GLUING MEANINGS AND SEMANTIC STRUCTURES

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Abstract

This paper explores the role of semantic structures in glue in the light of recent proposals regarding the internal content of these structures. I propose to 'split' meaning constructors into two, enabling a proper account of the dual role of semantic structures within glue expressions. This effects a solution to the granularity problem, which has long plagued treatments of information structure within LFG.

1 Introduction

The development of the 'glue' language as a means for resource-sensitive semantic composition can be counted the single most important development within LFG since the formulation of the theory by Kaplan and Bresnan (1982). Since the original proposals by Dalrymple et al. (1993), glue has become the established means of mediating the syntax-semantics interface within LFG, and thus of integrating a developed semantic representation into the LFG architecture; it has also been successfully applied to other grammatical frameworks (e.g. to LTAG by Frank and van Genabith 2001, and to HPSG by Asudeh and Crouch 2002).

The intuitions underlying glue have remain unchanged since its development, but the formal system itself has changed. The original form of glue as proposed by Dalrymple et al. (1993) was replaced by a formally simpler system (Dalrymple et al. 1996), which was the first glue system to gain wide currency. A 'new' glue notation was introduced by Dalrymple et al. (1999a), and this is now the standard form of glue met with in recent literature, not least due to its use in Dalrymple (2001). Only a few authors, such as Andrews (2004, 2008, 2010) and Kokkonidis (2008), have proposed significant changes to the standard glue approach, but no such proposals have been widely adopted.

In this paper I explore the role of semantic structures in glue in the light of recent proposals regarding the internal content of these structures and their use in relation to i(nformation)-structure. I propose to 'split' meaning constructors into two, in order to properly account for the dual role of semantic structures within glue expressions. This also results in a solution to the long-standing problem with analyses of i-structure in LFG, the so-called 'granularity problem'. I also explore the possibility of integrating my proposals with the structureless First-Order glue of Kokkonidis (2008).

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2 Associating meanings with s-structures

In glue, semantic composition is achieved by the pairing of meanings with instructions for combining those meanings. These pairings are represented as meaning constructors; most meaning constructors are associated with lexical items, but some can be introduced outside the lexicon, e.g. in c-structure (Dalrymple 2001: 240). So, the meaning constructors in (2) are associated with the lexical entries of the words in (1); (2a) with *Henry*, and (2b) with *slept*, of course. Both meaning constructors consist of two 'sides': the meaning side, to the left of the colon, and the glue side, to the right. The composition of these meanings, $henry$ and $\lambda x.sleep(x)$, is determined by the glue expressions paired with these meanings. The glue expression paired with the meaning of the verb requires that this meaning be combined with a meaning for the subject of the verb in order to produce a coherent meaning for the clause. Meaning composition such as this is specified by reference to f-structure; on the basis of an f-structure such as (3) the meaning of the verb can be applied to the meaning $henry$, to produce the meaning $sleep(henry)$.

(1) Henry slept.

(2) a. $henry : \uparrow_\sigma$

b. $\lambda x.sleep(x) :$
$(\uparrow \text{SUBJ})_\sigma \multimap \uparrow_\sigma$

(3)
$$s:\begin{bmatrix} \text{PRED} & \text{'sleep}\langle\text{SUBJ}\rangle\text{'} \\ \text{SUBJ} & h:\begin{bmatrix}\text{PRED} & \text{'Henry'}\end{bmatrix}\end{bmatrix}$$

Used in this way, the glue expressions that appear on the right-hand side of meaning constructors are essentially a means of constraining semantic composition by reference to f-structure. They therefore reflect Montague's (1974) original intuition that the order of semantic composition is based on syntax (albeit not the sort of syntax Montague had in mind).

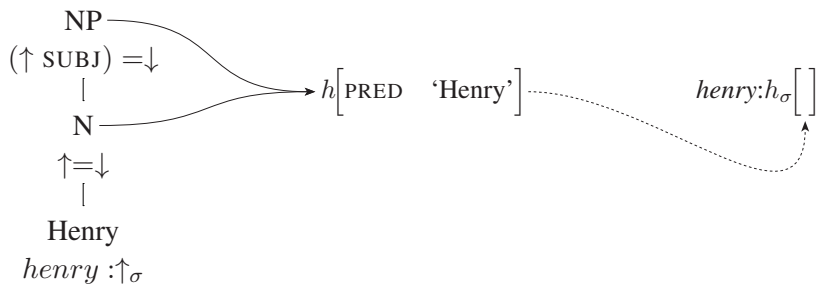
It is possible to use glue successfully, and in very detailed and complex ways, without considering glue expressions in any other way than that just described, i.e. as the means of constraining and determining semantic composition. However, this is not the whole story. The basic elements of glue expressions are formulae like $\uparrow_\sigma$ or $(\uparrow \text{SUBJ})_\sigma$; these formulae refer to *semantic structures*. These s(emantic)-structures are projected from f-structures via the projection function σ (Kaplan 1987, 1989), and thus provide the means by which semantics is integrated into the projection architecture.

A meaning constructor such as that in (2a) associates a meaning with an s-structure, via the glue expression with which the meaning is paired.[1] So $\uparrow_\sigma$ in the meaning constructor in (2a), for example, refers to an s-structure projected from the f-structure $\uparrow$, i.e. the f-structure projected from the preterminal node of the

[1] In 'old' style glue, meanings were directly associated with s-structures, as described by Dalrymple et al. (1997, 1999b), and as explicitly represented in the symbolism ($\uparrow_\sigma \rightsquigarrow meaning$). In the 'new' glue format, this association is indirect, via the pairing of meanings with glue expressions that refer to s-structures, but this difference is not entirely clear from the presentations in e.g. Dalrymple (2001) or Dalrymple and Nikolaeva (2011: 72).

c-structure which dominates the word concerned. Example (4) provides a partial configuration for (1), showing the c-structure and f-structure for the subject noun phrase *Henry*; the s-structure h_σ is projected from the f-structure h, and it is this s-structure with which the meaning $henry$ is associated by the meaning constructor $henry : \uparrow_\sigma$.

(4)



It is a moot point whether s-structures are inherently typed; typing of s-structures is in some sense irrelevant, since it is always directly inferrable from the meaning side of a meaning constructor, and since type alone never serves to distinguish one s-structure from another. Either way, in the current formulation of glue all s-structures are of, or correspond to meanings of, type e or type t. Only meanings of type e or t, then, can be associated with a *single* structure. More complex meanings are not associated with a single semantic structure, but with a relation, usually involving linear implication, between two or more structures. So the meaning $\lambda x.sleep(x)$ in (2b) is of type $\langle e \rightarrow t \rangle$, and accordingly the glue expression with which it is paired expresses a linear implication from an s-structure of type e (i.e. h_σ in 4) to an s-structure of type t, which is the semantic structure for the clause.

3 Features in s-structure

Glue expressions therefore have two related but distinct functions: they specify how meanings can be combined, and they do this by associating meanings with semantic structures. While the former function is naturally of considerable importance in any glue work, the latter function has been somewhat overlooked.

The association of meanings with s-structures has perhaps been ignored because very little information generally appears in s-structures. The initial motivation for s-structures was the need for more information in the semantic projection than simply the meanings projected from f-structure. In the original glue system of Dalrymple et al. (1993) meanings were directly projected from f-structures via σ, but semantic structures were introduced as a point of mediation between f-structure and meaning by Dalrymple et al. (1996), "because in general semantic projections carry more information than just the association to the meaning for the corresponding f-structure." For Dalrymple et al. (1996) this involved internally complex s-structures for nouns, with further s-structures embedded under the attributes VAR

and RESTR. Another long-standing s-structure feature is ANTECEDENT, used in anaphoric binding equations (Asudeh 2012: 69–71). Other phenomena also require s-structures to be embedded within other s-structures, including e.g. treatments of tense and aspect in glue (e.g. Fry 2005, Haug 2008, Lowe 2015), and the proposals of Asudeh and Giorgolo (2012) that argument structure relations be captured in semantic structure. Besides this embedding, however, no other features are traditionally assumed to appear in s-structure, meaning that any semantic derivation will necessarily involve a number of empty s-structures.[2] In comparison with f-structures, then, s-structures seem distinctly less purposeful. Some authors, such as Andrews (2007, 2008, 2010) and Kokkonidis (2008: discussed in §7), have proposed alternative models of glue which lack semantic structures.

A more significant role for s-structures is envisaged by Dalrymple and Nikolaeva (2011), in their proposals regarding i-structure in LFG. They propose that semantic structures are the locus for expressing i-structural and discourse-relevant properties of the elements of meaning in a sentence. For example, Dalrymple and Nikolaeva (2011: 79) rewrite the meaning constructor *john*:$\uparrow_\sigma$, appearing in a particular linguistic context where it is identifiable and topical, as follows:

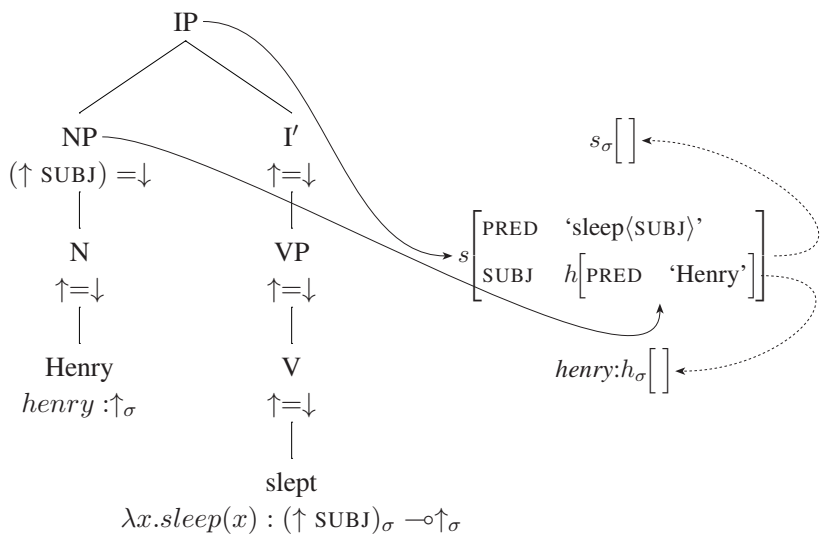
(5)
$$\textit{john}: \begin{bmatrix} \text{ANIMATE} & + \\ \text{HUMAN} & + \\ \text{STATUS} & \text{IDENTIFIABLE} \\ \text{ACTV} & \text{ACTIVE} \\ \text{DF} & \text{TOPIC} \end{bmatrix}$$

The meaning $john$ is associated with an s-structure, just like the meaning $henry$ in (4) above. This structure is not empty, however, but contains a variety of features relating to the discourse status of the meaning. The meaning $john$ in the context they assume has animate, human reference, is identifiable and active in the discourse, and is a topic at i-structure. These features relate to the meaning, not the corresponding syntactic unit, and are relevant not at the level of syntax but at the level of the discourse; they are therefore most appropriately represented at semantic structure and not, for example, at f-structure.

Using s-structures to represent discourse-relevant features such as these potentially opens up new avenues for the analysis of semantic and discourse phenomena in LFG. However, there are limitations to the use of s-structures in this way. A simple e type meaning such as a proper name is, as discussed above, associated with a single s-structure. But more complex meanings are not directly associated with a single structure. Consider again the sentence in (1); we can assume the simplified c-structure, f-structure and s-structure for this sentence provided in (6).

[2] As observed by Dalrymple apud Kokkonidis (2008: 63), this is formally problematic since empty structures would ordinarily be considered indistinguishable.

(6)



There are two s-structures involved in the analysis of this clause: h_σ, projected from the f-structure for the subject (as in 4), and s_σ, projected from the f-structure for the clause and verb. The semantic composition proceeds by reference to only these two structures: instantiating the variables in the glue expressions, the premises are h_σ and $h_\sigma \multimap s_\sigma$, from which we can conclude s_σ. The meaning associated with h_σ is $henry$, and the meaning associated with s_σ is the meaning that we conclude: $sleep(henry)$. But this means that we can only express discourse-relevant properties of these two meanings; there is no corresponding structure for the meaning of the verb: it is not directly associated with either structure, but with a relation between the two structures.

The same problem will of course apply to any meaning that is more complicated than a simple e or t type. As we will see, there are many complex meanings to which discourse-relevant properties can be attributed, such that some strategy is needed for circumventing the lack of appropriate s-structures. Before proposing such a strategy, I will discuss how Dalrymple and Nikolaeva (2011) license the application of s-structure features to complex meanings, albeit in a limited way.

4 I-structure features and the verb

In exemplifying their model of i-structure, Dalrymple and Nikolaeva (2011: 91) categorize a complex meaning, specifically a verbal meaning of similar form to that in (2b), at i-structure on the basis of their s-structure DF feature. The way in which they achieve this is limited in its potential application, however. I illustrate their analysis using the sentence in (1), taking the subject *Henry* to be topical and the verb to be in focus. The meaning constructors in (7) are taken to produce the i-structure in (8); the f-structure labels are the same as in (6).

(7) a. *henry* : h_σ[DF TOPIC]

b. $\lambda x.sleep(x) : h_\sigma \multimap s_\sigma[\text{DF FOCUS}]$

(8) $$\begin{bmatrix} \text{TOPIC} & \{henry : h_\sigma\} \\ \text{FOCUS} & \{\lambda x.sleep(x) : h_\sigma \multimap s_\sigma\} \end{bmatrix}$$

The critical line is (7b). The meaning constructor $\lambda x.sleep(x) : h_\sigma \multimap s_\sigma$, and by implication the meaning $\lambda x.sleep(x)$, is categorized in the focus set at i-structure by virtue of the feature DF FOCUS appearing in the s-structure s_σ. The rule that achieves this is the rule of i-structure categorization associated with all meanings in the lexicon:

(9) **meaning-constructor** $\in (\uparrow_{\sigma\iota} (\uparrow_\sigma \text{DF}))$

In the sentence under discussion, s is the f-structure for the clause, with PRED 'sleep⟨SUBJ⟩'. The s-structure $\uparrow_\sigma$ for the verb is therefore s_σ, and so the feature DF FOCUS in s_σ means that, by (9), the verbal meaning constructor is correctly categorized in the FOCUS set at i-structure.

While this is formally unproblematic, certain problems can be raised. Firstly, as stated, Dalrymple and Nikolaeva (2011) categorize the meaning constructor for *sleep* (7b) as part of the FOCUS set at i-structure by virtue of the feature DF FOCUS appearing in the s-structure s_σ. But, as should now be clear, the meaning $\lambda x.sleep(x)$ itself is not the meaning that is associated with s_σ. s_σ is (associated with a meaning) of type t, while $\lambda x.sleep(x)$ is of type $\langle e \rightarrow t\rangle$. The meaning associated with the s-structure s_σ is the meaning that results from applying $\lambda x.sleep(x)$ to the meaning of the subject, i.e. $sleep(henry)$. For Dalrymple and Nikolaeva (2011) this does not matter, because they are not concerned with categorizing the meaning $sleep(henry)$, nor the meaning constructor $sleep(henry) : s_\sigma$, at i-structure: they are categorizing only the lexically introduced meaning constructors in (7), and since $\uparrow_\sigma$ for the verb is s_σ, everything works out.

Looking back to (5), the appearance of discourse-relevant features in an s-structure was taken to represent features of the meaning associated with that structure. But this is not how Dalrymple and Nikolaeva (2011) use the DF feature that appears in s_σ: it is not used to express that the full clausal meaning $sleep(henry)$ has discourse function FOCUS at i-structure, only that the verb does. So the feature DF FOCUS in s_σ does not express any property of s_σ, but is used to categorize a different meaning (albeit a meaning that constitutes a part of s_σ) at i-structure. Although, as stated, this works perfectly well for their purposes, the analysis given by Dalrymple and Nikolaeva (2011: 91) implies the following meaning constructor:

(10) *sleep(henry)*: $\begin{bmatrix} \text{DF} & \text{FOCUS} \end{bmatrix}$

But while the feature DF TOPIC in (5) implies that the meaning *john* is in the TOPIC set at i-structure, the equivalent feature in (10) does not have the same implication for the meaning $sleep(henry)$. For Dalrymple and Nikolaeva (2011), then,

the feature DF is of a different order from other s-structure features such as appear in (5). While features like ANIMATE + and ACTV ACTIVE are semantically contentful and represent specific discourse features of the associated meaning, the DF feature is simply a label that is used to categorize lexically introduced meanings at i-structure, a label that has no semantic content and does not necessarily represent a discourse-relevant feature of the meaning with which it is associated.

It is a less elegant model that admits two types of s-structure feature, one contentful and applicable to the meaning associated with the s-structure in which it appears, the other not contentful and not applicable to the associated meaning. More seriously, however, Dalrymple and Nikolaeva's use of DF implies that there can be only one i-structure categorization for all meanings (or meaning constructors) projected from a single f-structure. Since σ is a function, an f-structure can be associated with at most one s-structure, and since there can be only a single DF feature in any one s-structure, all meanings associated with an f-structure must share the same i-structure categorization. This causes no problem when dealing with simplified verbal meanings like $\lambda x.sleep(x)$ and with proper name meanings like $henry$. But problems do arise under attempts to treat more complex semantic analyses.

Under an event semantic approach to verbal meanings, for example, a word like *slept* would have not the single meaning constructor in (2b), but could have the four in (11): (11a) represents the basic verbal meaning; (11b) represents perfective aspect; (11c) represents past tense; and (11d) represents finiteness, functioning to close off the open temporal variable.[3]

(11) a. $\lambda x.\lambda e.sleep(e) \wedge theme(e,x) : (\uparrow \text{SUBJ})_\sigma \multimap (\uparrow_\sigma \text{EV}) \multimap \uparrow_\sigma$

b. $\lambda P.\lambda t.\exists e.P(e) \wedge \tau(e) \prec t : ((\uparrow_\sigma \text{EV}) \multimap \uparrow_\sigma) \multimap (\uparrow_\sigma \text{RT}) \multimap \uparrow_\sigma$

c. $\lambda P.\lambda t'.\exists t.P(t) \wedge t \subseteq t' : ((\uparrow_\sigma \text{RT}) \multimap \uparrow_\sigma) \multimap (\uparrow_\sigma \text{PT}) \multimap \uparrow_\sigma$

d. $\lambda P.\exists t.P(t) : ((\uparrow_\sigma \text{PT}) \multimap \uparrow_\sigma) \multimap \uparrow_\sigma$

Since all these meanings are part of the lexical meaning of the verb, they must be introduced in the lexical entry of the verb. As such, they will all be projected from the same f-structure, i.e. the f-structure for which the verb provides the PRED. The same is true of periphrastic verb forms, at least those that are best analysed using a monoclausal rather than multiclausal f-structure. According to Falk (2003, 2008), supportive *do*, perfective *have*, and the modals *will*, *shall* and *would* are feature-carriers that do not head their own f-structure, while progressive *be* and the other modals are argument-taking predicates that do head their own f-structures.[4] This means that the f-structures for all the sentences in (12) will be structurally parallel to that in (3): there is only the outer f-structure, corresponding to the verb/clause, and one embedded f-structure, corresponding to the subject. This is exemplified in (13) for (12d).

[3]This assumes, for the sake of argument, that the English simple past is a past perfective category. The meanings constructors here are based on Haug (2008) and Lowe (2012, 2015).

[4]Dyvik (1999) argues for a similarly varied approach to Norwegian auxiliaries and modals.

(12) a. Henry did sleep.
b. Henry has slept.
c. Henry will sleep.
d. Henry will have slept.

(13)
$$\begin{bmatrix} \text{PRED} & \text{`sleep}\langle\text{SUBJ}\rangle\text{'} \\ \text{TENSE} & \text{FUTURE} \\ \text{ASPECT} & \text{PERFECTIVE} \\ \text{SUBJ} & \begin{bmatrix} \text{PRED} & \text{`Henry'} \end{bmatrix} \end{bmatrix}$$

The problem with Dalrymple and Nikolaeva's (2011) use of DF for i-structure categorization is that, since there is only a single f-structure corresponding to a periphrastic verb form like *will have slept*, all elements of the verb's meaning, including the basic verbal meaning and tense and aspect, must be categorized in the same set at i-structure. But it is perfectly possible for an auxiliary like *have*, or a modal like *will*, to be focused while the lexical verbal meaning is topical or backgrounded.

(14) Q. Have you found it?
A. I *had* found it (but I lost it again).

(15) Q. Have you read my paper?
A. No, but I *will* read it soon.

An i-structure analysis of (14), for example, should be able to categorize the meaning of past tense as 'in focus', but the other elements of the verbal meaning, including the basic lexical meaning, as backgrounded.[5]

Even on a more simple model that ignores tense and aspect, it is necessary to be able to distinguish the part of a verb's meaning that expresses the occurrence of an event from the part that expresses the event type (the basic verbal meaning). The answer in (16) is about Anna doing something; the fact that Anna did something is therefore not part of the focused material in the clause. What is focused is the nature, the kind, of the event that Anna undertook.[6] This can be analysed under a simplified event semantics, ignoring tense and aspect and assuming only two separate meaning constructors for the verb form *hit*, as in (17). The meaning constructor labelled **hit** will be categorized as 'in focus' at i-structure, whereas that labelled **event** will not. But under Dalrymple and Nikolaeva's model, there is no way to distinguish these meanings at i-structure, since both will be associated with the same f-structure and by implication with the same s-structure.

(16) Q. What did Anna do?
A. Anna hit Norman.

[5] I pass over here the problematic question of the tense and aspect properties of the English 'perfect', which have been widely discussed, e.g. by Bauer (1970), McCawley (1981), Klein (1992), Michaelis (1994), Kiparsky (2002), Katz (2003), Mittwoch (2008), and Meyer-Viol and Jones (2011).

[6] This intuition comes originally from Mycock (2009).

(17) a. **hit**: $\lambda y.\lambda x.\lambda e.hit(e) \wedge agent(e,x) \wedge patient(e,y) : (\uparrow \text{OBJ})_\sigma \multimap (\uparrow \text{SUBJ})_\sigma \multimap (\uparrow_\sigma \text{EV}) \multimap \uparrow_\sigma$

b. **event**: $\lambda P.\exists e.P(e) : ((\uparrow_\sigma \text{EV}) \multimap \uparrow_\sigma) \multimap \uparrow_\sigma$

Similarly, simple verbal negation does not usually involve a separate structure at f-structure, merely a feature such as POLARITY $-$, but it is incontestable that English *not*, for example, can be focused in separation from the verbal meaning it negates.

The problem may also extend to the categorization of non-verbal meanings. In (18), the answer is about the fact that some person or set of people ruined the economy, and the focused meaning, which supplies the information requested in the question, is who that person or set of people is.

(18) Q. Who ruined the economy?

A. Socialists ruined the economy.

It is therefore necessary to distinguish the part of the meaning of *Socialists* that refers to the existence of an entity from the part that refers to what kind of entity we are dealing with.[7] But there is only a single f-structure corresponding to *Socialists*, and only a single s-structure projected from that f-structure, which means that under Dalrymple and Nikolaeva's (2011) proposals all meaning constructors associated with this word must be categorized in the same way at i-structure, despite the information structural differences between the entity and entity-kind parts of the word's meaning.[8]

These problems are a manifestation of the long-standing problem of i-structure analysis is LFG, the so-called 'granularity problem'. Originally, this term referred to the fact that f-structure does not have sufficient granularity to be used as a basis for i-structure distinctions (King 1997). Most obviously, there is no f-structure that contains the verb and not also all of its arguments and adjuncts, so any model of i-structure that is based on f-structure is unable to represent phenomena such as narrow verb focus, or even the focusing of a verb and one, but not all, of its arguments.

Dalrymple and Nikolaeva's (2011) model of i-structure uses s-structure as the basis of i-structure categorization. Since it is a projection of f-structure, s-structure is (under normal assumptions) no more fine-grained. As described above, however,

[7] The distinction between the part of a noun's meaning that refers to the existence of an entity, and the part that refers to the kind of entity, was captured by the original use of the s-structure attributes VAR and RESTR in the 'old-style' glue formulation of Dalrymple et al. (1997: 236): "The value of VAR will play the role of *restr-arg*, supplying an entity-type variable, and the value of RESTR will play the role of *restr* in the meaning constructor of the determiner [$\approx$ a common noun meaning]." In 'new-style' glue, however, while VAR and RESTR remain, they no longer formally capture this distinction, since no lexically introduced meanings are directly associated with them.

[8] In the case of nouns with a determiner in English, it may be possible to make such a distinction by associating the reference to the existence of an entity with the determiner rather than with the noun itself, as long as SPEC is assumed to take an f-structure, not an atomic label, as its value.

Dalrymple and Nikolaeva set up their formalism in such a way as to permit the distinction of a verb from its arguments, by using the clausal s-structure to categorize the verbal meaning constructor and not the clausal meaning. But their model is unable to make finer information structural distinctions; in particular, it is unable to distinguish different parts of the meaning of a single word.

The other major model of i-structure in LFG is that of King (1997) and Butt and King (1997). As a way to avoid the granularity problem, they propose that i-structure be projected from c-structure, since c-structure does have sufficient granularity to distinguish a verb from its dependents. However, c-structure is also insufficiently fine-grained to permit different parts of a single word to be distinguished, since the granularity of c-structure is by definition restricted to the word level.[9]

To summarize the points made in this section, Dalrymple and Nikolaeva (2011) use the s-structure DF feature as a label to categorize both simple e or t type meanings, and more complex meanings, at i-structure. However, the means by which this is achieved has limitations: all meaning constructors projected from a single f-structure must necessarily be categorized in the same way at i-structure, which does not permit finer information structural distinctions to be made between different elements of verbal or nominal meanings. Their model therefore succumbs to a form of the granularity problem (which also equally affects the other major approach to i-structure in LFG).[10] Furthermore, all s-structures are of type e or t, so there are no s-structures in which *contentful* discourse features (as opposed to mere labels, like DF) of more complex meanings can be represented.

5 Complex-typed structures

Both these problems would disappear if every lexically introduced meaning, including those of complex type, were directly associated with a single semantic structure in the same way as the meaning $john$ is associated with a single s-structure in (5). As discussed above, however, under common assumptions (e.g. in Dalrymple 2001) all s-structures are (or are associated with) simple types, that is e or t, and complex meanings like $\lambda x.sleep(x)$ are not associated with a single s-structure but with a relation between multiple s-structures.

One way to look at this problem is that it derives from the dual function of glue expressions: glue expressions state constraints on semantic composition, but they do this by associating meanings with semantic structures or with relations between semantic structures. If the association with structures is treated merely as a feature of the architecture, and structures themselves as largely empty and little more than book-keeping devices, this dual functionality is unproblematic. But when, as proposed by Dalrymple and Nikolaeva (2011), the association with

[9] Moreover, the projection of i-structure from c-structure does not reflect the fact that i-structure is closely related to semantic structure and meaning (Mycock 2009).

[10] An approach to i-structure that incorporates the insights made here and consequently avoids the graularity problem altogether is proposed by Lowe and Mycock (2014).

semantic structures is used to provide a means for representing discourse-relevant features of meanings, a conflict arises with their other function: where a meaning is complex, the constraints on its composition with other meanings will involve reference to more than one s-structure, with the result that the glue expression cannot associate the meaning itself with a single s-structure, and there is nowhere for discourse-relevant features to be represented.

This conflict can be resolved by decomposing glue expressions of the traditional sort into two expressions, one of which functions to associate a meaning with a single semantic structure and the other of which states the necessary constraints on semantic composition.[11] I therefore propose that instead of a meaning constructor like (19), we in fact have two meaning constructors, as in (20).

(19) $\lambda x.sleep(x) : (\uparrow \text{SUBJ}) \multimap \uparrow_\sigma$

(20) a. $\lambda x.sleep(x) : (\uparrow_\sigma \text{REL})$

b. $\lambda P.P : (\uparrow_\sigma \text{REL}) \multimap (\uparrow \text{SUBJ})_\sigma \multimap \uparrow_\sigma$

In (20a), the meaning $\lambda x.sleep(x)$ is associated with a single, uniquely labelled, s-structure.[12] This structure can then be used in whatever way required to specify the i-structure categorization of the verbal meaning. A meaning constructor like this does not, however, include the necessary information for constraining semantic composition. It must therefore be composed with a meaning constructor that does contain the necessary information, as in (20b). This meaning constructor has an identity function on the meaning side, so it effectively makes no contribution to the meaning. Its glue expression, on the other hand, takes as input the same uniquely labelled structure as in (20a), and outputs a glue expression of the 'usual' sort, complete with the necessary information for correct semantic composition. The meaning constructor in (19) is the product of the application of (20b) to (20a); meaning constructors of the 'usual' sort can therefore be treated as compositions of two more basic meaning constructors.

[11] The decomposition of meaning constructors in the context of functional conflicts similar to this has a good pedigree in glue; cf. in particular the decomposition of adjectival meanings to permit recursive modification, as described by Dalrymple (2001: 264–269).

[12] Insofar as s-structures are typed (or at least associated with types), the uniquely labelled s-structures proposed here can be of complex type (when paired with a complex meaning on the meaning side of the glue expression). The s-structure $(\uparrow_\sigma \text{REL})$ in (20), for example, represents (or is) type $\langle e \rightarrow t \rangle$, since the meaning $\lambda x.sleep(x)$ is of this type. That is, to repeat (20) with types explicitly indicated:

(i) a. $\lambda x.sleep(x) : (\uparrow_\sigma \text{REL})_{\langle e \rightarrow t \rangle}$

b. $\lambda P.P : (\uparrow_\sigma \text{REL})_{\langle e \rightarrow t \rangle} \multimap (\uparrow \text{SUBJ})_{\sigma\langle e \rangle} \multimap \uparrow_{\sigma\langle t \rangle}$

In the case of a transitive verb, the uniquely labelled structure paired with it would be of (or would represent) type $\langle e \rightarrow \langle e \rightarrow t \rangle \rangle$, and so on. Ordinarily, s-structures are assumed to represent only simple types, but there is nothing to prevent the assumption of complex-typed structures. In the following, I do not explicitly represent or discuss the typing; the interested reader can easily infer types from the meaning side.

We cannot treat $\uparrow_\sigma$ as the uniquely labelled structure for any word, since in the case of a verb $\uparrow_\sigma$ is associated with a meaning of type t, while in the case of a noun it may be associated with a meaning of type e. I therefore make use of the s-structure attribute REL, using $(\uparrow_\sigma \text{ REL})$ as the uniquely labelled structure for verbal meanings. This differs somewhat from the use of the s-structure attribute REL by e.g. Asudeh et al. (2008, 2013), but shares the same intuition that $(\uparrow_\sigma \text{ REL})$ refers to the basic verbal meaning, specifying the kind of event referred to by the verb. We likewise require an embedded s-structure (i.e. not $\uparrow_\sigma$) to use as the uniquely labelled structure for the basic meanings of other kinds of words, such as nouns and adjectives. For consistency, I propose $(\uparrow_\sigma \text{ REL})$ be used for the basic meaning of all words.[13] For example, the basic meaning of a noun like *student* is composed of the two meaning constructors in (21). Similarly, for the basic lexical meaning of an adjective like *old*, I assume the two meaning constructors in (22).[14] Meaning constructors for the determiner *the* are given in (23).[15]

(21) a. $\lambda x.student(x) : (\uparrow_\sigma \text{ REL})$

b. $\lambda P.P : (\uparrow_\sigma \text{ REL}) \multimap (\uparrow_\sigma \text{ VAR}) \multimap (\uparrow_\sigma \text{ RESTR})$

(22) a. $\lambda x.old(x, P) : (\uparrow_\sigma \text{ REL})$

b. $\lambda P.P : (\uparrow_\sigma \text{ REL}) \multimap (\uparrow_\sigma \text{ VAR}) \multimap \uparrow_\sigma$

(23) a. $\lambda P.\lambda Q.\iota x.P(x) \wedge Q(x) : (\uparrow_\sigma \text{ REL})$

b. $\lambda P.P : \forall\alpha.(\uparrow_\sigma \text{ REL}) \multimap (((\text{SPEC } \uparrow)_\sigma \text{VAR}) \multimap$
$((\text{SPEC } \uparrow)_\sigma \text{RESTR})) \multimap ((\text{SPEC } \uparrow)_\sigma \multimap \alpha) \multimap \alpha$

[13] An alternative, which would avoid positing an embedded s-structure, would be for the basic lexical meaning of all words to be associated with $(\uparrow \text{ PRED})_\sigma$ (which would, satisfyingly, restore some value to the label 'semantic form'). I avoid this, however, since embedded s-structures are required for words with more than one component to their meaning, as discussed in the next section; assuming an embedded structure $(\uparrow_\sigma \text{ REL})$ here too results in a more consistent model.

[14] A consequence of the proposals made here is that the use of $(\uparrow_\sigma \text{ VAR})$ and $(\uparrow_\sigma \text{ RESTR})$ in the meaning constructors for nouns and adjectives is no longer necessary. That is, $(\uparrow_\sigma \text{ REL})$ in (21) and (22) alone represents the complexity of the noun and adjective meanings (which is the only thing VAR and RESTR do in 'new' glue: cf. fn. 12). The meaning constructors in (21b) and (22b), then, are strictly speaking unnecessary, but I retain them for consistency with more traditional glue analyses, so that glue expressions of the 'usual' sort can always be derived by composition of the lexical meaning with the identity function. Furthermore, as discussed in Lowe (2013), the basic lexical meanings of adjectives, and possibly also nouns, need to be combined with other meaning constructors in particular syntactic contexts in order to compose correctly with other meanings. For example, a meaning constructor like $\lambda x.old(x, P) : (\uparrow_\sigma \text{ VAR}) \multimap \uparrow_\sigma$, which is the composition of (22a) and (22b), must be combined with one meaning constructor in order to function as a modifier, and with another in order to function as the main predication in a nominal sentence. Since they are dependent on syntactic context, these additional meaning constructors must be introduced in the syntax, i.e. we are dealing with constructional meanings (Lowe 2013: 407). Therefore the function of the meaning constructors in (21b) and (22b) can alternatively be covered by the constructionally introduced meaning constructors, confirming their superfluity.

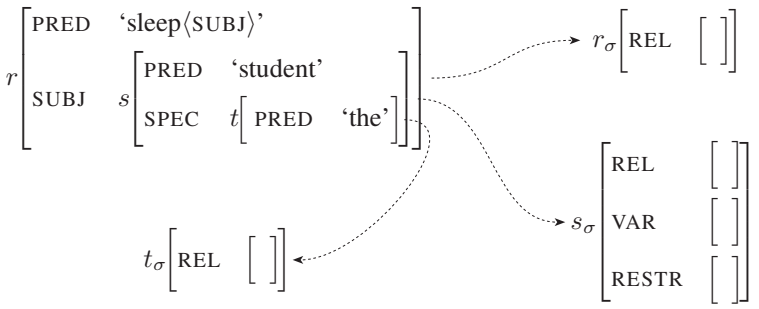
[15] It is not clear that *all* meaning constructors of the 'standard' sort need to be split: constructional meanings, for example, do not participate in discourse relations in the same way as lexical meanings, so it may be unnecessary to assume single structures with which to associate them.

The s-structure referred to by the glue term $(\uparrow_\sigma \text{ REL})$ will be unique to each lexical element in a clause; $(\uparrow_\sigma \text{ REL})$ appears in both the (a) and (b) meaning constructors for any word, ensuring that each identity meaning combines with the correct lexical meaning.

As a simple example, I analyse the sentence in (24). The f-structure and s-structures are provided in (25); the important point here is the presence of the s-structures embedded under the REL attributes. The glue proof for the sentence is given in Fig. (1), based on the meaning constructors provided above and instantiating the metavariables according to the labels in (25). It proceeds in entirely parallel manner to a 'regular' glue derivation of this sentence, since the two meaning constructors assumed for each word compose into a single meaning constructor of the 'usual' form.

(24) The student read.

(25)

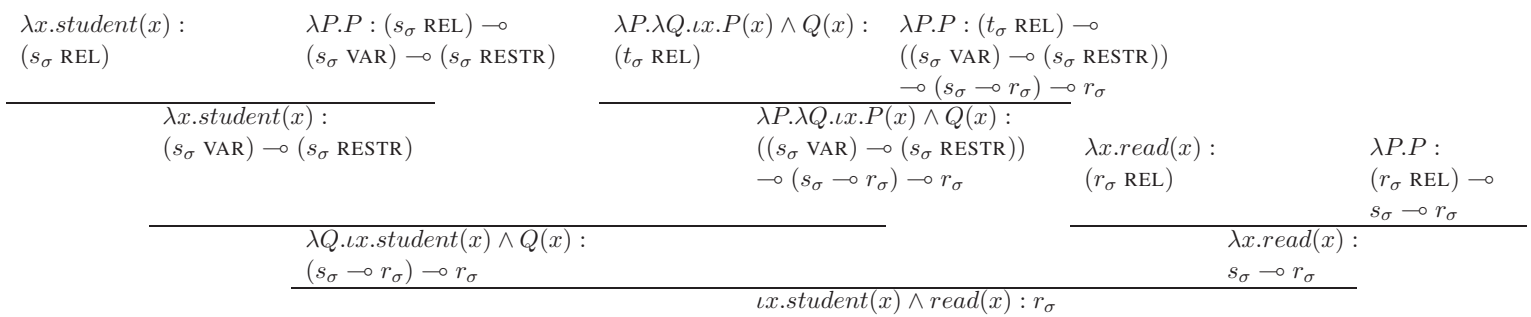


6 Multiple meanings per word

The proposal thus far solves the problem that complex meanings are not associated with a single s-structure, by introducing uniquely labelled structures with which they can be associated. The examples given in the previous section treat all words as contributing only one meaning, which in each case is associated with an s-structure $(\uparrow_\sigma \text{ REL})$ of appropriate type. As discussed above, however, it is sometimes necessary to distinguish different parts of the meaning of a single word (including periphrastic verb forms), such as the tense and aspect meanings of a verb, or the entity and entity-kind meanings of a noun.

Essentially, we can assume as many uniquely labelled structures as necessary for a particular word, i.e. as many as the number of meaning constructors assumed. The inventory of meaning constructors, and therefore uniquely labelled structures, required for any particular word or word type may vary according to the level of semantic detail required and possibly the semantic representation used, but the principle remains the same. These structures will be embedded within the s-structure projected from the f-structure associated with the word concerned, just like the

Figure 1: Glue proof for (24)



value of $(\uparrow_\sigma \text{REL})$, but must of course be values of different attributes. For example, if we assume a four-way division of verbal meaning into event-kind (i.e. the basic lexical meaning), aspect, tense and finiteness, as in (11), the four meanings concerned can be associated with the structures $(\uparrow_\sigma \text{REL})$, $(\uparrow_\sigma \text{ASP})$, $(\uparrow_\sigma \text{TNS})$ and $(\uparrow_\sigma \text{FIN})$ respectively.[16] The four meaning constructors in (11) can then be treated as compositions of the eight meaning constructors in (26).

(26) a. i. $\lambda x.\lambda e.sleep(e) \wedge theme(e,x) : (\uparrow_\sigma \text{REL})$
ii. $\lambda P.P : (\uparrow_\sigma \text{REL}) \multimap (\uparrow \text{SUBJ})_\sigma \multimap (\uparrow_\sigma \text{EV}) \multimap \uparrow_\sigma$

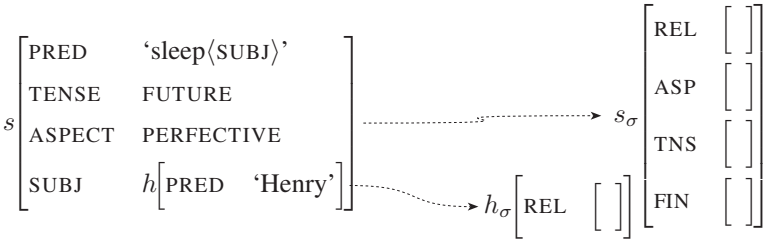
b. i. $\lambda P.\lambda t.\exists e.P(e) \wedge \tau(e) \prec t : (\uparrow_\sigma \text{ASP})$
ii. $\lambda P.P : (\uparrow_\sigma \text{ASP}) \multimap ((\uparrow_\sigma \text{EV}) \multimap \uparrow_\sigma) \multimap (\uparrow_\sigma \text{RT}) \multimap \uparrow_\sigma$

c. i. $\lambda P.\lambda t'.\exists t.P(t) \wedge t \subseteq t' : (\uparrow_\sigma \text{TNS})$
ii. $\lambda P.P : (\uparrow_\sigma \text{TNS}) \multimap ((\uparrow_\sigma \text{RT}) \multimap \uparrow_\sigma) \multimap (\uparrow_\sigma \text{PT}) \multimap \uparrow_\sigma$

d. i. $\lambda P.\exists t.P(t) : (\uparrow_\sigma \text{FIN})$
ii. $\lambda P.P : (\uparrow_\sigma \text{FIN}) \multimap ((\uparrow_\sigma \text{PT}) \multimap \uparrow_\sigma) \multimap \uparrow_\sigma$

Example (27) shows the embedding of s-structures that is implied by this in the analysis of (12d):

(27)



If we assume only a two-way division of verbal meaning into event and event-kind, as in (17), we require only two uniquely labelled structures; insofar as it provides existential closure for the verbal meaning(s) in the same way that finiteness does in the four-way division, we can treat the event meaning as associated with $(\uparrow_\sigma \text{FIN})$. Negatives like English *not* can be associated with a structure $(\uparrow_\sigma \text{NEG})$. Similarly, in order to capture the two parts of meaning of an indefinite plural like *Socialists* in (18b), we require reference to two distinct embedded structures, $(\uparrow_\sigma \text{REL})$ for the basic lexical meaning, and $(\uparrow_\sigma \text{ENT})$ for the existence of one or more entities. This can be achieved by assuming four meaning constructors in (28) for *Socialists*.[17]

(28) a. i. $\lambda x.Socialist(x) : (\uparrow_\sigma \text{REL})$

[16] These are alongside and in addition to the embedded stuctures usually assumed in treatments of event semantics, such as $(\uparrow_\sigma \text{EV})$/$(\uparrow_\sigma \text{EVENT})$ etc. (Fry 2005, Haug 2008, Lowe 2012, 2015, Asudeh 2012: 341–342); but see also §7.

[17] I ignore here the representation of plurality in the semantics.

ii. $\lambda P.P : (\uparrow_\sigma \text{ REL}) \multimap (\uparrow_\sigma \text{ VAR}) \multimap (\uparrow_\sigma \text{ RESTR})$

b. i. $\lambda P.\lambda Q.\exists x.P(x) \wedge Q(x) : (\uparrow_\sigma \text{ ENT})$

ii. $\lambda P.P : \forall \alpha.(\uparrow_\sigma \text{ ENT}) \multimap ((\uparrow_\sigma \text{ VAR}) \multimap (\uparrow_\sigma \text{ RESTR})) \multimap (\uparrow_\sigma \multimap \alpha) \multimap \alpha$

7 A first-order alternative

Kokkonidis (2008) discusses the development of glue and the place of s-structures within its different formulations. He argues that the assumption of a set of largely empty s-structures is questionable in the current glue formulation, and proposes a 'first-order' alternative that eliminates the need for s-structures. This structureless glue formulation is adopted by Bary and Haug (2011). In Kokkonidis' first-order glue, the terms of glue expressions are not semantic structures projected from f-structures, but the types E and T, treated as base type constructors taking f-structure labels as arguments.[18] So in 'first-order' glue, the meaning constructor in (2b), repeated as (29), is replaced by the meaning constructor in (30). $E_{(\uparrow \text{SUBJ})}$ and $T_\uparrow$ are base types, and composition is constrained by the types in the glue expressions without any need for semantic structures as a mediation between syntax and meaning.

(29) $\lambda x.sleep(x) : (\uparrow \text{ SUBJ})_\sigma \multimap \uparrow_\sigma$

(30) $\lambda x.sleep(x) : E_{(\uparrow \text{SUBJ})} \multimap T_\uparrow$

Under the proposals of Dalrymple and Nikolaeva (2011), as discussed above, there are good reasons to retain s-structures, since they are the locus for representing discourse-relevant features of meanings. However, the 'splitting' of meaning constructors proposed in this paper leads to a functional split between different sorts of semantic structures. The proposed uniquely labelled s-structures, i.e. the embedded structures with which a meaning is associated in the lexicon, are the structures in which discourse-relevant features are represented. On the other hand most or all of the embedded s-structures previously assumed in glue, such as $(\uparrow_\sigma \text{ VAR})$, $(\uparrow_\sigma \text{ RESTR})$ etc., do not contain such features, since no meaning is directly associated with them.

It may therefore be possible under the present proposals to combine the more traditional projection of s-structures, and Dalrymple and Nikolaeva's (2011) use of s-structures for the representation of discourse features, with Kokkonidis' (2008) structureless first-order glue. This would involve retaining the meaning constructors proposed above that associate meanings with uniquely labelled structures such as $(\uparrow_\sigma \text{ REL})$, but altering the identity constructors so that they convert glue expressions referring to s-structures into first-order glue expressions. For example, in place of (20) above, we would have:

[18] Bary and Haug (2011) propose that base type constructors should not be limited to E and T but can include, for example, constructors referring to events, times, etc.

(31) a. $\lambda x.sleep(x) : (\uparrow_\sigma \text{REL})$

b. $\lambda P.P : (\uparrow_\sigma \text{REL}) \multimap E_{(\uparrow \text{SUBJ})} \multimap T_\uparrow$

Under such an approach, the only s-structures required in the semantic analysis would be those that can host discourse-relevant features and that are relevant for i-structure categorization, and also the s-structures in which those are embedded. Crucially, there would be no necessarily empty s-structures; this approach would therefore preserve this major advantage of Kokkonidis' model, while also permitting the use of s-structures to host discourse relevant features.

8 Conclusion

Semantic structures have been as it were the poor relation in LFG's projection architecture, their existence implied by all standard glue expressions but rarely considered to have any independent significance outside their function within those expressions. The use of s-structures to represent the discourse-relevant features of meanings, however, is an important step forward in the task of tackling discourse-level phenomena within LFG. In this paper I have demonstrated the need for a set of uniquely labelled, embedded semantic structures, in which the discourse-relevant features of complex meanings can be represented. I have proposed that meaning constructors of the 'standard' form be split, and be considered compositions of two separate meaning constructors, one of which associates the lexical meaning with an s-structure of the appropriate type, and another which converts the glue expression of the former into a glue expression of the 'standard' form. Furthermore, the proposal made here effects a solution to the so-called 'granularity problem' of i-structure analysis in LFG, by enabling semantic distinctions of any granularity to be made in s-structure.[19]

It could be asked what it really means to assume two meaning constructors for every lexically introduced meaning. In fact the 'split' proposed correlates neatly with the two components required for semantic composition: meaning and realization. One sort of meaning constructor introduces lexical meaning, while the other introduces the information necessary for composition of lexical meaning. Glue expressions of the 'standard' form have a dual function, to both associate meanings with semantic structures (and thereby introduce meaning into the grammar) and to express constraints on composition. But this dual functionality is problematic when it comes to representing discourse-relevant features in s-structure. By 'splitting' meaning constructors in the way proposed, these two functions are separated, and the problem is resolved.

[19] It is a separate question how i-structure analysis is formalized, as well as other discourse processes for which s-structures and s-structure features may be relevant, given the proposals made here. Specific proposals in this respect are made by Lowe and Mycock (2014).

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