meaning contributions in the same way. *Meaning constraints* introduce values of MNG into s-structure, while *meaning constructors* describe how other meaning constraints can be derived (e.g. the meaning constraint corresponding to the MNG for a clause can be deduced on the basis of the MNG values of the predicate and its arguments). This sort of distinction has actually surfaced a number of other times in the glue literature – in broad terms, it corresponds to the distinction between the intrinsic meaning and combinatorial potential of modifiers discussed by Dalrymple (2001: 64ff.), the generalisation of this proposed by Lowe (2014), and/or the contrast between lexical and grammatical meaning constructors introduced by Andrews (2010a). Here this distinction is made explicit in the formalism.

A lexical entry can contribute multiple meaning constraints, each of which introduces a basic component of meaning. In order for that meaning to enter into the compositional analysis, however, it must be accompanied by a meaning constructor of the appropriate form. This distinction is what allows us to preseve the resource sensitivity of glue semantics, even though individual meaning contributions, in the form of meaning constraints, are now not resource sensitive. Because meanings by themselves are compositionally inert, their contribution to meaning assembly is wholly controlled by the meaning constructors which accompany them, and these *are* resource sensitive. The following three sections will present worked through examples that illustrate how this works in practice.

20.4.3 A simple example

Returning to our running example, the nouns make a very simple and predictable meaning contribution:[16]

[15] Bresnan et al. (2016: 60–61) discuss the use of a conditional connective in the constraint language, and conclude that it cannot have the same truth function as the material conditional, on the basis that this would allow its consequent to be true when its antecedent was false. Clearly, this concern does not affect us here, since falsity can never be true.

[16] In fact, proper nouns are somewhat anomalous in that they contribute only a meaning constraint, and no accompanying meaning constructor. This might be thought to cause resource sensitivity issues. I believe that the only way this would be the case is if the proper noun could be

(20) Barack N $(\uparrow_\sigma\ \textsc{mng}) = \mathbf{barack}$

(21) Michelle N $(\uparrow_\sigma\ \textsc{mng}) = \mathbf{michelle}$

The verb makes at least the following contributions:

(22) kissed V
$$\begin{array}{l}
(\uparrow \textsc{subj})_\sigma = (\uparrow_\sigma\ \textsc{arg}1)\\
(\uparrow \textsc{obj})_\sigma = (\uparrow_\sigma\ \textsc{arg}2)\\
(\uparrow_\sigma\ \textsc{predicate mng}) = \mathbf{kiss}\\
\forall P, X, Y.(\uparrow_\sigma\ \textsc{predicate mng}) = P \multimap\\
\quad ((\uparrow_\sigma\ \textsc{arg}1\ \textsc{mng}) = X \multimap (\uparrow_\sigma\ \textsc{arg}2\ \textsc{mng}) = Y \multimap\\
\qquad (\uparrow_\sigma\ \textsc{mng}) = P(X, Y))
\end{array}$$

The first two lines describe the mapping between syntax and semantics. There is a large literature on this under the rubric of (Lexical) Mapping Theory (see e.g. Bresnan and Kanerva 1989; Bresnan and Zaenen 1990; Butt 1995; Butt et al. 1997; Alsina 1996; Kibort 2007, 2014; Findlay 2016); I will not give any detailed proposals for how such mappings are established here, but will simply assume that some version of Mapping Theory has provided them, and therefore encode them directly in lexical entries.

From these lexical entries, and the f-structure presented earlier in (8), we obtain the following f-description:

(23)
$$\begin{array}{l}
(b_\sigma\ \textsc{mng}) = \mathbf{barack}\\
(m_\sigma\ \textsc{mng}) = \mathbf{michelle}\\
b_\sigma = (k_\sigma\ \textsc{arg}1)\\
m_\sigma = (k_\sigma\ \textsc{arg}2)\\
(k_\sigma\ \textsc{predicate mng}) = \mathbf{kiss}\\
\forall P, X, Y.(k_\sigma\ \textsc{predicate mng}) = P \multimap\\
\quad ((b_\sigma\ \textsc{mng}) = X \multimap (m_\sigma\ \textsc{mng}) = Y \multimap\\
\qquad (k_\sigma\ \textsc{mng}) = P(X, Y))
\end{array}$$

Instantiating P as **kiss**, X as **barack**, and Y as **michelle**, and substituting for identities, we can then derive the reduced f-description in (24):[17]

(24)
$$\begin{array}{l}
(k_\sigma\ \textsc{arg}1\ \textsc{mng}) = \mathbf{barack}\\
(k_\sigma\ \textsc{arg}2\ \textsc{mng}) = \mathbf{michelle}\\
(k_\sigma\ \textsc{predicate mng}) = \mathbf{kiss}\\
(k_\sigma\ \textsc{mng}) = \mathbf{kiss}(\mathbf{barack}, \mathbf{michelle})
\end{array}$$

The minimal s-structure satisfying this description is given in (25):[18]

(25)
$$\begin{bmatrix}
\textsc{mng} & \mathbf{kiss}(\mathbf{barack}, \mathbf{michelle})\\
\textsc{predicate} & \begin{bmatrix}\textsc{mng} & \mathbf{kiss}\end{bmatrix}\\
\textsc{arg}1 & \begin{bmatrix}\textsc{mng} & \mathbf{barack}\end{bmatrix}\\
\textsc{arg}2 & \begin{bmatrix}\textsc{mng} & \mathbf{michelle}\end{bmatrix}
\end{bmatrix}$$

This s-structure includes both the full meaning of the sentence as well as those of its component parts.[19] The outer

parsed by the syntax as if it were a modifier; in that case, we might license a sentence like **Barack yawned Michelle* with the meaning $\mathbf{yawn}(\mathbf{barack})$. Regardless, if the syntax alone cannot rule out such sentences, we can easily add a meaning constructor to the proper nouns' lexical entries to do the job. Specifically, we just give them the type-raising meaning constructor in (i):

(i) $\forall X, P.(\uparrow_\sigma\ \textsc{mng}) = X \multimap [(\uparrow_\sigma\ \textsc{mng}) = X \multimap ((\textsc{gf}\uparrow)_\sigma\ \textsc{mng}) = P(X)] \multimap ((\textsc{gf}\uparrow)_\sigma\ \textsc{mng}) = P(X)$

[17] Note that because meaning constraints are not resource sensitive, the lexical meaning contributions of the verb and the nouns are not 'used up' in deriving the constraint for the whole clause.

[18] Of course, we could also have included constraints introducing the additional attributes discussed above, such as INDEX or ANIMACY, if we wanted to add further detail. I omit them for the sake of simplicity, but nothing formally hangs on this decision.

[19] One significant consequence of encoding meanings, including sub-sentential meanings, at s-structure is that the grammar can now refer to them directly, so that, for example, we can write constraints that require the presence or absence of a specific meaning. This makes the theory presented here rather more powerful than standard LFG+glue, but I think this additional power is ultimately necessary, and show in Section 20.5 that there are at least two cases where having direct access to meanings in the grammar is important.

$$\begin{bmatrix} \textsc{mng} & \exists t, t', e.\mathbf{kiss}(e) \wedge \mathbf{agent}(e) = \mathbf{barack} \wedge \\ & \mathbf{patient}(e) = \mathbf{michelle} \wedge \tau(e) \prec t' \wedge t' \subseteq t \\ \textsc{predicate} & \begin{bmatrix} \textsc{mng} & \mathbf{kiss} \end{bmatrix} \\ \textsc{arg1} & \begin{bmatrix} \textsc{mng} & \mathbf{barack} \end{bmatrix} \\ \textsc{arg2} & \begin{bmatrix} \textsc{mng} & \mathbf{michelle} \end{bmatrix} \\ \textsc{asp} & \begin{bmatrix} \textsc{mng} & \lambda P \lambda t.\exists e.P(e) \wedge \tau(e) \prec t \end{bmatrix} \\ \textsc{tns} & \begin{bmatrix} \textsc{mng} & \lambda P \lambda t.\exists t'.P(t') \wedge t' \subseteq t \end{bmatrix} \\ \textsc{fin} & \begin{bmatrix} \textsc{mng} & \lambda P.\exists t.P(t) \end{bmatrix} \end{bmatrix}$$

Figure 20.7: Articulated s-structure for *Barack kissed Michelle*

MNG is derived ('constructed'), while the others are lexically contributed.

We can include as many additional meanings in a semantic structure as needed, by giving each a unique attribute (along the lines suggested by Lowe 2014). So, borrowing from Lowe (2014: 402), the lexical entry for *kissed* might actually include the following meaning contributions, corresponding to the core meaning, perfective aspect, past tense, and finiteness:

(26) a. $(\uparrow_\sigma \textsc{predicate mng}) = \mathbf{kiss}$
b. $\forall P, X, Y, E.(\uparrow_\sigma \textsc{predicate mng}) = P \multimap$
$(\uparrow_\sigma \textsc{arg1 mng}) = X \multimap (\uparrow_\sigma \textsc{arg2 mng}) = Y \multimap$
$(\uparrow_\sigma \textsc{event mng}) = E \multimap (\uparrow_\sigma \textsc{mng}) = P(E) \wedge \mathbf{agent}(E) = X \wedge \mathbf{patient}(E) = Y$

(27) a. $(\uparrow_\sigma \textsc{asp mng}) = \lambda P \lambda t.\exists e.P(e) \wedge \tau(e) \prec t$
b. $\forall P, Q, E, T.(\uparrow_\sigma \textsc{asp mng}) = Q \multimap$
$[(\uparrow_\sigma \textsc{event mng}) = E \multimap (\uparrow_\sigma \textsc{mng}) = P(E)] \multimap$
$(\uparrow_\sigma \textsc{rt mng}) = T \multimap (\uparrow_\sigma \textsc{mng}) = Q(P)(T)$

(28) a. $(\uparrow_\sigma \textsc{tns mng}) = \lambda P \lambda t.\exists t'.P(t') \wedge t' \subseteq t$
b. $\forall P, Q, T, T'.(\uparrow_\sigma \textsc{tns mng}) = Q \multimap$
$[(\uparrow_\sigma \textsc{rt mng}) = T' \multimap (\uparrow_\sigma \textsc{mng}) = P(T')] \multimap$
$(\uparrow_\sigma \textsc{pt mng}) = T \multimap (\uparrow_\sigma \textsc{mng}) = Q(P)(T)$

(29) a. $(\uparrow_\sigma \textsc{fin mng}) = \lambda P.\exists t.P(t)$
b. $\forall P, Q, T.(\uparrow_\sigma \textsc{fin mng}) = Q \multimap$
$[(\uparrow_\sigma \textsc{pt mng}) = T \multimap (\uparrow_\sigma \textsc{mng}) = P(T)] \multimap$
$(\uparrow_\sigma \textsc{mng}) = Q(P)$

Note again that since atomic statements involving EVENT, RT and PT will never be directly consumed or produced (i.e. they only ever appear in constructors, never constraints), the actual attributes do not need to appear at s-structure. Adding in these additional f-expressions, then, we obtain the much more richly populated semantic structure shown in Figure 20.7. Such a rich structure will be useful for solving the granularity problem at i-structure, as discussed by Lowe (2014), but for the rest of this chapter, the simpler s-structures will be sufficient.

20.4.4 Quantifiers

There is not very much to be said about quantifiers, other than to reassure the reader that they retain their usual glue interpretation. In order to assign a MNG value to each s-structure, I do assume that their composition proceeds in a more piecewise manner than usual, and thus include two meaning constructors to accompany their meaning constraint, but this does not ultimately affect the way they compose.

I assume that (singular) common nouns know that they must combine with a determiner, and therefore that their MNG attribute should be embedded inside the s-structure corresponding to their f-structure. (30) gives the relevant parts of the lexical entry for *politician* by way of illustration:

(30) politician N $(\uparrow \textsc{pred}) = \text{'politician'}$
$(\uparrow_\sigma \textsc{arg mng}) = \mathbf{politician}$
$\forall P, X.(\uparrow_\sigma \textsc{arg mng}) = P \multimap (\uparrow_\sigma \textsc{var mng}) = X \multimap (\uparrow_\sigma \textsc{restr mng}) = P(X)$

$$
\begin{bmatrix}
\textsc{pred} & \text{‘lie’} \\
\textsc{subj} & \begin{bmatrix} \textsc{pred} & \text{‘politician’} \\ \textsc{spec} & \begin{bmatrix} \textsc{pred} & \text{‘every’} \end{bmatrix} \end{bmatrix}
\end{bmatrix}
\xrightarrow{\sigma}
\begin{bmatrix}
\textsc{mng} & \mathbf{every}(x, \mathbf{politician}(x), \mathbf{lie}(x)) \\
\textsc{predicate} & \begin{bmatrix} \textsc{mng} & \mathbf{lie} \end{bmatrix} \\
\textsc{arg}1 & \begin{bmatrix} \textsc{mng} & \lambda S.\mathbf{every}(x, \mathbf{politician}(x), S(x)) \\ \textsc{predicate} & \begin{bmatrix} \textsc{mng} & \lambda R \lambda S.\mathbf{every}(x, R(x), S(x)) \end{bmatrix} \\ \textsc{arg} & \begin{bmatrix} \textsc{mng} & \mathbf{politician} \end{bmatrix} \end{bmatrix}
\end{bmatrix}
$$

Figure 20.8: F- and s-structures for *Every politician lies*

The second line contributes a MNG value not for the outer s-structure corresponding to the NP containing *politician*, but to a sub-structure, the value of ARG. The organisation of NP s-structures will mirror that of clausal ones, with quantifiers contributing a PREDICATE attribute and the nouns they combine with contributing an ARG attribute. The meaning constructor in the third line simply returns the standard form for common nouns assumed in glue semantics (as in e.g. Dalrymple et al. 1996). Note once again that it will not be possible to derive simple constraints involving VAR and RESTR, and so they do not appear at s-structure.

The lexical entry for *every* is given in (31):[20]

(31) every D $(\uparrow \textsc{pred}) = \text{‘every’}$

$$
\begin{aligned}
&(\textsc{spec}\uparrow)_\sigma = \%np \\
&(\%np\ \textsc{predicate mng}) = \lambda R \lambda S.\mathbf{every}(x, R(x), S(x)) \\
&\forall P, Q, X.(\%np\ \textsc{predicate mng}) = Q \multimap \\
&\qquad [(\%np\ \textsc{var mng}) = X \multimap (\%np\ \textsc{restr mng}) = P(X)] \multimap \\
&\qquad\qquad (\%np\ \textsc{mng}) = Q(P) \\
&\forall P, Q, X.\forall H.(\%np\ \textsc{mng}) = Q \multimap \\
&\qquad [(\%np\ \textsc{mng}) = X \multimap H = P(X)] \multimap H = Q(P)
\end{aligned}
$$

The first meaning constructor, in the fourth line, allows us to derive a MNG for the quantified NP's s-structure; the next meaning constructor allows us to use that to obtain the standard glue form for a quantifier. Together with the usual annotated c-structure rules and the obvious lexical entry for *lies*, this will give the f- and s-structures in Figure 20.8 for the sentence *Every politician lies*.[21]

Quantifier scope interactions will behave the same as in standard glue, but different scopings will correspond to different s-structures, since each reading is the result of deriving a different meaning constraint for some outer s-structure containing the quantifiers. The Appendix contains an analysis of *Every politician kissed a baby*, including partial glue proofs.[22]

20.4.5 Modification

The first step in representing modifiers at s-structure is to augment any adjunct-introducing phrase structure rules with an additional semantic structure equation to construct a recursive modification structure at s-structure which mirrors the ADJ set at f-structure. In particular, the following two rules will be relevant in this section:

(32) a.
$$
\text{N} \rightarrow \begin{array}{c} \text{AdjP} \\ \downarrow \in (\uparrow \textsc{adj}) \\ \downarrow_\sigma \in (\uparrow_\sigma \textsc{arg mod}) \end{array} \quad \begin{array}{c} \text{N} \\ \uparrow = \downarrow \\ \end{array}
$$

b.
$$
\text{Adj} \rightarrow \begin{array}{c} \text{AdvP} \\ \downarrow \in (\uparrow \textsc{adj}) \\ \downarrow_\sigma \in (\uparrow_\sigma \textsc{mod}) \end{array} \quad \begin{array}{c} \text{Adj} \\ \uparrow = \downarrow \\ \end{array}
$$

[20] I use a *local name* (Crouch et al. 2017), $\%np$, to declutter the meaning constructors. A local name is simply a name assigned to a structure that allows us to refer to it elsewhere in the same description. I also follow Dalrymple (2001) and Dalrymple et al. (2019) in using so-called *pair quantifiers* rather than the perhaps more familiar generalised quantifiers in the analysis of quantificational expressions. Dalrymple et al. (1991: 15f.) show that there is a one-to-one correspondence between the two types of quantifiers.

[21] The function σ is simply undefined from the quantifier's f-structure. If this is objectionable, it would of course be straightforward to add an equation $\uparrow_\sigma = ((\textsc{spec}\uparrow)_\sigma\ \textsc{predicate})$ to the lexical entry for *every*, and adjust the rest of the entry accordingly.

[22] In proofs, I adopt the following conventions: the rules of universal instantiation and β-reduction are applied freely and silently; square brackets surround hypothetical premises; unannotated proof steps represent implication elimination; implication introduction is annotated with the number of the hypothetical premise being discharged. Note also that $\mathbf{X}$ is an arbitrary meaning constant, whereas X is a variable.

Secondly, I note that the theory I have presented here places an important restriction on modifiers: they must apply to constructors, not constraints. That is, a modifier meaning constructor of the form given in (33) will cause a clash if X and Y are distinct meanings, since now there will be two contradictory constraints in the f-description.

(33) $(f_\sigma\ \textsc{mng}) = X \multimap (f_\sigma\ \textsc{mng}) = Y$

Instead, we require modifiers to be of the form given in (34), where both constructors differ only in the values assigned to some MNG attribute(s).

(34) $\langle\text{constructor}\rangle \multimap \langle\text{constructor}\rangle$

One effect of this is that the results of modification will only be seen at a level which does not have a lexically specified meaning. For example, in the s-structure for *the apparently Swedish man*, the meaning for *apparently Swedish man*, i.e. $\lambda x.\mathbf{apparently}(\mathbf{swedish})(x) \wedge \mathbf{man}(x)$, does not appear except inside the quantifier expression corresponding to the meaning of the whole NP:

(35)
$$\left[\begin{array}{ll} \textsc{mng} & \lambda S.\mathbf{the}(x, \mathbf{apparently}(\mathbf{swedish}(x)) \wedge \mathbf{man}(x), S(x)) \\ \textsc{predicate} & \left[\begin{array}{ll}\textsc{mng} & \mathbf{the}\end{array}\right] \\ \textsc{arg} & \left[\begin{array}{ll} \textsc{mng} & \mathbf{man} \\ \textsc{mod} & \left\{\left[\begin{array}{ll} \textsc{mng} & \mathbf{swedish} \\ \textsc{mod} & \left\{\left[\begin{array}{ll}\textsc{mng} & \mathbf{apparently}\end{array}\right]\right\} \end{array}\right]\right\} \end{array}\right] \end{array}\right]$$

There is simply nowhere else to represent this meaning, since the MNG value of ARG is lexically contributed, and so cannot be modified directly.

The relevant parts of the lexical entries for the modifiers in this example are given below (adapted from Dalrymple 2001: 264ff.):[23]

(36) Swedish Adj
$$\begin{array}{l} (\uparrow \textsc{pred}) = \text{‘Swedish’} \\ (\uparrow_\sigma\ \textsc{mng}) = \mathbf{swedish} \\ \forall Q, X.(\uparrow_\sigma\ \textsc{mng}) = Q \multimap \\ \quad [(\uparrow_\sigma\ \textsc{var mng}) = X \multimap (\uparrow_\sigma\ \textsc{mng}) = Q(X)] \\ (\textsc{adj} \in \uparrow)_\sigma\ = \%np \\ \forall P, Q, X.[(\uparrow_\sigma\ \textsc{var mng}) = X \multimap (\uparrow_\sigma\ \textsc{mng}) = Q(X)] \multimap \\ \quad [(\%np\ \textsc{var mng}) = X \multimap (\%np\ \textsc{restr mng}) = P(X)] \multimap \\ \qquad (\%np\ \textsc{var mng}) = X \multimap (\%np\ \textsc{restr mng}) = Q(X) \wedge P(X) \end{array}$$

(37) apparently Adv
$$\begin{array}{l} (\uparrow \textsc{pred}) = \text{‘apparently’} \\ (\uparrow_\sigma\ \textsc{mng}) = \mathbf{apparently} \\ \forall Q, X.(\uparrow_\sigma\ \textsc{mng}) = Q \multimap \\ \quad [(\uparrow_\sigma\ \textsc{var mng}) = X \multimap (\uparrow_\sigma\ \textsc{mng}) = Q(X)] \\ (\textsc{adj} \in \uparrow)_\sigma\ = \%adj \\ \forall P, Q, X.[(\uparrow_\sigma\ \textsc{var mng}) = X \multimap (\uparrow_\sigma\ \textsc{mng}) = Q(X)] \multimap \\ \quad [(\%adj\ \textsc{var mng}) = X \multimap (\%adj\ \textsc{mng}) = R(X)] \multimap \\ \qquad (\%adj\ \textsc{var mng}) = X \multimap (\%adj\ \textsc{mng}) = Q(R(X)) \end{array}$$

The Appendix contains a glue proof showing the derivation of the outer MNG for (35) using these lexical entries and lexical entries for *the* and *man* parallel to the ones provided earlier for *every* and *politician*.

Finally, note that the constraint on the form of modifiers mentioned above means that apparently sentence-level modifiers must actually operate on some pre-propositional dependency: they cannot operate on the simple clausal meaning alone, since this will take the form of a meaning constraint rather than a meaning constructor. In a suitably rich event semantics, this means adverbs like *surprisingly* might modify the verbal meaning once it has combined with its arguments but before its event argument has been closed off. Sentential negation, which out-scopes all of

[23] I use the more familiar $(\textsc{adj} \in \uparrow)_\sigma$ inside-out functional uncertainty to refer to the structure being modified, but we could have equivalently written $(\textsc{mod} \in \uparrow_\sigma)$; in the schematic framework offered here, these are identical. It is possible that teasing the two apart, and, for example, allowing for a more articulated MOD set at s-structure even when the f-structure ADJ set is flat could be of use in analysing various phenomena where e.g. modifier scope is fixed by some other level of the grammar like c-structure.

the existential quantification over events and times, could modify the final closure meaning constructor itself, e.g. the finiteness constructor derived from (29):

(38) $$\forall P, Q, T.[[(\uparrow_\sigma \text{ PT MNG}) = T \multimap (\uparrow_\sigma \text{ MNG}) = P(T)] \multimap (\uparrow_\sigma \text{ MNG}) = Q(P)] \multimap [(\uparrow_\sigma \text{ PT MNG}) = T \multimap (\uparrow_\sigma \text{ MNG}) = P(T)] \multimap (\uparrow_\sigma \text{ MNG}) = \neg Q(P)$$

20.4.6 From s-structure to a model-theoretic interpretation

On the view of the architecture we are entertaining, the ψ function, from s-structure to the model-theoretic interpretation, is just the familiar denotation function applied to the value of MNG; that is, for any s-structure s, the following will hold:

(39) $$s_\psi = [\![(s \text{ MNG})]\!]$$

Since this correspondence holds generally, it might be more efficient to encode it somewhere in the grammar itself, rather than having to include equations like (39) in every lexical entry, although of course there is no formal obstacle to doing so.

20.5 Applications/implications

20.5.1 Idioms

The most striking effect of the proposal explored in this chapter is that meanings are properly integrated into the architecture of the grammar, and, accordingly, can be referred to in constraints. One place in which this is relevant is in the analysis of certain flexible idioms.

Findlay (2019) gives an LFG account of various kinds of idioms and other 'multiword expressions'. But one area he has difficulty with is idioms which are 'lexically flexible', such as those in (40) (Findlay 2019: 321):

(40) a. It's time to put/place/lay/... our cards on the table.
b. That gave me a kick up the backside/rear/bum/booty/....
c. This adds/gives/brings/... grist to the mill.

The problem is that the idioms in question seem to permit any word to be used in these variable slots provided they share some *meaning* – for example, all of the possibilities in (40b) refer to the backside. But this isn't the sort of thing traditional LFG can describe, since the meanings which stand in correspondence to s-structures are not properly integrated into the grammar.

But of course, under the current proposal, this is exactly the sort of thing which can be described. Whatever f-structure analysis we assign to *kick up the backside*, let us assume that there is some f-structure f which corresponds to the flexible noun position. Then we can add (41) to some appropriate lexical entry (whether idioms are described phrasally or lexically does not matter for present purposes):

(41) $$f_{\sigma\psi} =_c [\![\mathbf{backside}]\!]$$

Given (39), this is equivalent to (42):

(42) $$[\![(f_\sigma \text{ MNG})]\!] =_c [\![\mathbf{backside}]\!]$$

That is, whatever the meaning of the flexible noun denotes, it is required to be coextensive with the denotation of *backside*.

This is of course far from a complete analysis, and there remain many open questions here about the representation of idioms – in particular, we don't want the *backside* meaning to 'survive' into the idiomatic interpretation, since a kick up the backside need not have anything to do with literal backsides. However, the current proposals open up promising new avenues of analysis, which I hope to explore in future work.[24]

[24] In particular, Findlay (2017: Appendix) rejects the glue-based semantic account of idioms proposed by Arnold (2015), since it suffers from a number of empirical failings. But the chief cause of those failings was an inability to refer to the *meanings* being 'thrown away' by the manager resources, which leads to an inability to handle idiom-internal modification. The current proposals may well make such an approach workable again.

20.5.2 Information structure

The proposals of Dalrymple and Nikolaeva (2011) are currently the state of the art in LFG theorising about information structure. There, i-structure is presented as an AVM with attributes corresponding to information structure categories (TOPIC, FOCUS, BACKGROUND and COMPLETIVE), the values of which are sets containing the meaning constructors (in the canonical sense, not that introduced in Section 20.4.2) that bear that particular role. They rely on two formal tools to achieve this: a feature DF at s-structure, whose value is the i-structure role of the meaning constructors associated with that s-structure (where 'associated with' means they are introduced by a word whose pre-terminal c-structure node ultimately projects to that s-structure), and a constraint which accompanies all meaning constructors of the form given in (43), ensuring that the meaning constructor is assigned to the i-structure role corresponding to the value of DF:

(43) **[meaning constructor]** $\in (\uparrow_{\sigma\iota}\ (\uparrow_{\sigma}\ \text{DF}))$

Some DF values are contributed by syntactic rules or morphological marking, others by the context. For example, the preference in English for subjects to be topics by default can be encoded in the following c-structure rule (cf. Dalrymple and Nikolaeva 2011: 84):

(44)
$$\text{S} \rightarrow \begin{array}{cc} \text{NP} & \text{VP} \\ (\uparrow \text{SUBJ}) = \downarrow & \uparrow = \downarrow \\ \uparrow_{\sigma\iota} = \downarrow_{\sigma\iota} & \\ \big((\downarrow_{\sigma}\ \text{DF}) = \text{TOPIC}\big) & \end{array}$$

The i-structure for our running example, uttered in a relatively neutral context, might then be as follows:

(45)
$$\begin{bmatrix} \text{TOPIC} & \Big\{\mathbf{barack} : b_{\sigma}\Big\} \\ \text{FOCUS} & \Big\{\lambda x \lambda y.\mathbf{kiss}(x,y) : b_{\sigma} \multimap m_{\sigma} \multimap k_{\sigma},\ \mathbf{michelle} : m_{\sigma}\Big\} \end{bmatrix}$$

This is a formally ingenious approach and empirically fairly successful, but there are two major things to take issue with.

Dalrymple and Nikolaeva's (2011: 71) stated position on information structure is that it "partitions sentence meaning into information structure categories". This position is repeated in Dalrymple et al. (2019: 381), where it is added that "a formal theory of information structure should represent the structuring of meanings, and the assignment of information structure roles to meanings, and not, for example, to syntactic elements". Thus, it is clear that the fundamental building blocks of i-structure must be meanings; the job of this level of representation is to divide these meanings up appropriately and to assign them to information structural categories. So the naïve reader may be somewhat confused by the fact that the theory presented by Dalrymple and Nikolaeva (2011) divides up not *meanings* but meaning *constructors*. Meaning constructors are not meanings; they are pairings of meanings with expressions in linear logic over semantic structures. Such hybrid objects are not the sort of things which should figure in information structure.[25]

What is more, the feature DF is not properly a semantic feature: as discussed in Section 20.3.2, information-structure properties are not part of the *meaning* of an expression, so should not be represented at semantic structure (just as they should not be represented at f-structure, a position rightly criticised by Dalrymple and Nikolaeva 2011: 65ff.). In essence, DF is a bookkeeping feature, and so it really makes no formal or empirical difference at what level of representation it appears.[26]

Both of these slightly awkward compromises arise from the fact that meanings are not properly integrated into the LFG architecture (although see fn. 25 for a solution to the first within the existing architecture). The intended effect of the third annotation under the NP in (44) is to add the meaning of the subject to the TOPIC set at i-structure. But there is no meaning for the annotation to refer to, and the c-structure node cannot 'see' whatever meaning constructors are associated with the subject, so the best we can do is assign a value to an attribute in a

[25] Ash Asudeh (p.c.) points out that this first issue could be solved in Dalrymple and Nikolaeva's (2011) system by treating meaning constructors as pairs $\langle M, G\rangle$ of a meaning language expression and a linear logic glue term, and then specifying in the lexical entry that it is the first projection of the pair, i.e. the meaning, which appears at i-structure; that is, we include constraints like (i) in our lexical entries instead of (43):

(i) π_1(**[meaning constructor]**) $\in (\uparrow_{\sigma\iota}\ (\uparrow_{\sigma}\ \text{DF}))$

This doesn't help with the second issue mentioned in the text, however, which turns on the fact that neither meanings nor meaning constructors are properly integrated into the LFG projection architecture, and so cannot be referred to except by the lexical entry or phrasal annotation which introduces them.

[26] Indeed, it would be a trivial change to put the DF feature in the f-structure instead, and as far as I can see would result in no empirical differences; all we would need to do is replace $(\uparrow_{\sigma}\ \text{DF})$ in (43) with $(\uparrow\ \text{DF})$ and modify other annotations accordingly.

structure that *is* integrated into the projection architecture, and then include a constraint in the lexical entry which uses that to say something about the lexically introduced meaning constructor. Not particularly elegant.

In our new approach, we can solve these issues straightforwardly. Because meanings now have a place in the architecture of the grammar, we can refer to them directly, without also bringing along the linear logic expression which controls their combinatorics. And because meanings are included within s-structures, we can refer to them explicitly in c-structure annotations, rather than having to use a mediating attribute like DF. For example, the default subject topic annotation from (44) can be replaced by (46):

(46) $\big((\downarrow_\sigma\ \textsc{mng}) \in (\uparrow_{\sigma\iota}\ \textsc{topic})\big)$

Other assignments will follow a similar structure. Following Lowe (2014), I assume that the s-structure will contain as many attributes as are needed for a fine-grained i-structure analysis (see e.g. (26)–(29) and Figure 20.7 above). Some of these can be targetted by, for example, stressing particular phrase structure positions. (47) shows two rules that introduce a focussed negative word like *not* and a focussed auxiliary, respectively, using the prosodic notation of Mycock and Lowe (2013):

(47) a. $\text{VP} \rightarrow \begin{array}{c} \text{Neg} \\ \uparrow = \downarrow \\ \left(\begin{array}{c} (\downarrow_\sigma\ \textsc{neg mng}) \in (\uparrow_{\sigma\iota}\ \textsc{focus}) \\ \text{DF\_Focus} \in (\searrow_{\text{R}}) \end{array}\right) \end{array} \quad \begin{array}{c} \text{VP} \\ \uparrow = \downarrow \end{array}$

b. $\text{I}' \rightarrow \begin{array}{c} \text{I} \\ \uparrow = \downarrow \\ \left(\begin{array}{c} \{(\downarrow_\sigma\ \textsc{tns mng}) | (\downarrow_\sigma\ \textsc{asp mng})\} \in (\uparrow_{\sigma\iota}\ \textsc{focus}) \\ \text{DF\_Focus} \in (\searrow_{\text{R}}) \end{array}\right) \end{array} \quad \begin{array}{c} \text{VP} \\ \uparrow = \downarrow \end{array}$

20.6 Conclusions

Despite the impressive theoretical gains afforded by glue semantics, it has arguably represented a step backwards in terms of integrating meanings into the architecture of the grammar. Semantic structure became an enfeebled and unimportant component of the projection architecture, and meanings did not figure at all, merely standing in some kind of unspecified correspondence with s-structures. At the same time, the 'new glue' representation of meaning constructors led to them appearing to stand apart from other kinds of functional annotation, making the semantic component of the grammar seem even more out of sync with the rest of the overall framework. In this chapter, I have attempted to remedy this situation, by representing meanings explicitly at semantic structure, and by making clear how meaning constructors fit into the standard LFG formalism. This retains all the theoretical gains of glue semantics, but, for the first time since Dalrymple et al. (1993b), properly integrates meaning into the architecture of the LFG grammar. Such a move has immediate benefits in the analysis of idioms, in the theory of the semantics-information structure interface, and no doubt in other areas ripe for future investigation.

Appendix

Quantifier scope: *Every politician kissed a baby*

This has the f-structure given in (48):

(48) $$k\begin{bmatrix} \textsc{pred} & \text{`kiss'} \\ \textsc{subj} & p\begin{bmatrix} \textsc{pred} & \text{`politician'} \\ \textsc{spec} & \begin{bmatrix} \textsc{pred} & \text{`every'} \end{bmatrix} \end{bmatrix} \\ \textsc{obj} & b\begin{bmatrix} \textsc{pred} & \text{`baby'} \\ \textsc{spec} & \begin{bmatrix} \textsc{pred} & \text{`a'} \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

The two proofs for the value of $(k_\sigma\ \textsc{mng})$ are given in Figures 20.9 (for the reading where *every* outscopes *a*) and 20.10 (where *a* outscopes *every*). These correspond to the s-structures in (49) and (50), respectively.

(49)
$$\begin{bmatrix} \textsc{mng} & \mathbf{every}(x, \mathbf{politician}(x), \mathbf{a}(y, \mathbf{baby}(y), \mathbf{kiss}(x, y))) \\ \textsc{predicate} & \begin{bmatrix} \textsc{mng} & \mathbf{kiss} \end{bmatrix} \\ \textsc{arg}1 & \begin{bmatrix} \textsc{mng} & \lambda S.\mathbf{every}(x, \mathbf{politician}(x), S(x)) \\ \textsc{predicate} & \begin{bmatrix} \textsc{mng} & \lambda R \lambda S.\mathbf{every}(x, R(x), S(x)) \end{bmatrix} \\ \textsc{arg} & \begin{bmatrix} \textsc{mng} & \mathbf{politician} \end{bmatrix} \end{bmatrix} \\ \textsc{arg}2 & \begin{bmatrix} \textsc{mng} & \lambda S.\mathbf{a}(x, \mathbf{baby}(x), S(x)) \\ \textsc{predicate} & \begin{bmatrix} \textsc{mng} & \lambda R \lambda S.\mathbf{a}(x, R(x), S(x)) \end{bmatrix} \\ \textsc{arg} & \begin{bmatrix} \textsc{mng} & \mathbf{baby} \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

(50)
$$\begin{bmatrix} \textsc{mng} & \mathbf{a}(x, \mathbf{baby}(x), \mathbf{every}(y, \mathbf{politician}(y), \mathbf{kiss}(y, x))) \\ \textsc{predicate} & \begin{bmatrix} \textsc{mng} & \mathbf{kiss} \end{bmatrix} \\ \textsc{arg}1 & \begin{bmatrix} \textsc{mng} & \lambda S.\mathbf{every}(x, \mathbf{politician}(x), S(x)) \\ \textsc{predicate} & \begin{bmatrix} \textsc{mng} & \lambda R \lambda S.\mathbf{every}(x, R(x), S(x)) \end{bmatrix} \\ \textsc{arg} & \begin{bmatrix} \textsc{mng} & \mathbf{politician} \end{bmatrix} \end{bmatrix} \\ \textsc{arg}2 & \begin{bmatrix} \textsc{mng} & \lambda S.\mathbf{a}(x, \mathbf{baby}(x), S(x)) \\ \textsc{predicate} & \begin{bmatrix} \textsc{mng} & \lambda R \lambda S.\mathbf{a}(x, R(x), S(x)) \end{bmatrix} \\ \textsc{arg} & \begin{bmatrix} \textsc{mng} & \mathbf{baby} \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

Modification: *the apparently Swedish man*

This has the f-structure in (51):

(51)
$$m \begin{bmatrix} \textsc{pred} & \text{'man'} \\ \textsc{spec} & \begin{bmatrix} \textsc{pred} & \text{'the'} \end{bmatrix} \\ \textsc{adj} & \left\{ s \begin{bmatrix} \textsc{pred} & \text{'Swedish'} \\ \textsc{adj} & \left\{ \begin{bmatrix} \textsc{pred} & \text{'apparently'} \end{bmatrix} \right\} \end{bmatrix} \right\} \end{bmatrix}$$

Figure 20.11 shows the glue proof for the value of (m_σ MNG), as seen in the text in example (35).

$$
\dfrac{
  \begin{array}{c}((p_\sigma\ \textsc{mng}) = \mathbf{X} \multimap (k_\sigma\ \textsc{mng}) = \lambda u.\mathbf{a}(y, \mathbf{baby}(y), \mathbf{kiss}(u, y))(\mathbf{X})) \multimap \\ (k_\sigma\ \textsc{mng}) = \mathbf{every}(x, \mathbf{politician}(x), \mathbf{a}(y, \mathbf{baby}(y), \mathbf{kiss}(x, y)))\end{array}
  \qquad
  \dfrac{
    \dfrac{
      \dfrac{
        \dfrac{
          \dfrac{(p_\sigma\ \textsc{mng}) = \mathbf{X} \multimap (b_\sigma\ \textsc{mng}) = \mathbf{Y} \multimap (k_\sigma\ \textsc{mng}) = \mathbf{kiss}(\mathbf{X}, \mathbf{Y}) \qquad [(p_\sigma\ \textsc{mng}) = \mathbf{X}]^1}{(b_\sigma\ \textsc{mng}) = \mathbf{Y} \multimap (k_\sigma\ \textsc{mng}) = \mathbf{kiss}(\mathbf{X}, \mathbf{Y})}
          \qquad [(b_\sigma\ \textsc{mng}) = \mathbf{Y}]^2
        }{(k_\sigma\ \textsc{mng}) = \mathbf{kiss}(\mathbf{X}, \mathbf{Y})}
      }{(b_\sigma\ \textsc{mng}) = \mathbf{Y} \multimap (k_\sigma\ \textsc{mng}) = \lambda z.\mathbf{kiss}(\mathbf{X}, z)(\mathbf{Y})}\multimap_{\mathcal{I},2}
      \qquad
      \begin{array}{c}((b_\sigma\ \textsc{mng}) = \mathbf{Y} \multimap (k_\sigma\ \textsc{mng}) = \lambda z.\mathbf{kiss}(\mathbf{X}, z)(\mathbf{Y})) \multimap \\ (k_\sigma\ \textsc{mng}) = \mathbf{a}(y, \mathbf{baby}(y), \mathbf{kiss}(\mathbf{X}, y))\end{array}
    }{(k_\sigma\ \textsc{mng}) = \mathbf{a}(y, \mathbf{baby}(y), \mathbf{kiss}(\mathbf{X}, y))}
  }{(p_\sigma\ \textsc{mng}) = \mathbf{X} \multimap (k_\sigma\ \textsc{mng}) = \lambda u.\mathbf{a}(y, \mathbf{baby}(y), \mathbf{kiss}(u, y))(\mathbf{X})}\multimap_{\mathcal{I},1}
}{(k_\sigma\ \textsc{mng}) = \mathbf{every}(x, \mathbf{politician}(x), \mathbf{a}(y, \mathbf{baby}(y), \mathbf{kiss}(x, y)))}
$$

Figure 20.9: Glue proof for the $\mathbf{every} \gg \mathbf{a}$ reading of *Every politician kissed a baby*

$$
\dfrac{
\begin{array}{l}((b_\sigma\ \textsc{mng}) = \mathbf{Y} \multimap (k_\sigma\ \textsc{mng}) = \lambda u.\mathbf{every}(y, \mathbf{politician}(y), \mathbf{kiss}(y,u))(\mathbf{Y})) \multimap \\ (k_\sigma\ \textsc{mng}) = \mathbf{a}(x, \mathbf{baby}(x), \mathbf{every}(y, \mathbf{politician}(y), \mathbf{kiss}(y,x)))\end{array}
\quad
\dfrac{
\dfrac{
\dfrac{
\dfrac{
\dfrac{(p_\sigma\ \textsc{mng}) = \mathbf{X} \multimap (b_\sigma\ \textsc{mng}) = \mathbf{Y} \multimap (k_\sigma\ \textsc{mng}) = \mathbf{kiss}(\mathbf{X},\mathbf{Y}) \quad [(p_\sigma\ \textsc{mng}) = \mathbf{X}]^1}{(b_\sigma\ \textsc{mng}) = \mathbf{Y} \multimap (k_\sigma\ \textsc{mng}) = \mathbf{kiss}(\mathbf{X},\mathbf{Y})}
\quad [(b_\sigma\ \textsc{mng}) = \mathbf{Y}]^2}{(k_\sigma\ \textsc{mng}) = \mathbf{kiss}(\mathbf{X},\mathbf{Y})}
}{(p_\sigma\ \textsc{mng}) = \mathbf{X} \multimap (k_\sigma\ \textsc{mng}) = \lambda z.\mathbf{kiss}(z,\mathbf{Y})(\mathbf{X})}\multimap_{\mathcal{I},1}
\quad
\begin{array}{l}((p_\sigma\ \textsc{mng}) = \mathbf{X} \multimap (k_\sigma\ \textsc{mng}) = \lambda z.\mathbf{kiss}(z,\mathbf{Y})(\mathbf{X})) \multimap \\ (k_\sigma\ \textsc{mng}) = \mathbf{every}(y, \mathbf{politician}(y), \mathbf{kiss}(y,\mathbf{Y}))\end{array}
}{(k_\sigma\ \textsc{mng}) = \mathbf{every}(y, \mathbf{politician}(y), \mathbf{kiss}(y,\mathbf{Y}))}
}{(b_\sigma\ \textsc{mng}) = \mathbf{Y} \multimap (k_\sigma\ \textsc{mng}) = \lambda u.\mathbf{every}(y, \mathbf{politician}(y), \mathbf{kiss}(y,u))(\mathbf{Y})}\multimap_{\mathcal{I},2}
}{(k_\sigma\ \textsc{mng}) = \mathbf{a}(x, \mathbf{baby}(x), \mathbf{every}(y, \mathbf{politician}(y), \mathbf{kiss}(y,x)))}
$$

Figure 20.10: Glue proof for the $\mathbf{a} \gg \mathbf{every}$ reading of *Every politician kissed a baby*

$$
\dfrac{
\begin{array}{l}(m_\sigma\ \textsc{var mng}) = \mathbf{X} \multimap (m_\sigma\ \textsc{restr mng}) = \lambda y.[\mathbf{apparently}(\mathbf{swedish}(y)) \wedge \mathbf{man}(y)](\mathbf{X}) \multimap\\ (m_\sigma\ \textsc{mng}) = \lambda S.\mathbf{the}(x, \lambda y.[\mathbf{apparently}(\mathbf{swedish}(y)) \wedge \mathbf{man}(y)](x), S(x))\end{array}
\quad
\dfrac{
\dfrac{
\dfrac{
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Figure 20.11: Glue proof for *the apparently Swedish man*

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