RESOURCE SPLITTING AND REINTEGRATION WITH SUPPLEMENTALS

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Abstract

Arnold and Sadler (2010) provides a 'Pottsian' analysis of supplemental constructions, in particular appositive (non-restrictive) relative clauses, in the framework of LFG and glue semantics. The account utilizes an inference rule that splits single glue resources into their 'at-issue' and supplemental sub-parts, and introduces other resources that re-integrate the at-issue and supplemental content, so that the supplemental content gets 'widest' scope, rather than (as in Potts' account) being scopeless. No proper justification is given for either of these aspects of the analysis. This paper shows that while the splitting rule is unnecessary, apparatus for re-integration is essential. The resulting treatment is both better justified and formally cleaner.

1 Introduction

Arnold and Sadler (2010) (hence A&S) gives a 'Pottsian' analysis of 'supplementals', specifically non-restrictive relative clauses such as the emphasised part of (1), in the framework of LFG with resource-sensitive ('glue') semantics (e.g. Asudeh, 2004; Dalrymple, 2001; Andrews, 2011).

(1) Kim, *who Sam dislikes*, did not come to the party.

The analysis involves two innovations, neither properly justified, and both potentially problematic:

i. an inference rule that 'splits' resources;
ii. apparatus for recombining at-issue and supplemental content.

The goal of this paper is to show that (i) is unnecessary (the splitting rule is dispensable, and dispensing with it produces a better analysis), but (ii) is necessary: without it the standard LFG approach to anaphora, as described in (e.g. Asudeh, 2004; Dalrymple, 2001), makes empirically wrong predictions about anaphora into and out of supplementals. The analysis we provide here has the virtues of the analysis presented in A&S, but is better motivated, and technically cleaner. More generally, (ii) relates to what has become one of the main conceptual and empirical issues in discussions of Potts' 2005 approach to semantics, namely, the question of how '*at-issue*' (normal) semantic content should be related to what Potts calls 'conventionally implicated' (*ci*) content, including supplemental content.

The paper is structured as follows. Section 2 gives a basic overview of the relevant phenomena, Potts' account, and the LFG implementation presented

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in A&S. Section 3 shows, based on straightforward and uncontroversial facts about anaphora, that assumption (ii) is necessary, given the standard LFG approach to anaphora. Section 4 discusses (i), the need for an inference rule that splits resources, and shows that it is not necessary, and that in fact one can provide a basic account of the semantics of supplementals using only standard glue apparatus (specifically, the same apparatus that is used for anaphora). Unfortunately, a basic account is not quite a complete account. Recent work has shown that the relationship between supplemental and *at-issue* content is more subtle and varied than suggested in Potts (2005). Accordingly, Section 5 seeks to broaden the discussion of (ii) by considering some of the relevant data.

2 Background

2.1 The Phenomena

Focusing on appositive (non-restrictive) relative clauses, such as (2), A&S considers how the analysis of 'supplemental' expressions (e.g. appositives, parentheticals, emotives, and honorifics) developed in Potts (2005) can be implemented in the resource sensitive approach to the syntax-semantics interface characteristic of LFG.

(2) Kim, who Sam dislikes, left early.

The fundamental distinction between appositive relative clauses (ARCs) and superficially similar restrictive relative clauses (RRCs) is semantic, in that restrictive modifiers typically introduce an implicit 'contrast set', which can be the antecedent of an expression like *the others*. Thus, (3a) with an RRC is acceptable, but (3b) with an ARC is anomalous. There is also very often an intonational difference (non-restrictives are often set off by 'comma' intonation).

(3) a. Kim has three friends that I like (the others I don't). [RRC]
b. Kim has three friends, who I like (#the others I don't). [ARC]

Syntactically, the evidence for appositives being integrated into the syntactic structure in the same ways as the restrictives seems to be overwhelming (e.g. Jackendoff, 1977; Kempson, 2003; Arnold, 2007; Arnold and Sadler, 2010). But there is an impressive body of evidence that they are not similarly integrated semantically – for example, ARCs, instead of being interpreted where they appear syntactically, seem to behave in some ways like independent clauses.

For example, in (4) the natural interpretation of (4a) involves Kim having a belief about the set of linguists who are IPA users. By contrast, while the natural interpretation of (4b) still involves Kim having a belief about the set of linguists, neither the IPA nor its users need figure in Kim's beliefs at all – the proposition associated with the appositive relative clause (that linguists use the IPA) is outside the scope of the propositional verb. In essence, (4b) is interpreted as (4c),

(4) a. Kim believes that linguists who use the IPA are clever. [RRC]
b. Kim believes that linguists, who use the IPA, are clever. [ARC]
c. Kim believes that linguists are clever. They use the IPA.

Similarly, in the ARC in (5b), the proposition that linguists use the IPA is not part of the question (i.e. if one assumes that questions involve a question operator, then the content of the ARC has escaped its scope). (4b) is interpreted as something like (4c).

(5) a. Are linguists who use the IPA invariably clever people? [RRC]
b. Are linguists, who use the IPA, invariably clever people? [ARC]
c. Are linguists invariably clever people? (They use the IPA.)

The contrast in (6) shows that negative polarity items (NPIs) like *any* behave differently in RRCs and ARCs. Plausibly this is because RRCs, and hence any NPIs they contain, are in the scope of main clause negation. But an ARC, as in (6b), is not in the scope of the main clause negation, so the NPI it contains is unlicensed, just as it would be in an independent clause, as in (5c)

(6) a. But of course, we didn't introduce the president to the three guests that had any real opinions. [RRC]
b. *But of course, we didn't introduce the president to the three guests, who had any real opinions. [ARC]
c. *But of course, we didn't introduce the president to the three guests. They had any real opinions.

Given this data, ARCs are standardly analysed as being either 'scopeless' (as in Potts (2005)), or having wide – more precisely, 'widest' – scope (see Arnold (2007), and references there). The difference between these analyses is one of the main themes of this paper.

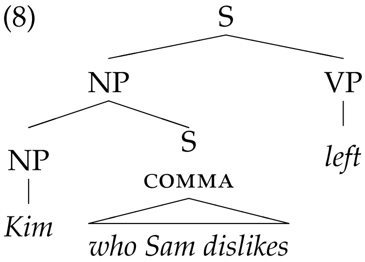
2.2 Potts' Approach

The fundamental idea of Potts' account of these constructions (as well as other supplements, emotives and honorifics) is that the interpretation of every expression involves (at least) two dimensions: (i) an *at-issue* dimension of normal truth-conditional content; and (ii) a 'conventional implicature' *ci*-dimension. The main technical apparatus he uses consists of syntactic and semantic parse-trees with associated conventions (admissibility conditions), and an extended type-theory. In addition to the normal ('at-issue') logical types (e, t, $\langle e, t\rangle$, etc), he introduces a collection of *ci-types*, in particular, the type t^c (the type of *ci*-propositions), and a collection of *at-issue to ci* types, such as $\langle e, t^c\rangle$ – the type of functions from normal '*at-issue*' entities to *ci*-propositions. Crucially, however, there are no types $\langle \sigma^c, \tau\rangle$ for any σ, τ – that is, there are no functions from *ci* objects (e.g. *ci* propositions) to *at-issue* objects. The immediate consequence of this is a radical separation of *ci* and *at-issue* content. In particular, *ci* content cannot be the argument of any function, cannot be in the scope of any operator, and is hence necessarily 'scopeless'.

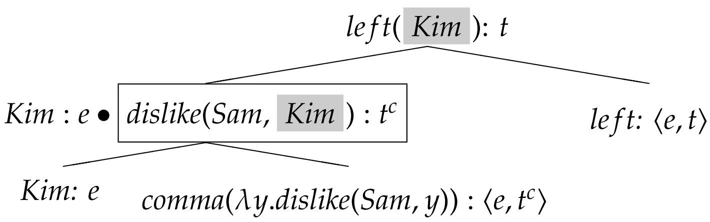
For Potts, the analysis of an example like (7) involves the syntactic parsetree in (8), and the semantic parsetree in (9), reflecting respectively the syntactic and semantic derivations (the syntactic parsetree is thus not necessarily a representation of the surface syntactic structure – however, the distinction will not be important here).

(7) Kim, who Sam dislikes, left.

(8)



(9)



With respect to the syntactic parsetree, the only points of interest are (a) the fact that the ARC is syntactically integrated, and (b) the presence of the COMMA feature. This feature provides the interface between the phonological and semantic properties: on the phonological side, it will trigger 'comma intonation'; on the semantic side it changes the type of the ARC from $\langle e, t\rangle$ (the type of a normal *at-issue* NP modifier) into $\langle e, t^c\rangle$ – the type of a function from entities to *ci*-propositions.

With respect to the semantic parsetree, the first point to notice is that the content associated with the root node is $left(Kim) : t$, this is normal *at-issue* content (type *t*), and just the content of (7) without the ARC. The second point to note is the presence of two kinds of content on the node corresponding to *Kim, who Sam dislikes*: the content of the ARC, and the content of the host NP *Kim*. The two kinds of content are linked by the • symbol, with the *ci*-content in a box (strictly speaking, every node should have both kinds of content, but for every other node in the tree the *ci*-content is empty, so we have omitted it). The third point to notice is that though the host NP *Kim* appears only once in the syntax, the corresponding content is used twice, once in deriving the *at-issue* content on the root node, and once in deriving the *ci* content (both uses are highlighted).

The main technical point of interest is the semantics of COMMA, defined as in

(10).

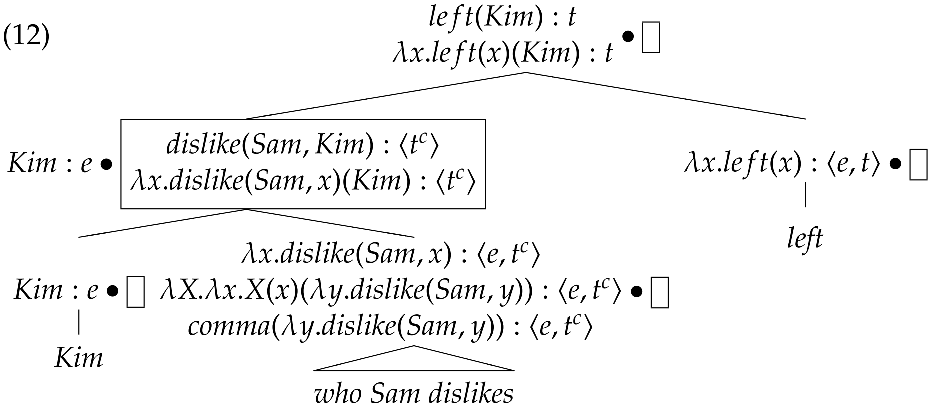
(10) COMMA: $\lambda X.\lambda x.X(x) : \langle\langle\sigma, t\rangle, \langle\sigma, t^c\rangle\rangle$ FOR $\sigma \in \{e, s, t\}$

In case it is applied to an expression of type $\langle e, t\rangle$, such as $\lambda y.dislike(Sam, y)$, corresponding to *who Sam dislikes*, the result is an equivalent expression of type $\langle e, t^c\rangle$, cf. (11):

(11) a. $comma(\lambda y.dislike(Sam, y)) : \langle e, t^c\rangle =$
b. $\lambda X.\lambda x.X(x)(\lambda y.dislike(Sam, y)) : \langle e, t^c\rangle =$
c. $\lambda x.dislike(Sam, x) : \langle e, t^c\rangle$

A more detailed view of the semantic derivation is given in (12), where every node is labelled with both *at-issue* and *ci* content (the later normally empty), the content of the ARC has been spelled out more precisely, and β-conversion of λ-expressions has been carried out. The content of the node corresponding to *Kim, who Sam dislikes* is produced by a node admissibility condition which requires that where one daughter of a node has a type like $\langle e, t^c\rangle$, the *ci* content of the mother will be produced by applying the content of this daughter to that of the other daughter, while the *at-issue* of content of the mother node will be the content of the other daughter (hence the double consumption of *Kim*, consumed once in the derivation of the *ci* content, once in the derivation of the *at-issue* content).

(12)



The interpretation of a semantic parsetree is as follows. Let $\mathcal{T}$ be a semantic parsetree with the *at-issue* term $\alpha : \sigma$ on its root node (a semantic expression α of type σ), and distinct terms $\beta_1 : \tau^c, \ldots, \beta_n : \tau^c$ on its nodes, then the interpretation of $\mathcal{T}$ is the tuple:

(13) $\left\langle [\![\alpha : \sigma]\!]^{M,g},\ [\![\beta_1 : \tau^c]\!]^{M,g}, \ldots,\ [\![\beta_n : \tau^c]\!]^{M,g} \right\rangle$

In words, the interpretation of a semantic parsetree consisting of an *at-issue* formula and a collection of *ci* formulae is found by interpreting all formulae in the same model (M), with the same variable assignment function g. Thus, for example, the interpretation of (12) will be as in (14):

(14) $\left\langle [\![left(Kim) : t]\!]^{M,g},\ [\![dislike(Sam, Kim) : t^c]\!]^{M,g} \right\rangle$

Notice that this means the model theoretic interpretation of *Kim, who Sam dislikes* is essentially the same as that of (15) (recall the intuition about ARCs and independent clauses above).

(15) Kim left. Sam dislikes Kim.

From a general theoretical point of view, the key point is that the approach involves a radical separation of *at-issue* and *ci* content: (i) because there are no expressions of type $\langle \tau^c, \sigma^a \rangle$, *ci* content cannot be an argument of (in the scope of) any semantic operator – *ci* content is scopeless; (ii) in fact *ci* and *at-issue* content is never integrated, even 'at the top', and the only semantic relation is that *at-issue* and *ci* content are interpreted in the same model(s).

From an LFG/glue perspective, however, there is an additional issue: the challenge to 'resource sensitivity' posed by the double consumption of the host of the ARC. Dealing with this is the main focus of A&S.

2.3 Resource-Sensitivity

From an LFG/glue perspective, a key problem with Potts's approach is that it involves a resource deficit: some semantic resources, specifically those associated with the host of an ARC, need to be consumed more than once. Following a suggestion of Potts', A&S proposes that ARCs and other supplementals should be associated with resources like (16), where np_e is the resource associated with the host NP, and np_{t^c} is the resource associated with the ARC.

(16) $np_e \multimap [np_e \otimes np_{t^c}]$

Schematically, the semantics of *Kim, who Sam dislikes* involves a glue derivation along the lines of (17). Here the inputs are the normal contents of *Kim*, and the (restrictive) relative clause *who Sam dislikes*. The vertical dots in (17) abbreviate a number of things, notably the change in the glue type from that of a restrictive relative to the type in (16), and a corresponding change in the logical type of the left part of the glue expression. These details are not relevant here.

(17)
$$\dfrac{\begin{array}{c} \text{Kim} \\ \\ \vdots \\ Kim : np_e \end{array} \qquad \begin{array}{c} \text{who Sam dislikes} \\ \lambda Q.\lambda X.dislike(Sam, X) \wedge Q(X) : [v \multimap r] \multimap [v \multimap r] \\ \vdots \\ \lambda Y.[Y, \lambda X.dislikes(Sam, X)(Y)] : np_e \multimap [np_e \otimes np_{t^c}] \end{array}}{[Kim, dislikes(Sam, Kim)] : np_e \otimes np_{t^c}}$$

In the conclusion of this proof fragment we have, on the meaning side, a pair of meanings corresponding to *Kim* and the proposition that Sam dislikes Kim; on the glue side, a 'tensor' resource consisting of two resources, one in the *at-issue* dimension, and one in the *ci* dimension.

A&S assumes we need to split these resources, so they can be used separately (for example, in the derivation of the *at-issue* content of the whole sentence), and so introduce a new inference rule: *at-issue-ci-split* (*ACiS*):

(18) $$\frac{[M, M'] : R_e \otimes R_{t^c}}{M : R_e \quad M' : R_{t^c}} \text{ ACiS (at-issue-ci-split)}$$

The effect of this can be seen in the proof in (19), where the righthand part of the proof continues (17), first splitting the tensor resource, and combining one of the objects produced ($Kim : np_e$) with the resource associated with the main verb, so that we end up with two separate resources (a resource of type t corresponding to *Kim left* and a t^c resource corresponding to *Sam dislikes Kim*).

(19)

$$\dfrac{\begin{array}{c}\text{left} \\ \vdots \\ \lambda Y.left(Y) : \\ np_e \multimap s_t\end{array} \qquad \dfrac{\dfrac{\begin{array}{c}\text{Kim} \\ \vdots \\ Kim : np_e\end{array} \qquad \begin{array}{c}\text{who Sam dislikes} \\ \lambda Q.\lambda X.dislike(Sam, X) \wedge Q(X) : [v \multimap r] \multimap [v \multimap r] \\ \vdots \\ \lambda Y.[Y, \lambda X.dislikes(Sam, X)(Y)] : np_e \multimap [np_e \otimes np_{t^c}]\end{array}}{[Kim, dislikes(Sam, Kim)] : np_e \otimes np_{t^c}}}{Kim : np_e \qquad dislikes(Sam, Kim) : np_{t^c}}\ ACiS}{left(Kim) : s_t \qquad dislikes(Sam, Kim) : np_{t^c}}$$

A faithful implementation of Potts' ideas could stop here. A reasonable approximation to Potts' ideas would take the goal of a glue derivation to be a single *at-issue* resource with zero or more *ci* resources: $\left\{s_t, f^0_{t^c} \ldots f^n_{t^c}\right\}$ where s_t is associated with the root f-structure, each f^i is of type t^c. The final line of (19) is just like this.

However, on the standard view, a successful LFG-glue derivation should produce a single resource associated with the root S, and it is assumed in A&S, without discussion, that this should be the goal of a 'Pottsian-LFG' glue derivation.

A&S considers several approaches which produce the standard integration into a single resource. The one we will assume here associates a resource of the form (20) with each supplemental. This consumes the content of the supplemental itself ($\downarrow_{\sigma t^c}$) and produces a resource which consumes the content of the main clause (s) and produces a conjunction of the main clause and supplemental content (this is again associated with the main clause – s).[1]

[1]Producing a definition of s is straightforward using inside-out functional uncertainty and off-path constraints. The definition can be found in A&S Section 5; see example (84) and surrounding discussion.

A&S also considers an alternative approach which associates an 'of course' '!' meaning constructor with the root S node, and an outside-in functional uncertainty to pick out supplemental content. The use of 'of course' resources – resources that can be used as often as desired – is somewhat at odds with the spirit of resource sensitivity, so we avoid it here.

This **[root-s]** resource violates Potts' requirement that there are no functions from the domain of *ci* types – this is the price we pay for integrating *ci* and *at-issue* content. However, A&S also mentions an alternative implementation which dispenses with this function from the *ci* domain

(20) **[root-s]** $\lambda q.\lambda p.(p \wedge q) : [\downarrow_{\sigma^{t^c}} \multimap [s \multimap s]]$

An example of the use of this resource can be seen in (21), where the other inputs are the (unsplit) resource associated with *Kim, who Sam dislikes*, and the resource associated with *left*.

(21)

$$\dfrac{\dfrac{\dfrac{\lambda Y.left(Y) : np_e \multimap s_t \qquad \dfrac{[Kim, dislikes(Sam,Kim)] : np_e \otimes np_{t^c}}{Kim : np_e \qquad dislikes(Sam,Kim) : np_{t^c}}}{left(Kim) : s_t \qquad dislikes(Sam,Kim) : np_{t^c}} \qquad \lambda q.\lambda p.(p \wedge q) : np_{t^c} \multimap [s_t \multimap s_t]}{left(Kim) : s_t \qquad \lambda p.(p \wedge dislikes(Sam,Kim)) : s_t \multimap s_t}}{left(Kim) \wedge dislikes(Sam,Kim) : s_t}$$

To sum up: A&S proposes an implementation of Potts' approach which involves several pieces of apparatus. Two in particular are introduced essentially without motivation. The first is an inference rule which splits a tensor resource into two separate resources. In what follows we will see that this rule is unnecessary. The second involves resources that allows *at-issue* and *ci* content to be integrated. In what follows we will see that this is necessary if we want to preserve the standard LFG-glue approach to pronouns.

We will begin with the second piece of apparatus, and show that integration of *at-issue* and *ci* content is necessary, if we accept standard LFG assumptions.

3 Integration is Essential

The basic structure of the argument here is straightforward: (i) if supplemental content is not integrated, supplementals should be anaphoric islands, given the standard LFG approach to anaphora; (ii) but supplementals are *not* anaphoric islands.

The empirical point is easily established: (22) gives examples of in- and outbound anaphora with a supplemental (an ARC). In (22a) a main clause pronoun has its antecedent inside the ARC. In (22b) the pronoun is in the ARC and its antecedent is in the main clause. Such examples are completely normal.

(22) a. Pissarro, *who Matisse$_i$ met in 1898*, encouraged him$_i$ greatly.
b. Matisse$_i$ was greatly encouraged by Pissarro, *who he$_i$ met in 1898*.

So far as we are aware, this state of affair holds quite generally: there are no cases where anaphora into and out of a supplemental is more constrained than anaphora into and out of the corresponding non-supplemental (e.g. restrictive

– one simply has to take the supplemental content to be a function that consumes the *at-issue* meaning of the root sentence and produces another *at-issue* meaning. While this is a technical fix, it is at odds with Potts' conception of there being two dimensions of content, associated with different semantic types.

relatives).[2] Supplementals are not anaphoric islands.[3]

We now turn to the theoretical point: the standard LFG approach to anaphora resolution requires anaphor and antecedent to co-exist in a single semantic structure. Demonstrating this requires a brief review of the standard LFG approach (e.g. Asudeh, 2004; Dalrymple, 2001). Consider example (23).

(23) Kim thinks she won.

The standard approach assumes that the pronoun *she* consumes its antecedent (*Kim*) and produces a resource like $Kim \times Kim : a \otimes p$, ($a$ being the resource corresponding to the antecedent and p the resource corresponding to the pronoun itself), and uses hypothetical reasoning to produce a 'context' into which pairwise substitution of antecedent and anaphor can occur, using a special inference rule.[4]

In (24), to derive the semantics of (23), we hypothesise two resources $[X : a]$ and $[Y : p]$, corresponding to the antecedent (main clause subject) and pronoun (embedded subject) respectively. With these we are able to produce a (hypothetical) glue expression for the whole sentence — $thinks(X, won(Y)) : s$. We also have the tensor resource formed by combining pronoun and antecedent ($Kim \times Kim : a \otimes p$). The rule for tensor elimination $\otimes\varepsilon$, allows simultaneous, pairwise substitution of the elements of the tensor resource in place of the hypothesised resources to produce the **let** expression, which can be β-reduced to give a semantics for the sentence as a whole.

[2]Notice we are not claiming there is no difference in the way anaphora works *inside* ARCs vs restrictive relatives. Safir (1986) presented examples which purport to show the existence of a WCO effect in restrictives like (b), which is absent from ARCs like (a):

a. John, who$_i$ his$_i$ wife loves t$_i$, arrived early.

b. *A man who$_i$ his$_i$ wife loves t$_i$ arrived early.

But this is a difference in the internal grammar of ARCs and restrictives, not a difference in the conditions on in- and out-bound anaphora. In any case, following Levine and Hukari (2006), we are persuaded that the problem with (b) reflects a processing problem, rather than something inherent to restrictive relatives. Restrictive relatives with the configuration of pronouns in (b) can be acceptable, as in (c). What seems to matter is how easy it is to determine the reference of the pronoun apart from the reference of the crossing element (the relative pronoun):

c Arthur is someone who$_i$ not even his$_i$ wife listens to t$_i$.

[3]Just one example: VP Ellipsis behaves in the same way as pronominal anaphora. In (a) ellipsis in a restrictive relative is anteceded by a VP inside the ARC. In (b) the situation is reversed:

a. Sandy, who *brought a bottle$_i$*, was rude to everyone who didn't Δ_i.

b. Everyone who *brought a bottle$_i$*, was rude to Sandy, who didn't Δ_i.

We will not pursue this here, however, because this is only relevant if VP Ellipsis is 'semantic' in the sense of involving a relation between semantic objects. If the all that is involved is some form of f-structure (near) identity between antecedent and ellipsis site, then these data would just be evidence of syntactic integration.

[4]Intuitively, hypothetical reasoning allows one to avoid ordering problems in glue derivations. Without it, resources must always be produced before they are needed. With it, one can at any point simply invent a hypothetical resource of the kind one needs. The proof will succeed if (and only if) one can later find a real resource of the right kind to discharge the hypothetical resource.

(24)

$$\dfrac{\dfrac{\begin{array}{c}\vdots\\ \mathit{Kim} \times \mathit{Kim} : a \otimes p\end{array} \quad \begin{array}{c}[X : a]^1 \quad [Y : p]^2\\ \vdots\\ \mathit{thinks}(X, \mathit{won}(Y)) : s\end{array}}{\textbf{let}\ \mathit{Kim} \times \mathit{Kim}\ \textbf{be}\ X \times Y \text{ in } \mathit{thinks}(X, \mathit{won}(Y)) : s}\otimes\varepsilon,1,2}{\mathit{thinks}(\mathit{Kim}, \mathit{won}(\mathit{Kim})) : s}\beta \Rightarrow$$

The point is quite straightforward: anaphora resolution requires pairwise substitution into a context, which plainly requires there to *be* a context. But if *at-issue* and *ci* content are not integrated, there will be no such context in cases involving supplementals. In other words, if *ci* and *at-issue* content are not integrated supplementals should be anaphoric islands, which they are not.

On the other hand, if *at-issue* and *ci* content *are* integrated, anaphora into and out of supplementals can be handled straightforwardly. Consider the case of in-bound anaphora in (25), parallel to (22a) (using *John*, *Mary* and *her* makes the proof easier to follow by making the pronoun-antecedent relation more obvious).

(25) John, who Mary_i dislikes, admires her_i

We begin by assuming two hypothetical resources: $Z : a$ for the antecedent (*Mary*), and $Y : p$ for pronoun (*her*). With these we can produce resources corresponding to the VP (the verb plus its object, '*admire Y*'), the subject (*John*), and the ARC ('*Z dislikes John*' – the latter after we have used the splitting rule in the analysis of the ARC). The VP resource can then consume the subject resource so that we have a resource of type t associated with the root sentence, and a resource of type t^c. These can be integrated using the [**root-s**] constructor.to produce a 'context' $\mathit{admire}(\mathit{John}, Y) \wedge \mathit{dislikes}(Z, \mathit{John}) : s_t$. Independently, the pronominal resource associated with *her* can consume the resource associated with its antecedent *Mary*, to produce the tensor resource $\mathit{Mary} \times \mathit{Mary} : a \otimes p$. Tensor elimination ($\otimes\varepsilon$) and pairwise substitution do the rest. See (26).

(26)

$$\dfrac{\dfrac{\mathit{Mary} \times \mathit{Mary} : a \otimes p \qquad \dfrac{\dfrac{\dfrac{\begin{array}{c}[Y : p]^1\\ \vdots\\ \lambda X.\mathit{admire}(X, Y) :\\ np_e \multimap s_t\end{array} \quad \dfrac{\begin{array}{c}[Z : a]^2\\ \vdots\\ [\mathit{John}, \mathit{dislikes}(Z, \mathit{John})] : np_e \otimes np_{t^c}\end{array}}{\mathit{John} : np_e \qquad \mathit{dislikes}(Z, \mathit{John}) : np_{t^c}}}{\mathit{admire}(\mathit{John}, Y) : s_t \quad \dfrac{\mathit{dislikes}(Z, \mathit{John}) : np_{t^c} \qquad \begin{array}{c}\lambda q.\lambda p.(p \wedge q) :\\ np_{t^c} \multimap [s_t \multimap s_t]\end{array}}{\lambda p.(p \wedge \mathit{dislikes}(Z, \mathit{John})) : s_t \multimap s_t}}}{\mathit{admire}(\mathit{John}, Y) \wedge \mathit{dislikes}(Z, \mathit{John}) : s_t}}{}}{\textbf{let}\ \mathit{Mary} \times \mathit{Mary}\ \textbf{be}\ Y \times Z \text{ in } \mathit{admire}(\mathit{John}, Y) \wedge \mathit{dislikes}(Z, \mathit{John}) : s_t}\otimes\varepsilon,1,2}{\mathit{admire}(\mathit{John}, \mathit{Mary}) \wedge \mathit{dislikes}(\mathit{Mary}, \mathit{John}) : s_t}\beta \Rightarrow$$

Example (25) and the proof in (26) involve anaphora into a supplemental. The case of anaphora out of a supplemental is equally straightforward.

(27) John, who she$_i$ dislikes, admires Mary$_i$

The proof required for (27) is just the same as (26) except that the antecedent (a) and pronoun (p) resources are switched (i.e. associate the variable Y with the antecedent resource a, and put Z with the pronoun resource p, and leave the rest of the proof exactly the same).

In short: if we want to do pronoun resolution using the standard LFG approach, then integration of *ci* and *at-issue* content is essential. Once we do this, pronoun resolution is straightforward.

4 No Need for Resource Splitting

Having shown that integration is necessary, in this section we will show that splitting is *not* necessary: it is not necessary to use an inference rule to split *ci* and *at-issue* content, as assumed in A&S. In fact, it turns out that if *at-issue* and *ci* content are integrated, we can dispense with splitting and treat supplementals and their hosts in the same way as pronouns and their antecedents, using hypothetical reasoning.

The change required to the apparatus assumed in A&S is almost trivial. The idea is that for a host plus supplemental like *Kim, who Sam dislikes* we produce (28), instead of (29), which is what was proposed in A&S, and what we have assumed so far. That is, we produce a resource whose meaning side is a product expression $A \times B$ rather than a pair expression $[A, B]$.[5]

(28) $Kim \times dislikes(Sam, Kim) : np_e \otimes np_{t^c}$
(29) $[Kim, dislikes(Sam, Kim)] : np_e \otimes np_{t^c}$

Ignoring details, this gives a glue derivation like (30) for *Kim, who Sam dislikes*.

(30)
$$\dfrac{\begin{array}{c}\text{Kim}\\ \vdots \\ Kim : np_e\end{array} \quad \begin{array}{c}\text{who Sam dislikes}\\ \lambda Q.\lambda X.dislike(Sam, X) \wedge Q(X) : [v \multimap r] \multimap [v \multimap r]\\ \vdots \\ \lambda Y.Y \times \lambda X.dislikes(Sam, X)(Y) : np_e \multimap [np_e \otimes np_{t^c}]\end{array}}{Kim \times dislikes(Sam, Kim) : np_e \otimes np_{t^c}}$$

The derivation for a full sentence (*Kim, who Sam dislikes, left*) involves hypothetical reasoning. We begin by hypothesising two resources $[Y : e]^1$ for the host NP, and $[R : t^c]^2$ for the supplemental, and we use the [**root-s**] constructor associated with the supplemental to integrate *ci* and *at-issue* content. This allows the derivation of $left(Y) \wedge R : s_t$; together with the tensor resource from

[5]This requires only a trivial reformulation of the [**comma**] meaning constructor. Where A&S have (a), we would now have (b). We have highlighted the differences.

a. $\lambda P.\lambda Y.\ [\ Y, (P(\lambda Z.true))(Y)\ ]\ : [[v \multimap r] \multimap [v \multimap r]] \multimap [np_e \multimap [np_e \otimes np_{t^c}]]$

b. $\lambda P.\lambda Y.Y \times (P(\lambda Z.true))(Y) : [[v \multimap r] \multimap [v \multimap r]] \multimap [np_e \multimap [np_e \otimes np_{t^c}]]$

(30), this gives us the glue resources we need to eliminate the tensor, and perform pairwise substitution for the host NP and the supplement. See (31).

(31)
$$\dfrac{\dfrac{\dfrac{\dfrac{[Y : np_e]^1 \quad \lambda X.left(X) : np_e \multimap s_t}{left(Y)} \qquad \dfrac{[R : t^c]^2 \quad \lambda q.\lambda p.(p \wedge q) : np_{t^c} \multimap [s_t \multimap s_t]}{\lambda p.(p \wedge R) : s_t \multimap s_t}}{left(Y) \wedge R : s_t} \qquad \begin{matrix} \vdots \\ Kim \times dislikes(Sam, Kim) : np_e \otimes np_{t^c} \end{matrix}}{\textbf{let}\ Kim \times dislikes(Sam, Kim)\ \textbf{be}\ [Y, R]\ \text{in}\ left(Y) \wedge R : s_t}\ \otimes\mathcal{E},1,2}{left(Kim) \wedge dislikes(Sam, Kim) : s_t}\ \beta \Rightarrow$$

In short, we see that there is no need for the 'at-issue-ci-split' rule assumed in A&S and given in (18) above. It can be eliminated by judicious use of standard apparatus – specifically, hypothetical reasoning and pairwise substitution, as used in the treatment of anaphora.

Formally, this is a useful result, because it means that glue derivations are always 'reducing', in the sense that inference rules do not produce more resources than they consume (cf. the A&S splitting rule takes one resource as input, and outputs two resources), and this means that we can remain within the standard tensor fragment of linear logic.[6]

Notice that nothing we have said in this section has any impact on the preceding discussion of issues relating to the scope and integration of *ci* and *at-issue* content. In particular, it is entirely consistent with 'widest scope' integration of supplemental and *at-issue*, and with the treatment of anaphora discussed above. More generally, the approach proposed in this section inherits all the virtues of the approach described in A&S. It differs only in the formal details.

For the most part this is obvious and unsurprising. However, there is one point where it is not obvious, and an interesting issue arises. The approach described in this section involves supplementals pairing with their hosts, and this might lead one to expect that they would have to be one-to-one with their hosts. The approach described in A&S does not have this property: once the resources associated with the supplemental and host have been split, the host resource is available for use with other supplementals, so each host can be associated with several supplementals. This might lead one to expect the A&S account and the account described here to make different predictions with respect to the possibility of 'stacking' supplementals.

In the following subsection we will show that this is wrong. There is no such difference between the accounts: an analysis of stacked supplementals is a straightforward consequence of the approach.

[6]As regards the formal apparatus, this approach establishes a strong link between the antecedent-anaphor relation and the host-supplemental relation – both involve tensor resources and pair-wise substitution. The difference between them is that the host-supplemental relation is far more constrained syntactically – the supplemental must be an adjunct of the host.

4.1 Stacking

Stacking of restrictive relatives is exemplified in (32):

(32) People who have liver problems who drink alcohol should take special care.

It was at one time standard wisdom that ARCs do not stack in this way (e.g. Jackendoff, 1977). This is untrue, as can be seen from attested examples like (33).[7]

(33) What a tragedy it is that so many of our talented sixth formers, *who really would do well in your universities, who are dying to get there, who queue, fight, struggle, work hard to get there, who have tremendous talents*, are denied access . . . [BNC KRG/1584]

(34) Kim, who Sam dislikes, who Les HATES, left early.

Clearly, there is no problem with this sort of example if the resources associated with host and supplement are split as on the original A&S proposal – after the host resource has been used with one supplemental, the 'splitting' rule will put it back in the resource pool, ready for re-use with another. Without splitting, since we substitute host and supplement resources pair-wise, there might seem to be a problem. However there is no problem in fact – we just need to make proper use of hypothetical reasoning.

This is most easily demonstrated by showing a proof.

Consider (35), a slightly simpler version of (34).

(35) Kim, who Sam dislikes, who Les hates, left.

We begin with a hypothetical proof that introduces three hypothetical resources, one ($[W]^1$) corresponding to *Kim*, and one for each of the supplementals ($[P]^2$, $[Q]^3$); and uses two instances of the root-s constructor (again, one per supplemental), to integrate main and supplemental content:

[7] Example (33) is from the British National Corpus. Arnold (2007) contains more examples. The observation that ARCs can stack is not novel (e.g. Grosu and Landman, 1998; Grosu, 2000; de Vries, 2002; Kempson, 2003; Arnold, 2007), but it is worth repeating because the alternative view survived so long unchallenged. It is true that not all examples of stacked non-restrictives seem equally good, which is why the myth of their unacceptability was relatively long lived, and there seem to be discourse constraints of some kind. In particular, the examples are much more acceptable if the supplementals in some sense 'make the same point', especially if the later ones re-enforce the earlier ones. Thus, (34) is better with the focus on *hates*, as indicated (the presumed point being Kim's unpopularity).

(36)
$$\dfrac{\dfrac{\dfrac{[W:k]^1 \quad \begin{array}{c}\lambda X.left(X):\\ k \multimap s\end{array}}{left(W):s} \quad \dfrac{[P:r]^2 \quad \begin{array}{c}\lambda q.\lambda p.(p\wedge q):\\ r\multimap[s\multimap s]\end{array}}{\begin{array}{c}\lambda p.(p\wedge P):\\ s\multimap s\end{array}}}{left(W)\wedge P : s} \quad \dfrac{[Q:r']^3 \quad \begin{array}{c}\lambda q'.\lambda p'.(p'\wedge q'):\\ r'\multimap[s\multimap s]\end{array}}{\begin{array}{c}\lambda p'.(p'\wedge Q):\\ s\multimap s\end{array}}}{left(W)\wedge P\wedge Q : s}$$

We can summarise this as:

(37)
$$\dfrac{[W:k]^1 \quad \lambda X.left(X):k\multimap s \quad [P:r]^2 \quad [Q:r']^3}{\begin{array}{c}\vdots\\ left(W)\wedge P\wedge Q:s\end{array}}$$

We now deal with the relative clauses themselves. Recall that we want to produce tensor resources of the form $np \otimes r$, where np is an 'NP resource' corresponding to the host, and r is the resource associated with the supplemental relative. It is straightforward to produce such a resource from one of the ARCs (e.g. *who Kim dislikes*) and the NP *Kim*, as is show in abbreviated form in (38).

(38)
$$\dfrac{Kim : np_e \qquad \begin{array}{c}\lambda Q.\lambda X.dislikes(Sam,X)\wedge Q(X):[v\multimap r]\multimap[v\multimap r]\\ \vdots \\ \lambda Y.Y\times(\lambda X.dislikes(Sam,X)(Y)):k\multimap k\otimes r\end{array}}{Kim\times dislikes(Sam,Kim):k\otimes r}$$

At this point there might seem to be a problem, because we have not done anything with the other relative clause (*who Sam hates*), and we do not have an 'NP resource' to combine it with. However, here we can avail ourselves of the flexibility afforded by hypothetical reasoning. We hypothesise a resource of the right kind, say $[Z]^1$, and procede as in (39).

(39)
$$\dfrac{\begin{array}{c}[Z]^1\\ \vdots\\ Z:k\end{array} \qquad \begin{array}{c}\lambda Q.\lambda X.hates(Les,X)\wedge Q(X):[v\multimap r]\multimap[v\multimap r]\\ \vdots \\ \lambda Y.Y\times(\lambda X.dislikes(Les,X)(Y)):k\multimap k\otimes r'\end{array}}{Z\times hates(Les,Z):k\otimes r'}$$

Thus, by hypothesising $[W:k]^1$, $[P:r]^2$, $[Q:r']^3$, and $[Z]^4$, we have produced the following resources:

(40)
$$\begin{array}{lll} left(W)\wedge P\wedge Q: & Kim\times dislikes(Sam,Kim): & Z\times hates(Les,Z):\\ s & k\otimes r & k\otimes r' \end{array}$$

With these resources, the following proof is possible – it simply involves pair-wise substitution of tensor resources into the 'context' of the main content followed by β-reduction, as in (41). Here we first perform pair-wise substitution of the 'hypothetical' host plus supplemental $Z\times hates(Les,Z):k\otimes r'$ and then perform the same inference step with the non-hypothetical host plus supplemental $Kim \times dislikes(Sam, Kim) : k \otimes r$. A moment's reflection should show that this approach can be extended to an arbitrary number of 'hypothetical' host plus supplemental resources, allowing an arbitrary number of stacked supplementals to be handled.[8]

(41)

$$
\dfrac{
  \dfrac{
    Kim \times dislikes(Sam,Kim) : k \otimes r
    \qquad
    \dfrac{
      \dfrac{
        \begin{array}{c}[Z:k]^4\\ \vdots \\ Z \times hates(Les,Z) : k \otimes r'\end{array}
        \qquad
        \begin{array}{c}[W:k]^1 \quad [P:r]^2 \quad [Q:r']^3 \\ \vdots \\ left(W) \wedge P \wedge Q : s\end{array}
      }{
        \textbf{let}\ Z \times hates(Les,Z)\ \textbf{be}\ W \times Q\ \text{in}\ left(W) \wedge P \wedge Q : s
      }\otimes\mathcal{E},1,3
    }{
      left(Z) \wedge P \wedge hates(Les,Z) : s
    }\Rightarrow_\beta
  }{
    \textbf{let}\ Kim \times dislikes(Sam,Kim)\ \textbf{be}\ Z \times P\ \text{in}\ left(Z) \wedge P \wedge hates(Les,Z) : s
  }\otimes\mathcal{E},4,2
}{
  left(Kim) \wedge dislikes(Sam,Kim) \wedge hates(Les,Kim) : s
}\Rightarrow_\beta
$$

Once one appreciates the possibilities of using hypothetical reasoning there is nothing very radical here. However, in a Pottsian context there is an important theoretical point. As we have seen, dealing with stacked supplementals requires use of hypothetical reasoning – in particular, the use of a hypothetical resources corresponding to the supplementals, but hypothetical reasoning involves implication ($\multimap$) introduction and elimination: if one has a resource B, hypothesising a resource $[A]^1$ yields a resource $A \multimap B$, corresponding to a function from objects with the glue type A on the meaning side, and eliminating a hypothetical resource corresponds to function application on the meaning side, as can be seen from (42) and (43), (cf. Asudeh, 2004; Dalrymple et al., 1999). In the case of supplementals, the hypothesised meanings are of type t^c, objects in the *ci* domain, so the approach requires functions from the *ci* domain, which Potts forbids. Without hypothetical reasoning – without these types – one will only be able to deal with one supplemental per host, which is empirically incorrect.

(42)

$$
\dfrac{\begin{array}{c}[x : A]^1 \\ \vdots \\ f : B\end{array}}{\lambda x.f : A \multimap B}\multimap_{x,1}
$$

(43)

$$
\dfrac{\begin{array}{c}\vdots \\ a : A\end{array} \qquad \begin{array}{c}\vdots \\ f : A \multimap B\end{array}}{f(a) : B}\multimap\mathcal{E}
$$

[8]Though we have not seen it discussed in the literature, exactly the same trick can be used with pronouns. In an example with more than one pronoun dependent on one antecedent (e.g. *The boys$_i$ know their$_i$ mother loves them$_i$*), the approach that is normally described involves 'chaining', so that (e.g.) *their* is the antecedent of *them* (or *vice versa*), but careful use of hypothetical resources will also allow proofs where all pronouns are directly linked to a single antecedent, paralleling the situation here, where several supplementals depend on a single host. We are grateful to Ash Asudeh for insightful discussion on this issue.

5 Discussion

To sum up: on the purely technical level, we have shown that we do not need a special inference rule to split *ci* and *at-issue* content. In fact, dispensing with such a rule gives a formally neater treatment, since we are within the framework of the modality-free, multiplicative fragment of intuitionistic linear logic (MILL) that is assumed in, for example, Asudeh (2004), and it turns out that we do not need *any* special semantic apparatus to deal with supplementals – the only general apparatus required is that used independently in the analysis of anaphora. The fact that no special apparatus is required is a positive result for the Pottsian enterprise.

However, we have also seen that there are problems with the Potts' approach – in particular, problems for assumptions about the strict separation of *ci* and *at-issue* content. We have seen that the standard LFG approach to anaphora requires *ci* and *at-issue* content to be integrated, and we have seen that the treatment of stacked supplementals requires the existence of functions from the *ci* domain, which are forbidden under Potts approach.

While these conclusion are clear enough in themselves, their implications are less obvious because the issue of integration of *ci* and *at-issue* is more puzzling and complicated than we have suggested so far. In this final section we will broaden the discussion by considering some of these complications.

The discussion so far has assumed implicitly that there are only two positions worth considering: the Pottsian position, where supplementals are completely un-integrated, hence 'scopeless', and the position taken in much of the standard literature that they are integrated at the highest level – that they have 'widest' scope. In particular, while the evidence discussed at the start of Section 2 is consistent with both these positions, there is a growing body of research which shows this to be a great over simplification, for there appear to be cases where supplementals must be analysed as being semantically integrated, and having intermediate scope (e.g. Sells, 1985; Roberts, 2006; Amaral et al., 2007; Nouwen, 2006; Harris and Potts, 2010; Wang et al., 2005; Schlenker, 2010; AnderBois et al., 2010).

Sells (1985) drew attention to examples like (44), where the relative clause contains a relative pronoun and a definite noun phrase (*the box*) associated with a NP (*a spare pawn*) in the scope of a universal quantifier. Intuitively, this would appear to be a supplemental in the scope of a universal (cf. also Kempson, 2003).

(44) Every chess set comes with a spare pawn, which you will find taped to the top of the box.

Similarly, Roberts (2006) discusses examples like (45), where the interpretation of the subject of the relative clause depends on that of *his wife*, which is in the scope of the universal *every professional man*:

(45) Every professional man I polled said that while his wife, *who had earned a bachelor's degree*, nevertheless had no work experience, he thought she could use it to get a good job if she needed one.

Arnold (2007) notes examples like (46), where there seems to be a kind of scope paradox: the pronoun *her* is semantically dependent on the negatively quantified NP *no properly trained linguist*, so one might think that it, and presumably the whole supplemental, is in the scope of the negative NP. However, this cannot be the case, because if were so, then the negative polarity item *ever* should be licensed, which it is not.

(46) No properly qualified linguist, who would (*ever) have been taught phonetics as part of her training, would have made that mistake.

Examples like this indicate that the issue of scope of supplementals is complex. However, they are not necessarily indicative of supplementals taking narrow scope. Sells noted that the cases where this is possible are cases where the supplemental content can be conveyed with a separate clause, compare (5):

Every chess set comes with a spare pawn. You will find it taped to the top of the box.

So it is possible that whatever mechanism is responsible for extending the scope of the universal in such cases is also operative in supplementals like (44) (Arnold (2007, 2004) develops this approach to account for examples like (46)). If this is correct, then these are not really examples of intermediate scope, but rather examples of widest scope/scopelessness subject to some other mechanism.

However, Schlenker (2010) discusses examples like (47) from French, which shows a subjunctive in a supplemental relative clause. Crucially, the supplemental here is interpreted as being in the semantic scope of *être concevable* (roughly the sense 'it is conceivable that John may have called his mother/Anne, who may conceivably have called her lawyer').

(47) Il est concevable que Jean ait appelé sa mère/Anne, *qui*
It is conceivable that Jean has-sub called his mother/Anne, who
ait appelé son avocat.
had-sub called her lawyer.

Harris and Potts (2010) provide an empirical study incorporating corpus and experimental data that make it clear that cases of narrow scope do exist. It is clear from the context of (48) that the supplemental *which was installed last week* is in the scope of *(Joan) believes*.

(48) Joan is crazy. She's hallucinating that some geniuses in Silicon Valley have invented a new brain chip that's been installed in her left temporal lobe and permits her to speak any of a number of languages she's never studied. Joan believes that her chip, *which was installed last month*, has a twelve year guarantee. (emphasis in original) (Harris and Potts, 2010).

There are also clear cases where other kinds of supplemental take narrow scope. Wang et al. (2005) gives examples like the following, where nominal appositive supplementals are in the scope of, respectively, *want*, *believe*, and *might*.

(49) Mary wants to marry an Italian, *a rich one*.
(50) John believes that a professor, *a quite famous one*, published a new book.
(51) A wolf, *a ferocious animal*, might come into your house.

However, Wang et al. (2005) note that it is much harder to give supplemental *relatives* (i.e. ARCs) narrow scope in this way, so for example while (49) has a *de dicto* interpretation with *an Italian* under the scope of *want*, (52) has only a *de re* interpretation, where Mary wants to marry a specific Italian. It is not obvious why this should be the case (but see Nouwen, 2006, for some discussion).

(52) Mary wants to marry an Italian, *who is rich/who is a rich one*.

Some of these examples involve quite subtle judgements or unusual situations, but it is worth emphasising that this is not always the case. Though it appears not to have been commented on in the literature, cases where supplementals appear to be integrated below the level of widest scope are rather commonplace. Consider (53).

(53) In this portait, the King, *who is dressed in armour and holding a commanders baton*, is wearing a the medallion of a Garter Sovereign.

Here it is clear that the supplemental content is to be interpreted with respect to the embedded situation of the picture, not the (widest) scope context. Of course, it is not completely obvious that there is an issue of scope here – one would need to provide a proper semantics to show this, but notice that it is quite possible for the host of the supplemental to be quantified, as in (54).

(54) In this picture, two knights, *who are evidently drunk*, are chasing two dragons, while several other knights look on.

Similar examples can be constructed with, e.g. *in my dream*, *in this novel*, *in this possible world*, and with the corresponding verbs (e.g. *dream*):

(55) Sam dreamed that she kissed George Bush, *who was wearing a strange uniform*.
(56) Sam dreamed that she kissed two strangers, *who were wearing strange uniforms*.

What is one to make of this? These data are clearly challenges for both 'scopeless' and 'widest scope' accounts, and while it is not at all clear to us what the right approach is, we can point to what we think would be a *wrong* approach.

In Section 2.3 we presented a meaning constructor that could be associated with each supplemental, and would integrate the supplemental content with that of the main clause. If the glue term s is associated with the f-structure of the root clause, this will give the supplemental content 'widest' scope (cf (20), repeated here):

(57) **[root-s]** $\lambda q.\lambda p.(p \wedge q) : [\downarrow_{\sigma^{t^c}} \multimap [s \multimap s]]$

The way to ensure that s picks out the root clause is to use an inside-out functional uncertainty, and an off-path constraint, which says that the relevant f-structure must not be the value of any attribute. It would be easy to replace this off-path constraint with another, e.g. one which says that the relevant f-structure must contain some value for TENSE. This would allow the supplemental to scope at the level of any f-structure containing a tense value (any clause, for example).

It seems to us that this is clearly the wrong approach to take. There are two key points. The first is that wide scope or something similar (e.g. scopelessness) represents something like the default case. The second is that deviation from this default case is something to do with maintaining some kind of discourse coherence. The reason we get narrow scope in (48) is that giving the supplemental wide scope would involve attributing to the speaker the same kind of delusional beliefs as Joan – beliefs that the speaker herself is characterising as delusional. Similarly, we interpret examples like (53)–(56) as we do because they 'make more sense that way' (e.g. in the case of (53), there is no king in the context outside the picture to support a wide scope reading). Whatever processes are involved here seem to be clearly pragmatic in nature, and not something that should be dealt with at the syntax-semantics interface which is the domain of glue logic.

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