Chapter 1

'A Unified Theory of Scope' Revisited

Quantifier Retrieval Without Spurious Ambiguities

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ABSTRACT. This paper presents an HPSG theory of quantification which builds and in various ways improves upon Pollard and Yoo (1997). By allowing only lexical retrieval, *à la* Manning *et al.* (1997), it is free from the spurious ambiguities problem. By shifting weight from VALENCE to ARG-ST, it is compatible with both traced and traceless analyses of extraction. The theory is formalized in Relational Speciate Re-entrant Logic (Richter, 1997).

The aim of this paper[1,2] is to provide an HPSG theory of quantification which builds on Pollard and Yoo (1997) (henceforth, PY) and improves upon their analysis in some important ways. In particular, our account naturally avoids the problem of spurious ambiguities, it properly states certain generalizations missing in PY, it is (arguably) simpler than their analysis, and, unlike their account, it is compatible with both traced and traceless theories of extraction. We also show that our theory extends easily to *wh*-retrieval.

1 Pollard and Yoo's (1997) Account

PY offer a substantial improvement over the theory of quantification of Pollard and Sag (1994, ch.8) (henceforth, PS): they provide a solution to the problem of wrong behaviour of PS's analysis of quantification in raising and extraction environments, such as (1.1) below.

(1.1)	a.	A unicorn appears to be approaching.	(ambiguous)
	b.	Five books, I believe John read.	(ambiguous)

[1]My greatest thanks go to Carl Pollard, who has been very generous with his time and wisdom. His comments on earlier drafts led to several improvements in the theory presented here. I am also grateful to Tilman Höhle and Frank Richter, as well as the participants of the HPSG seminars at Tübingen and Ohio for useful comments on earlier versions of the paper. All the remaining flaws are *mea culpa*. The work reported in this paper was supported in part by the KBN grant 8 T11C 011 10.

[2]This paper is an abridged version of Przepiórkowski (1997), which additionally introduces a formalization of the 'adjuncts-as-complements' approach to modification (inspired by Manning *et al.* (1997)) and shows that this formalization properly interacts with the theory of quantification presented here.

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Since in PS's analysis a quantifier starts its life only at the surface position of the phrase to which it corresponds, only the wide-scope (*de re*) reading is predicted. The solution PY propose boils down to making the quantifier corresponding to a raised constituent available at the "initial" position, e.g., in (1.1a), at the embedded verb *approaching*. The quantifier then percolates up and can be retrieved either inside or outside the scope of *appear*.

For lack of space, and because of the rather high complexity of PY's analysis, we cannot present it in this paper. We will, however, point out certain problems with their account.

The foremost is perhaps the problem of spurious ambiguities (of which PY are well aware): for example, in (1.1a), there are four possible retrievals corresponding to the narrow reading, and three corresponding to the wide reading. Secondly, the analysis of PY is rather complex. If a simpler analysis with the same coverage can be obtained, it should be preferred. Thirdly, it is not compatible with the traceless analyses of extraction (e.g., ch.9 of PS). For example, getting the *de dicto* reading of (1.1b) requires *five books* to be a selected argument of the lower verb, *read*. However, in the traceless account of extraction, there is no element on *read*'s VALENCE corresponding to *five books*, so the latter is not a selected argument of *read*. Fourthly, by assuming that each word belonging to the 'amalgamating class' does so by virtue of its lexical properties, this analysis misses certain generalizations: the lexical entry of each word in this class must encode the same complex constraint (cf. PY's (15)).[3] Finally, PY's analysis preserves what we view as a conceptual problem of PS, namely the distribution of a *sign*'s semantics between CONTENT and QSTORE.[4] The analysis below solves these problems.

2 An Alternative Account

Our theory of quantification is summarized below.

(1.2)

a. $$\begin{bmatrix} \textit{content} \\ \text{QSTORE set(quant)} \end{bmatrix}$$

psoa *nom-obj* *quant*

b. $$\begin{bmatrix} \textit{word} \\ \ldots \\ \text{NEW-QS set(quant)} \end{bmatrix}$$

(1.3) *word* $\rightarrow$ $\text{Desc}_1 \vee \text{Desc}_2$

[3] As pointed out to us by an anonymous reviewer, this generalization can be properly stated in the hierarchical lexicon. As far as we can see, PY do not invoke the 'hierarchical lexicon' approach, nor are we aware of any formalization of this approach in SRL (King, 1989, 1994), a logic for HPSG close to that assumed by at least one of the authors of *A unified theory of scope...* (Pollard, 1998), so we maintain our claim that missing generalizations are at least a potential problem for Pollard and Yoo (1997).

[4] For example, the phrases *every person* and *some person* have the same values of CONTENT; they differ only in QSTORE.

$$(1.4)\qquad \text{Desc}_1 = \begin{bmatrix} \text{SS}|\text{LOC}|\text{CONT} & \begin{bmatrix} \textit{nom-obj} \vee \textit{quant} \\ \text{QSTORE } \boxed{1} \end{bmatrix} \vee \begin{bmatrix} \textit{psoa} \\ \text{QSTORE } \boxed{2} \\ \text{QUANTS } \boxed{3} \end{bmatrix} \\ \text{NEW-QS } \boxed{5} & \end{bmatrix}$$

where $\boxed{1} = \boxed{5} \uplus$ the union of QSTOREs of selected arguments,
$\boxed{4} =$ the set of elements of $\boxed{3}$,
$\boxed{1} = \boxed{2} \uplus \boxed{4}$.

$$(1.5)\qquad \text{Desc}_2 = \begin{bmatrix} \text{SS}|\text{LOC}|\text{CONT } \boxed{1} \\ \text{ARG-ST } \langle \ldots, [\text{CONTENT } \boxed{1}], \ldots \rangle \end{bmatrix}$$

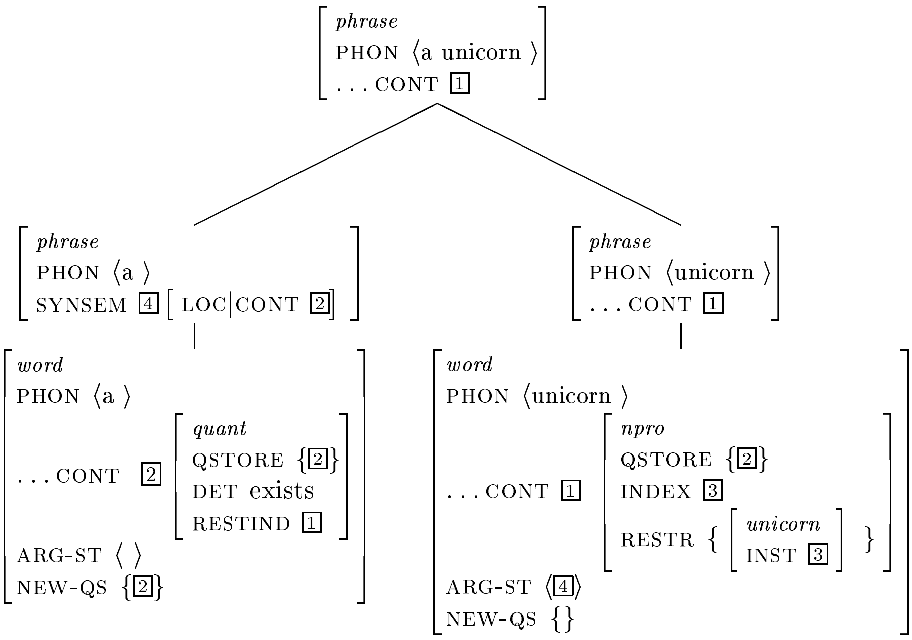
The way this analysis works is following. We build on Manning *et al.* (1997) and postulate lexical retrieval only. Thus, everything happens via the constraint on *words* (1.3). Specifically, unless a word is semantically vacuous (its semantics is taken over from one of its arguments), cf. Desc_2 in (1.5), it must satisfy Desc_1 in (1.4). According to this description, if the word's CONTENT value is not of sort *psoa*, then this word simply amalgamates all quantifiers of its selected arguments, adding the quantifiers that it itself introduced (the quantifiers introduced by a word are present in this word's NEW-QUANTIFIERS value, cf. (1.2b)). On the other hand, if the word's CONTENT is *psoa*, then all these quantifiers are split between the word's QSTORE (they will be retrieved higher up) and its QUANTS (the quantifiers retrieved at this word). Since QSTORE is a part of *content* (cf. (1.2a)), it percolates to the maximal projection with the rest of the CONTENT value via the Semantics Principle.

In the above, we implicitly assumed PY's definition of selected arguments. This notion, as defined there, is heterogeneous: it takes into consideration VALENCE features (SUBJ, COMPS and SPR), the MOD feature, and *thematic* properties of some arguments. Since the only intended effect of these definitions is to prevent a quantifier from being retrieved more than once in cases of raised arguments, it seems reasonable to us to redefine the notion *selected arguments* in these terms: *selected arguments* are those members of ARG-ST, which are not raised from other arguments. For example, in (1.1a), the synsem element corresponding to *a unicorn* is a selected argument on the ARG-ST of *approaching*, but not on the ARG-STs of *be*, *to*, and *appears* because in each of these cases it is raised from the VP arguments of these verbs.[5] This shift of weight from VALENCE to ARG-ST will make our analysis compatible with traceless theories of extraction.

We will illustrate this analysis with example (1.1a). Let us start with the phrase *a unicorn.*

[5]This definition avoids a minor technical problem of PY's definition of thematic arguments: it is not clear how to formalize the notion of 'a role in the CONT|NUCLEUS' in their definition, short of enumerating all the attributes appropriate for various subsorts of *qfpsoa*.

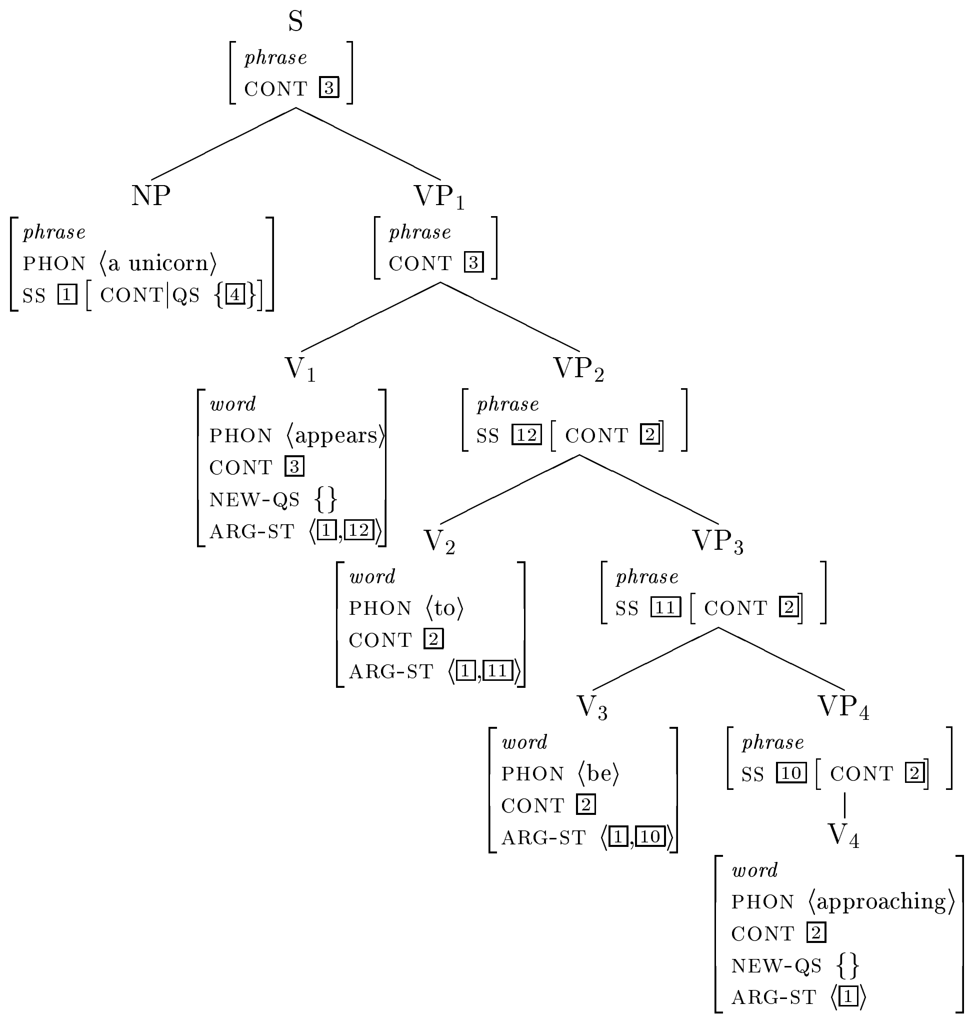
(1.6)



There are two *word* structures in this tree which must satisfy (1.3): *a* and *unicorn*. The former introduces a quantifier in NEW-QS and incorporates it into QSTORE via Desc_1 (1.4). This value percolates together with the whole CONTENT value to the maximal projection courtesy of the Semantic Principle. Since the synsem of this maximal projection is present in *unicorn*'s ARG-ST, this quantifier is amalgamated, again via Desc_1, to the noun's QSTORE. And, again courtesy of the Semantic Principle, it is present on the NP's QSTORE.

Let us now look at the tree structure corresponding to (1.1a).

(1.7)



There are six words in this structure (*a*, *unicorn*, *appears*, *to*, *be*, *approaching*), and they all have to satisfy the constraint (1.3). We have already considered the first two: since they are not semantically vacuous, they must satisfy Desc_1 (1.4). Another two of them, i.e., *to* and *be*, are semantically vacuous, so they trivially satisfy (1.3) by satisfying Desc_2 (1.5). The last two are, again, semantically non-vacuous and they can satisfy (1.3) only by satisfying Desc_1. Before we consider ways in which *appears* and *approaching* can satisfy Desc_1, a couple of notes are in order.

First, there are only two CONTENT values of sort *psoa* around. The approaching-*psoa* ($\boxed{2}$) is structure shared between the verb *approaching* (V_4) and its maximal projection (VP_4) by virtue of the Semantics Principle. This value is then taken over by the semantically vacuous verb *be* (V_3) and, again, structure shared with the maximal projection (VP_3). Analogously, also the

CONTENT value of *to* (V_2) and its projection (VP_2) is $\boxed{2}$. The other *psoa* is the appears-*psoa* ($\boxed{3}$), which is shared by the verb *appears* (V_1) and its projections (VP_1 and S).

Second, since both QUANTS and QSTORE are parts of CONTENT, any quantifier retrieval can happen only at the two *psoa*-valued CONTENTs, namely at $\boxed{2}$ and $\boxed{3}$.

Third, there is only one quantifier to be retrieved, i.e., '$\exists x$ unicorn(x)' ($\boxed{4}$). This quantifier originates in the NP *a unicorn*, so the value of this phrase's CONT|QSTORE is $\{\boxed{4}\}$ (see the discussion below (1.6) on p.4). The whole SYNSEM value of this NP is structure shared with the (selected!) argument of *approaching*, hence, the QSTORE value of this selected argument is $\{\boxed{4}\}$, and thus, "the union of QSTOREs of selected arguments" (cf. (1.4)) of *approaching* is $\{\boxed{4}\}$. Since NEW-QS of this verb is empty, the pool of quantifiers to take care of at this node consists only of $\boxed{4}$.

Now there are two ways for *approaching* to satisfy Desc_1 (1.4): either $\boxed{4}$ becomes the (only) element of QSTORE (and QUANTS is empty), or it becomes the element of QUANTS (and QSTORE is empty). This results in two possible values of CONTENT $\boxed{2}$ illustrated below:

(1.8) a. narrow scope: $\boxed{2} = \begin{bmatrix} \textit{psoa} \\ \text{QSTORE } \{\} \\ \text{QUANTS } \langle\boxed{4}\rangle \\ \text{NUCL approach} \end{bmatrix}$ b. wide scope: $\boxed{2} = \begin{bmatrix} \textit{psoa} \\ \text{QSTORE } \{\boxed{4}\} \\ \text{QUANTS } \langle\rangle \\ \text{NUCL approach} \end{bmatrix}$

In case of the narrow scope (1.8a), the value of QSTORE of *approaching* is the empty set, and so is the value of QSTORE of $\boxed{12}$ (cf. V_1 in (1.7)), i.e., of the only selected argument of *appears* ($\boxed{1}$ is not a selected argument here!). Hence, the set of quantifiers collected at *appears* is the empty set:

(1.9) $\boxed{3} = \begin{bmatrix} \textit{psoa} \\ \text{QSTORE } \{\} \\ \text{QUANTS } \langle\rangle \\ \text{NUCL appear} \end{bmatrix}$

On the other hand, in case of the wide scope (1.8b), the QSTORE value of the selected argument of *appears* is the singleton set $\{\boxed{4}\}$, so, by the same reasoning, there are two possible values of $\boxed{3}$, cf. (1.10). Of course, once there is a constraint on root clauses to the effect that their QSTORE be empty, only (1.10a) is possible.

(1.10) a. $\boxed{3} = \begin{bmatrix} \textit{psoa} \\ \text{QSTORE } \{\} \\ \text{QUANTS } \langle\boxed{4}\rangle \\ \text{NUCL appear} \end{bmatrix}$ b. $\boxed{3} = \begin{bmatrix} \textit{psoa} \\ \text{QSTORE } \{\boxed{4}\} \\ \text{QUANTS } \langle\rangle \\ \text{NUCL appear} \end{bmatrix}$

This exhausts the possibilities of quantifier retrieval.

The following features of this account should be noted: 1) there are no spurious ambiguities: the quantifier can be retrieved either at the approaching-*psoa* or at the appear-*psoa* rendering narrow and wide scope, respectively; 2) since the selected arguments are defined in terms of ARG-ST rather than VALENCE, this analysis is compatible with both traced and traceless analyses of extraction; 3) the constraint responsible for amalgamation and retrieval of quantifiers, (i.e., Desc_1 in (1.3)) is stated only once in the grammar; 4) all semantics of a sign (including quantificational semantics) is present at one place in the sign, i.e., in *content*; 5) the analysis presented above is arguably much cleaner than that of PY.

3 *Wh*-Retrieval

PY make two observations concerning the scope of *wh*-elements in English. First, a fronted *wh*-phrase has exactly the scope indicated by the surface realization of the phrase. Second, the quantifier corresponding to an *in situ* *wh*-phrase (thus, also subject *wh*-phrase) can be retrieved only when there is a left periphery (subject or filler) *wh*-phrase. This can be illustrated with example (1.11) cited by PY after Baker (1970).

(1.11) Who remembers where we bought which book?

This example has two readings (given here by possible answers):

(1.12)
a. John and Martha remember where we bought which book.
b. John remembers where we bought the physics book and Martha and Ted remember where we bought *The Wizard of Oz*.

These readings are captured by the observations above. First, the extracted phrase *where* has to scope immediately over *bought*. Secondly, *Who* cannot be retrieved any higher than its surface position, so it scopes immediately over *remembers*. However, the quantifier corresponding to *which book* can be retrieved either together with the filler *where*, or together with the subject *Who*, thus giving two possible readings. On the basis of these observations, PY propose the following principle governing the scope of *wh*-quantifiers:

(PY 37) Syntactic Licensing Constraint on *Wh*-Retrieval (for 'English-like' syntactic *wh*-movement languages)

a. At any node, retrieval, if any, of *wh*-operators must include the member of the left peripheral daughter's QUE value.
b. At any filler-head node, if the filler has nonempty QUE value, then its member must belong to the node's RETRIEVED value.

Since formalizing this principle requires retrieval at phrases, PY claim that "phrase-level retrieval is necessary in our analysis of interrogatives" (p.10).

Note, however, that there is nothing in the original observations that requires phrasal retrieval; they can be easily restated in our approach. First, (PY 37b) is trivially equivalent to (1.13):

(1.13) At any filler-head node, if the filler has nonempty QUE value, then its member must belong to the node's QUANTS value.

Second, (PY 37a) can be replaced by a principle to the effect that whenever a *wh*-operator is retrieved, there must be some retrieval from a left peripheral phrase. More carefully:

(1.14) If the QUANTS of a *psoa* contains a *wh*-quantifier, it must also contain the QUE member of a left peripheral daughter of some semantic projection of this *psoa*.

In other words, when a *wh*-quantifier is retrieved at a lexical item, there must be a semantic projection of this item, which is either a head-filler node or a head-subject node, such that the left periphery (filler or subject) contains QUE whose member is also retrieved at this lexical item.

Note that this formalization involves non-locality: although *wh*-quantifiers are retrieved lexically, this retrieval depends on the properties of projections of the lexical item. This is the main difference between our analysis and that of PY and it is the price we have to pay for allowing lexical retrieval only. Nevertheless, we do not consider it an excessive price and, in view of the advantages lexical retrieval brings, we are willing to pay it.

4 RSRL Formalization

This section presents a formalization of the above analysis in (a minor notational variant of) RSRL (Relational Speciate Re-entrant Logic) developed by Frank Richter and Manfred Sailer (Richter, 1997) on the basis of Paul J. King's SRL (King, 1989, 1994).

The Signature We assume that the signature contains the following pieces of sort hierarchy and appropriateness specifications:

(1.2)

a.
$$\begin{array}{ccc} & \begin{bmatrix} \textit{content} \\ \textsc{qstore}\ \text{set(quant)} \end{bmatrix} & \\ \swarrow & \downarrow & \searrow \\ \textit{psoa} & \textit{nom-obj} & \textit{quant} \end{array}$$

b.
$$\begin{bmatrix} \textit{word} \\ \ldots \\ \textsc{new-qs}\ \text{set(quant)} \end{bmatrix}$$

Quantification The constraint (1.3)–(1.5) above can be formalized as in (1.15)–(1.19):[6]

(1.15) $$\begin{array}{l} word \rightarrow \\ \quad \exists u, u', s \hfill (\text{Desc}_1) \\ \quad\quad \texttt{qs-union}(:\text{ARG-ST}, u) \;\wedge \\ \quad\quad \texttt{set-union}(\langle u, :\text{NEW-QS}\rangle, u') \;\wedge \\ \quad\quad\quad [[\neg:\text{SS}|\text{LOC}|\text{CONTENT} \sim psoa \wedge \\ \quad\quad\quad :\text{SS}|\text{LOC}|\text{CONTENT}|\text{QS} \approx u'] \\ \quad\quad\quad \vee \\ \quad\quad\quad [:\text{SS}|\text{LOC}|\text{CONTENT} \sim psoa \wedge \\ \quad\quad\quad \texttt{list-to-set}(:\text{SS}|\text{LOC}|\text{CONTENT}|\text{QUANTS}, s) \wedge \\ \quad\quad\quad \texttt{set-union}(\langle :\text{SS}|\text{LOC}|\text{CONTENT}|\text{QS}, s\rangle, u')]] \\ \quad \vee \\ \quad \exists a \hfill (\text{Desc}_2) \\ \quad\quad \texttt{member}(a, :\text{ARG-ST}) \;\wedge \\ \quad\quad :\text{SS}|\text{LOC}|\text{CONTENT} \approx a{:}\text{LOC}|\text{CONTENT} \end{array}$$

The auxiliary relation `qs-union/2` is defined as follows:

(1.16) $$\forall a_0, u[\texttt{qs-union}(a_0, u) \leftrightarrow \texttt{selected-qs-union}(a_0, a_0, u)]$$

(1.17) $$\begin{array}{l} \forall a_0, a, u[\texttt{selected-qs-union}(a_0, a, u) \leftrightarrow \\ \quad [a \sim elist \wedge u \sim eset] \;\vee \\ \quad \exists u_1, u_2 \\ \quad\quad \texttt{selected-qs-union}(a_0, a{:}\text{REST}, u_1) \wedge \\ \quad\quad \texttt{get-selected-qs}(a{:}\text{FIRST}, a_0, u_2) \wedge \\ \quad\quad \texttt{set-union}(\langle u_1, u_2\rangle, u)]] \end{array}$$

(1.18) $$\begin{array}{l} \forall e, a_0, u[\texttt{get-selected-qs}(e, a_0, u) \leftrightarrow \\ \quad [\neg\texttt{raised}(e, a_0) \wedge u \approx e{:}\text{LOC}|\text{CONTENT}|\text{QS}] \vee \\ \quad [\texttt{raised}(e, a_0) \wedge u \approx eset]] \end{array}$$

An element a in a list l is `raised` iff there in an element b in this list such that a is in a VALENCE attribute of b.

(1.19) $$\begin{array}{l} \forall a, l[\texttt{raised}(a, l) \leftrightarrow \\ \quad \exists b\; \texttt{member}(b, l) \;\wedge \\ \quad\quad [\texttt{member}(a, b{:}\text{LOC}|\text{CAT}|\text{VAL}|\text{SUBJ}) \vee \\ \quad\quad \texttt{member}(a, b{:}\text{LOC}|\text{CAT}|\text{VAL}|\text{SPR}) \vee \\ \quad\quad \texttt{member}(a, b{:}\text{LOC}|\text{CAT}|\text{VAL}|\text{COMPS})]] \end{array}$$

[6] As it is not clear what the representation of sets should be, we do not formalize relations on sets such as `list-to-set/2` and `set-union/2`. Intuitively, the former establishes the relationship between a list and the set of its elements, while the latter takes as its first argument a list of sets and specifies its second argument to be the (disjoint) union of the elements of this list.

***Wh*-retrieval** Finally, Pollard and Yoo's (1997) theory of *wh*-retrieval for English can be reformulated as below. (1.13) (corresponding to the second clause of (PY 37)) is trivial to formalize:

(1.20) $$\forall q[\texttt{set-member}(q, \text{:DTRS|FILL-DTR|SS|QUE}) \rightarrow \texttt{member}(q, \text{:SS|LOC|CONTENT|QUANTS})]$$

(1.14) (cf. the first clause of (PY 37)) is less trivial: an appropriate constraint has to be more global than in Pollard and Yoo (1997).[7] What the constraint below says is that if the QUANTS list of a *psoa* contains a *wh*-quantifier, there must be a semantic projection involving a left-periphery *wh*-phrase, whose QUE member is also on this QUANTS list. This description is meant to hold of root clauses.[8,9]

(1.21) $$\begin{aligned}&\forall w, q[\ [\texttt{wh-quantifier}(q) \wedge w \sim \textit{word} \wedge \\ &\quad \texttt{member}(q, w\text{:SS|LOC|CONTENT|QUANTS})] \rightarrow \\ &\quad [\exists n, q_1 \\ &\qquad [\texttt{semantic-projection}(n, w) \wedge \\ &\qquad \texttt{member}(q_1, n\text{:QUANTS}) \wedge \\ &\qquad\quad [\texttt{set-member}(q_1, n\text{:DTRS|SUBJ-DTR|SS|LOC|QUE}) \vee \\ &\qquad\quad \texttt{set-member}(q_1, n\text{:DTRS|FILL-DTR|SS|LOC|QUE})]]]]\end{aligned}$$

A node is a semantic projection of a word if it is the word or if a semantic projection of the word is the semantic daughter of the node:

(1.22) $$\begin{aligned}&\forall n, w[\texttt{semantic-projection}(n, w) \leftrightarrow \\ &\quad [n \approx w \ \vee \\ &\quad \exists n_1[\texttt{semantic-projection}(n_1, w) \wedge \\ &\qquad \texttt{semantic-daughter}(n_1, n)]]]\end{aligned}$$

The relation `semantic-daughter` is defined as in Pollard and Sag (1994):

(1.23) $$\begin{aligned}&\forall n, n_1[\texttt{semantic-daughter}(n_1, n) \leftrightarrow \\ &\quad [[n\text{:DTRS} \sim \textit{head-adj-str} \ \wedge \ n_1 \approx n\text{:ADJ-DTR}] \vee \\ &\quad [\neg n\text{:DTRS} \sim \textit{head-adj-str} \ \wedge \ n_1 \approx n\text{:HEAD-DTR}]]]\end{aligned}$$

[7] See Koenig (1998) for a different approach to stating such constraints.

[8] Thus, the complete constraint will have the form (i), where RootDesc depends on the particular analysis of root (unembedded) clauses, e.g., (ii) (cf. Uszkoreit's (1987) MAIN CLAUSE).

(i) RootDesc $\rightarrow$ (1.21)

(ii) $$\text{RootDesc} = \begin{bmatrix} \textit{phrase} \\ \text{MC} \ + \end{bmatrix}$$

[9] On the basis of Pollard and Yoo (1997), a wh-*quantifier* could be preliminarily defined as a quantifier whose DET is of sort *which*, i.e.:

(i) $$\forall q[\texttt{wh-quantifier}(q) \leftrightarrow q\text{:DET} \sim \textit{which}]$$

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