In defense of an HPSG-based theory of non-constituent coordination: A reply to Kubota and Levine

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1 Introduction

Kubota and Levine (2015) argue that the HPSG-based theories of non-constituent coordination proposed in Yatabe (2001), Beavers and Sag (2004), and later works compare unfavorably with a theory that can be formulated using a version of Categorial Grammar (CG) that they call Hybrid Type-Logical Categorial Grammar. At the heart of their criticism of the HPSG-based theories is the long-known fact that sentences involving non-constituent coordination can mean something different from what is meant by the supposedly corresponding sentences involving only constituent coordination, as shown by the examples below.

(1) a. Terry gave no man a book on Friday or a record on Saturday.

    b. Terry gave no man a book on Friday or gave no man a record on Saturday.

(2) a. I said different things to Robin on Thursday and Leslie on Friday.

    b. I said different things to Robin on Thursday and said different things to Leslie on Friday.

According to Kubota and Levine, the above-mentioned HPSG-based theories claim that sentences like (1a) and (2a) are generated by applying prosodic ellipsis to sentences like (1b) and (2b) respectively, and as a result, the theories are unable to capture the semantic contrast between (1a) and (1b) and between (2a) and (2b) without recourse to some ad-hoc mechanism.

In this response to Kubota and Levine (2015), we will first show, in section 2, that these authors' characterization of the HPSG-based theories is inaccurate and that the HPSG-based theory proposed in Yatabe (2001) and modified in Yatabe (2012) does not have the problems that Kubota and Levine claim it does. We will next propose, in section 3, a theory of *respectively* readings that is compatible with the HPSG-based theory of non-constituent coordination, so as to ensure that the theory has the same empirical coverage as Kubota and Levine's. We will note at that point that Kubota and Levine's theory of *respectively* interpretation has some empirical inadequacies and that their account of the internal readings of symmetric and summative predicates is

invalidated by those inadequacies. In section 4, we will discuss in what ways the particular HPSG-based theory we advocate is superior to the theory proposed in Beavers and Sag (2004). And in section 5, we will argue that there are empirical reasons to prefer this HPSG-based theory over Kubota and Levine's, even disregarding the inadequacies of their account of *respectively* interpretation.

2   A synopsis of an HPSG-based theory of non-constituent coordination

Kubota and Levine say the following about the HPSG-based theories of non-constituent coordination.

> In this approach (Yatabe 2001; Crysmann 2003; Beavers and Sag 2004; Chaves 2007), advocated by several authors in the recent HPSG literature utilizing the so-called linearization-based architecture of HPSG, examples like those in (1) receive analyses roughly along the following lines:
>
> (2)   a. [$_S$ I gave Robin a book] and [$_S$ ~~(I) gave~~ Terry a pair of pliers].
>   b. [$_S$ I gave Robin ~~a pair of pliers~~] and [$_S$ Leslie offered Terry, a pair of pliers].
>   c. [$_S$ Leslie bought a CD], and [$_S$ Robin ~~bought~~ a book].
>
> The key claim, which is effectively the same as the old idea of CONJUNCTION REDUCTION (Gleitman 1965; Jackendoff 1971) from the transformational literature, is that the apparent non-constituent coordination in these examples is in fact only apparent, and that these examples all involve full-fledged coordination in the 'underlying' combinatoric structure feeding into semantic interpretation. The surface form of the sentence is obtained by ellipsis of the relevant part of the sentence via identity in form to some string in the other conjunct. (p. 522)

This is arguably an accurate characterization of what is proposed in Beavers and Sag (2004), except that the sentence cited as (2c) here is an instance of Gapping, a phenomenon that is generally distinguinshed from non-constituent coordination in the HPSG literature.

However, the passage above is demonstrably inaccurate as a description of the theory proposed in Yatabe (2001), the first document cited in it. On the first page of that document, it is stated that "In the theory proposed, it is claimed that semantic composition (including 'quantifier retrieval') takes place not when some signs are syntactically combined to produce a new, larger sign but when some domain objects (which are essentially prosodic constituents) are merged (by the total or partial compaction operation) to produce a new domain object (i.e. a new, larger prosodic constituent)." In other words, the structure that feeds into semantic interpretation in this theory is not the 'underlying', i.e. pre-ellipsis, syntactic structure but rather the surface, i.e. post-ellipsis, prosodic structure.

In this section, we will explain exactly how the theory in question computes the meaning of a sentence on the basis of its surface prosodic structure, as opposed to its syntactic structure. What is presented below is largely a recapitulation of what is proposed in Yatabe (2001) and Yatabe (2012), but fills in some details that are left unspecified there. We will presuppose familiarity with the basics of the textbook version of HPSG (see Sag *et al.* (2003)) but nothing more.
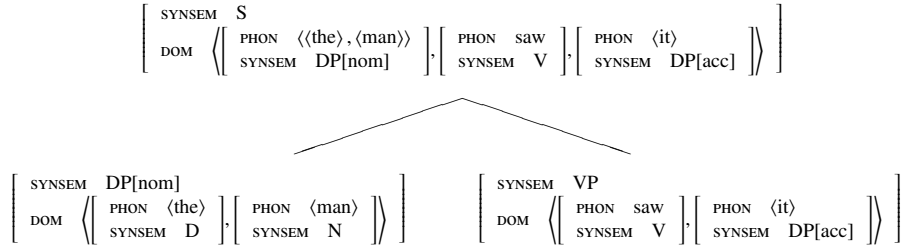
$$\begin{bmatrix} \text{SYNSEM} & \text{S} \\ \text{DOM} & \left\langle \begin{bmatrix} \text{PHON} & \langle\langle\text{the}\rangle,\langle\text{man}\rangle\rangle \\ \text{SYNSEM} & \text{DP[nom]} \end{bmatrix}, \begin{bmatrix} \text{PHON} & \text{saw} \\ \text{SYNSEM} & \text{V} \end{bmatrix}, \begin{bmatrix} \text{PHON} & \langle\text{it}\rangle \\ \text{SYNSEM} & \text{DP[acc]} \end{bmatrix} \right\rangle \end{bmatrix}$$

$$\begin{bmatrix} \text{SYNSEM} & \text{DP[nom]} \\ \text{DOM} & \left\langle \begin{bmatrix} \text{PHON} & \langle\text{the}\rangle \\ \text{SYNSEM} & \text{D} \end{bmatrix}, \begin{bmatrix} \text{PHON} & \langle\text{man}\rangle \\ \text{SYNSEM} & \text{N} \end{bmatrix} \right\rangle \end{bmatrix} \qquad \begin{bmatrix} \text{SYNSEM} & \text{VP} \\ \text{DOM} & \left\langle \begin{bmatrix} \text{PHON} & \text{saw} \\ \text{SYNSEM} & \text{V} \end{bmatrix}, \begin{bmatrix} \text{PHON} & \langle\text{it}\rangle \\ \text{SYNSEM} & \text{DP[acc]} \end{bmatrix} \right\rangle \end{bmatrix}$$

Figure 1: Total compaction of a DP and liberation of a VP

2.1 Linearization-based HPSG

The syntactic framework that we use to develop our theory is Linearization-based HPSG, the version of HPSG proposed in works such as Reape (1994) and Kathol and Pollard (1995). In this framework, each node in a syntactic phrase-structure tree is associated with what is called an *order domain*, which can be viewed as a list of prosodic constituents that the words dominated by that node are assembled into. An order domain is a list of *domain objects*, and is given as the value of the DOM feature. A domain object, which represents a prosodic constituent, is very much like a sign; unlike a sign, however, it does not carry any information as to its internal morphosyntactic structure. Departing from an assumption adopted in most versions of Linearization-based HPSG, we will assume in the present article that morphosyntactic constituency is represented not by an unordered tree but by a tree, and that the order of domain objects in an order domain largely reflects the order of the signs that have given rise to those domain objects. (More specifically, we assume that the order of domain objects is subject to the set of constraints stated in Appendix A.)

We will use a concrete example to explicate the relationship between signs, which are each associated with a node, and domain objects. Figure 1 shows part of the structure assigned to the English sentence *The man saw it*. What is shown is the local subtree in which the subject DP and the VP combine to become the matrix clause. The order domain (i.e. the DOM value) of the VP node consists of two domain objects, one that is pronounced *saw*, and the other one that is pronounced *it*; this indicates that this VP is to be pronounced *saw it*. Likewise, the order domain of the DP node indicates that this DP is to be pronounced *the man*, and the order domain of the S node indicates that the S node is to be pronounced *The man saw it*.

Notice that the subject DP node, whose order domain contains two domain objects, contributes to the order domain of the S node only one domain object, which is pronounced *the man*. What is at work here is an operation called *total compaction*. (3) is a simplified description of the way the total compaction operation takes a sign and turns it into a single domain object.

(3) Total compaction (Preliminary description)

$$\begin{bmatrix} \text{SYNSEM} & \alpha_0 \\ \text{DOM} & \left\langle \begin{bmatrix} \text{PHON} & \beta_1 \\ \text{SYNSEM} & \alpha_1 \end{bmatrix}, \cdots, \begin{bmatrix} \text{PHON} & \beta_n \\ \text{SYNSEM} & \alpha_n \end{bmatrix} \right\rangle \end{bmatrix}$$

$$\Rightarrow \begin{bmatrix} \text{PHON} & \langle \beta_1, \cdots, \beta_n \rangle \\ \text{SYNSEM} & \alpha_0 \end{bmatrix}$$

What is shown on the left of the arrow is the input to the operation; the input is a sign. On the right of the arrow is shown the output of the operation; the output is a domain object. The domain object that is created by totally compacting a sign X is placed in

the order domain of the mother of *X*. In Figure 1, the domain object that is created by totally compacting the subject DP has been placed in the order domain of the S.

We say that a node has been *liberated* when the node is not totally compacted and all the domain objects in the order domain of the node are inherited unaltered by the order domain of the mother of that node. The VP in Figure 1 is liberated. The two domain objects in the order domain of the VP node are both integrated, unaltered, into the order domain of the S node.

There is a third process that a node may undergo, besides total compaction and liberation. We say that a sign has been *partially compacted* when (i) zero or more domain objects are excised from its order domain and (ii) the sign thus altered is compacted. Note that, by definition, total compaction is in fact a type of partial compaction, not a process separate from it. When a sign is partially compacted, the domain objects that were excised from its order domain (if any) are inherited by the order domain of the mother of that sign, and the domain object that is newly created by compaction is also placed in the order domain of the mother. We will say that those domain objects that were excised from the order domain of a sign and inherited by the order domain of the mother of that sign have *escaped compaction*, and we will say that the domain objects that were not excised and thus were part of the sign that was compacted (in stage (ii) of partial compaction) have *undergone compaction*.

In the original definition of partial compaction presented in Kathol and Pollard (1995), it is assumed that only domain objects corresponding to extraposable types of expressions (such as domain objects corresponding to relative clauses in English) can escape compaction, but here we drop that restriction and assume that, in a head-first language like English, any domain object can escape compaction as long as it is not the leftmost element of an order domain. (4) illustrates the way the partial compaction operation takes a sign and turns it into one or more domain objects, which are to be placed in the order domain of the mother of that sign.

(4) Partial compaction for head-first languages (Preliminary description):

$$
\begin{bmatrix} \text{SYNSEM} & \alpha_0 \\ \text{DOM} & \left\langle \begin{bmatrix} \text{PHON} & \beta_1 \\ \text{SYNSEM} & \alpha_1 \end{bmatrix}, \cdots, \begin{bmatrix} \text{PHON} & \beta_n \\ \text{SYNSEM} & \alpha_n \end{bmatrix} \right\rangle \end{bmatrix}
$$

$$
\Rightarrow \begin{bmatrix} \text{PHON} & \langle \beta_1, \cdots, \beta_i \rangle \\ \text{SYNSEM} & \alpha_0 \end{bmatrix}, \begin{bmatrix} \text{PHON} & \beta_{i+1} \\ \text{SYNSEM} & \alpha_{i+1} \end{bmatrix}, \cdots, \begin{bmatrix} \text{PHON} & \beta_n \\ \text{SYNSEM} & \alpha_n \end{bmatrix}
$$

In (4), the DOM value of the sign that is fed to the operation as the input has *n* domain objects in it. Of those domain objects, the first (i.e. leftmost) *i* domain objects are bundled together and turned into a single domain object, while the remaining domain objects, if any, are left out of the bundle and continue to be separate domain objects.

Various types of extraposition constructions may result when an expression is partially compacted and surfaces as a discontinuous constituent. Figure 2 shows how the English extraposition construction can be generated via partial compaction. What is shown in the figure is the local subtree in which the subject DP *a man who was wearing a black cloak* and the VP *entered* combine to become the sentence *A man entered who was wearing a black cloak*. Here, the subject DP has been partially compacted; the relative clause has been left out of the bundle and appears in the sentence-final position.

What happens to each sign must conform to the following set of constraints.

(5)   a.   In a head-complement structure whose head is not nominal and in a head-subject structure, the head is liberated and the non-head is partially compacted.
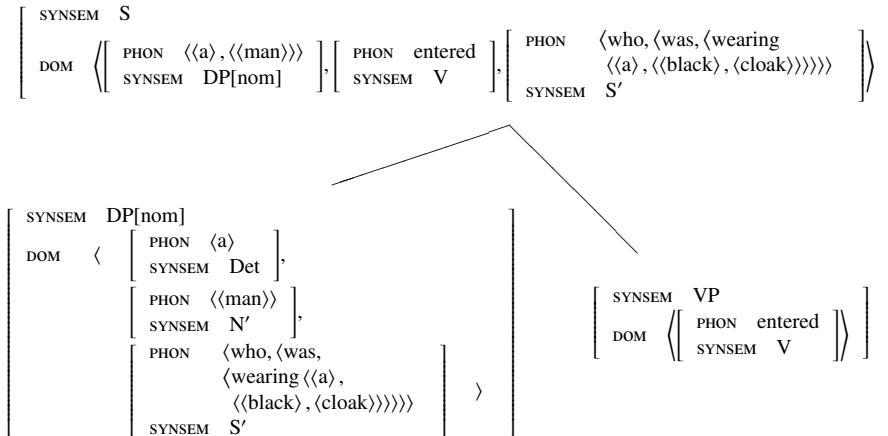
4

$$
\begin{bmatrix}
\text{SYNSEM} & S \\
\text{DOM} & \left\langle
\begin{bmatrix}
\text{PHON} & \langle\langle a\rangle, \langle\langle man\rangle\rangle\rangle \\
\text{SYNSEM} & \text{DP[nom]}
\end{bmatrix},
\begin{bmatrix}
\text{PHON} & entered \\
\text{SYNSEM} & V
\end{bmatrix},
\begin{bmatrix}
\text{PHON} & \langle who, \langle was, \langle wearing \\
& \quad \langle\langle a\rangle, \langle\langle black\rangle, \langle cloak\rangle\rangle\rangle\rangle\rangle\rangle \\
\text{SYNSEM} & S'
\end{bmatrix}
\right\rangle
\end{bmatrix}
$$

$$
\begin{bmatrix}
\text{SYNSEM} & \text{DP[nom]} \\
\text{DOM} & \left\langle
\begin{bmatrix}
\text{PHON} & \langle a\rangle \\
\text{SYNSEM} & \text{Det}
\end{bmatrix},
\begin{bmatrix}
\text{PHON} & \langle\langle man\rangle\rangle \\
\text{SYNSEM} & N'
\end{bmatrix},
\begin{bmatrix}
\text{PHON} & \langle who, \langle was, \\
& \quad \langle wearing \langle\langle a\rangle, \\
& \quad \langle\langle black\rangle, \langle cloak\rangle\rangle\rangle\rangle\rangle\rangle \\
\text{SYNSEM} & S'
\end{bmatrix}
\right\rangle
\end{bmatrix}
$$

$$
\begin{bmatrix}
\text{SYNSEM} & VP \\
\text{DOM} & \left\langle
\begin{bmatrix}
\text{PHON} & entered \\
\text{SYNSEM} & V
\end{bmatrix}
\right\rangle
\end{bmatrix}
$$

Figure 2: Partial compaction of a DP

    b. In a head-adjunct structure whose head is not nominal, the head and the adjunct are both partially compacted.

    c. In a headed structure whose head is nominal (i.e. an N, a D, or a projection thereof) and whose non-head is not a marker, the head is totally compacted and the non-head is partially compacted.

We assume that a phrase like *the man* is headed by the determiner, so the sign *man* in Figure 1 is only required to be partially compacted, although in this case it happens to be totally compacted.

Two caveats concerning the style of our presentation are in order here before proceeding further. First, Linearization-based HPSG is, just like the textbook version of HPSG, a constraint-based formalism in which each grammatical rule or principle is employed not to build a phrase-structure tree from the bottom up but rather to determine whether a given, fully formed representation is admissible or not, but throughout this article, we will talk as if a phrase-structure tree were constructed from the bottom up when that way of talking makes the presentation easier to follow. Second, in our exposition, we will sometimes use the words *sign* and *node* interchangeably, since a sign is always associated with a node in a syntactic phrase-structure tree, and the distinction between the two can be immaterial.

2.2 Minimal recursion semantics

Now we turn to the issue of semantic composition. We make essential use of a modified version of Minimal Recursion Semantics (MRS), a theory of semantic composition proposed in Copestake *et al.* (2005), so we need to present the basics of MRS first.

MRS is one of the several mutually related semantic formalisms in which semantic representations are allowed to be underspecified so that they can stand for more than one reading of a sentence simultaneously. In MRS, the meaning of a word is expressed by what is called an elementary predication, which consists of a predicate and its arguments, and the meaning of a phrase is expressed by a sequence of elementary predications. Each elementary predication in such a sequence is given a handle, which indicates precisely how that elementary predication is to fit into the overall semantic

representation. Let us take the following sequence of five elementary predications as an example.

(6) ⟨ $h0$: every(x, $h1$, $h2$),
        $h1$: smart(x),
        $h1$: student(x),
        $h3$: probably($h4$),
        $h5$: agrees(x)   ⟩

These five elementary predications, each prefaced with its handle, represent the meaning of the words *every*, *smart*, *student*, *probably*, and *agrees* respectively, and the sequence as a whole is supposed to represent the two possible meanings of the sentence *Every smart student probably agrees*, one in which *every smart student* outscopes *probably* and another in which the universal quantifier is outscoped by the adverb. The three arguments of the predicate *every* are the variable that the quantifier binds, the restriction of the quantifier, and the (nuclear) scope of the quantifier, respectively.

In an MRS representation, elementary predications that are prefaced by the same handle are interpreted as being conjoined with each other. Thus, the second and the third elementary predication in this example, which both have the handle $h1$, are interpreted as conjoined with each other.

The capacity of an MRS representation to serve as an underspecified representation that can stand for more than one semantic interpretation comes from the fact that handles that are given different names (such as $h1$ and $h2$) may or may not be the same handle. The representation in (6) becomes (7) if $h2 = h3$ and $h4 = h5$, and becomes (8) if $h4 = h0$ and $h2 = h5$.

(7) ⟨ $h0$: every(x, $h1$, $h2$),
        $h1$: smart(x),
        $h1$: student(x),
        $h2$: probably($h4$),
        $h4$: agrees(x)   ⟩

(8) ⟨ $h4$: every(x, $h1$, $h2$),
        $h1$: smart(x),
        $h1$: student(x),
        $h3$: probably($h4$),
        $h2$: agrees(x)   ⟩

When the name of a handle argument (i.e. an argument slot whose name starts with h) and the handle of a set of elementary predications are identical, the set of elementary predications is interpreted as filling the argument slot represented by the handle-argument name. Thus, the representation in (7), in which $h0$ is the top handle, i.e. the outermost handle, can be rewritten as (9), and (8), in which $h3$ is the top handle, can be rewritten as (10). The former is the reading in which the universal quantifier takes wide scope over the adverbial and the latter is the reading in which the adverbial takes scope over the universal quantifier.

(9) every(x, smart(x) ∧ student(x), probably(agrees(x)))

(10) probably(every(x, smart(x) ∧ student(x), agrees(x)))

These two are the only meanings that correspond to the underspecified representation in (6) because it is assumed (i) that every handle-argument name must be equated with the handle of some elementary predication and (ii) that the handle of an elementary

predication cannot be equated with more than one handle-argument name. The second assumption, which requires that elementary predications in an MRS representation should form a tree, prevents $h5$ from being equated with $h1$ and with $h2$ at the same time, for example. Another constraint that is imposed on MRS representations is that a variable that is bound by a quantifier in an MRS representation cannot be reused as a free variable or a variable bound by another quantifier in the same MRS representation, although this condition, which is referred to as the variable binding condition in the literature, plays no role in the above example.

2.3 Compaction-driven meaning assembly

We are now in a position to explicate how semantic composition can be performed on the basis of prosodic structure. It turns out that all that is required is a simple modification to the way MRS is integrated into Linearization-based HPSG.

Figure 3 illustrates how semantic composition is performed in a standard variety of Linearization-based HPSG. In this figure, which shows the syntactic phrase-structure tree assigned to the sentence *Some boy saw every girl* in standard versions of Linearization-based HPSG, a determiner *every* and a noun *girl* combine to form a DP, which combines with a transitive verb *saw* to become a VP, which then combines with a subject DP *some boy* (whose internal structure is suppressed in this figure) to become a sentence. The sign at each node in the representation is associated with the SYNSEM feature and the DOM feature. The value of the SYNSEM feature is a feature structure that is equipped with the CATEGORY feature, which is called SYNTAX in Sag *et al.* (2003) and is abbreviated here as CAT, and the CONTENT feature, which is called SEMANTICS in Sag *et al.* (2003) and is abbreviated as CONT here. The CONT value of the sign associated with each node represents the semantic content of that node; when MRS is used, the CONT value of each node is an MRS representation of the content of that node. In each local subtree, the CONT value of the mother is computed on the basis of the CONT values of the daughter nodes.

What is to be noted here is that, in this standard picture, meaning assembly proceeds along two routes, so to speak. On the one hand, the meaning of successively larger signs is computed on the basis of the meaning of their daughters. But at the same time, as a side effect of this, the meaning of successively larger domain objects is computed as well, since the CONT value of each domain object mirrors the CONT value of the sign whose compaction gave rise to that domain object. For instance, let us see how the meaning of *every* and that of *girl* are combined to yield the meaning of the phrase *every girl* in Figure 3. This process takes place in the local subtree at the very bottom, where the meaning of the DP sign *every girl* (i.e. the denotation of $\boxed{10}$) is computed on the basis of the meaning of the D sign *every* (i.e. the denotation of $\boxed{12}$) and the meaning of the N sign *girl* (i.e. the denotation of $\boxed{14}$). (The denotation of $\boxed{10}$ is schematically shown within the sign associated with the top node, and the denotations of $\boxed{12}$ and $\boxed{14}$ are schematically shown within the sign associated with the object DP node.) But at the same time, if you ignore the CONT values of signs and instead focus on the CONT values of domain objects in the figure, it looks as though the semantic content of the second domain object in the order domain of the VP node (namely the domain object to be pronounced "every girl") had been computed by combining the semantic content of the first and the second domain object in the order domain of the object DP node (namely the two domain objects to be pronounced "every" and "girl" respectively.)

In the theory to be explicated below, we control this second route of meaning assembly, which is realized in the CONT values of domain objects, directly, rather than

$$\begin{bmatrix} \text{SYNSEM} & \begin{bmatrix} \text{CAT} & \boxed{1} \\ \text{CONT} & \boxed{2} \end{bmatrix} \\ \text{DOM} & \left\langle \begin{bmatrix} \text{PHON} & \langle\langle\text{some}\rangle,\langle\text{boy}\rangle\rangle \\ \text{SYNSEM} & \begin{bmatrix} \text{CAT} & \boxed{3} \\ \text{CONT} & \boxed{4} \end{bmatrix} \end{bmatrix}, \begin{bmatrix} \text{PHON} & \text{saw} \\ \text{SYNSEM} & \begin{bmatrix} \text{CAT} & \boxed{7} \\ \text{CONT} & \boxed{8} \end{bmatrix} \end{bmatrix}, \begin{bmatrix} \text{PHON} & \langle\langle\text{every}\rangle,\langle\text{girl}\rangle\rangle \\ \text{SYNSEM} & \begin{bmatrix} \text{CAT} & \boxed{9} \\ \text{CONT} & \boxed{10}\begin{bmatrix} \text{RELS} & \left\langle \boxed{15}\begin{bmatrix} \text{HNDL} & h1 \\ \text{RELN} & \text{every} \\ \text{VAR} & x \\ \text{RESTRICTOR} & h2 \\ \text{SCOPE} & h3 \end{bmatrix}, \boxed{16}\begin{bmatrix} \text{HNDL} & h4 \\ \text{RELN} & \text{girl} \\ \text{INSTANCE} & x \end{bmatrix} \right\rangle \end{bmatrix} \end{bmatrix} \end{bmatrix} \right\rangle \end{bmatrix}$$

$$\begin{bmatrix} \text{SYNSEM} & \begin{bmatrix} \text{CAT} & \boxed{3} \\ \text{CONT} & \boxed{4} \end{bmatrix} \\ \text{DOM} & \left\langle \begin{bmatrix} \text{PHON} & \langle\text{some}\rangle \end{bmatrix}, \begin{bmatrix} \text{PHON} & \langle\text{boy}\rangle \end{bmatrix} \right\rangle \end{bmatrix} \qquad \text{some boy}$$

$$\begin{bmatrix} \text{SYNSEM} & \begin{bmatrix} \text{CAT} & \boxed{5} \\ \text{CONT} & \boxed{6} \end{bmatrix} \\ \text{DOM} & \left\langle \begin{bmatrix} \text{PHON} & \text{saw} \\ \text{SYNSEM} & \begin{bmatrix} \text{CAT} & \boxed{7} \\ \text{CONT} & \boxed{8} \end{bmatrix} \end{bmatrix}, \begin{bmatrix} \text{PHON} & \langle\langle\text{every}\rangle,\langle\text{girl}\rangle\rangle \\ \text{SYNSEM} & \begin{bmatrix} \text{CAT} & \boxed{9} \\ \text{CONT} & \boxed{10} \end{bmatrix} \end{bmatrix} \right\rangle \end{bmatrix}$$

$$\begin{bmatrix} \text{SYNSEM} & \begin{bmatrix} \text{CAT} & \boxed{7} \\ \text{CONT} & \boxed{8} \end{bmatrix} \\ \text{DOM} & \left\langle \begin{bmatrix} \text{PHON} & \text{saw} \\ \text{SYNSEM} & \begin{bmatrix} \text{CAT} & \boxed{7} \\ \text{CONT} & \boxed{8} \end{bmatrix} \end{bmatrix} \right\rangle \end{bmatrix}$$

$$\begin{bmatrix} \text{SYNSEM} & \begin{bmatrix} \text{CAT} & \boxed{9} \\ \text{CONT} & \boxed{10} \end{bmatrix} \\ \text{DOM} & \left\langle \begin{bmatrix} \text{PHON} & \langle\text{every}\rangle \\ \text{SYNSEM} & \begin{bmatrix} \text{CAT} & \boxed{11} \\ \text{CONT} & \boxed{12}\begin{bmatrix} \text{RELS} & \langle \boxed{15}\rangle \end{bmatrix} \end{bmatrix} \end{bmatrix}, \begin{bmatrix} \text{PHON} & \langle\text{girl}\rangle \\ \text{SYNSEM} & \begin{bmatrix} \text{CAT} & \boxed{13} \\ \text{CONT} & \boxed{14}\begin{bmatrix} \text{RELS} & \langle \boxed{16}\rangle \end{bmatrix} \end{bmatrix} \end{bmatrix} \right\rangle \end{bmatrix}$$

$$\begin{bmatrix} \text{SYNSEM} & \begin{bmatrix} \text{CAT} & \boxed{11} \\ \text{CONT} & \boxed{12} \end{bmatrix} \\ \text{DOM} & \left\langle \begin{bmatrix} \text{PHON} & \text{every} \\ \text{SYNSEM} & \begin{bmatrix} \text{CAT} & \boxed{11} \\ \text{CONT} & \boxed{12} \end{bmatrix} \end{bmatrix} \right\rangle \end{bmatrix} \qquad \begin{bmatrix} \text{SYNSEM} & \begin{bmatrix} \text{CAT} & \boxed{13} \\ \text{CONT} & \boxed{14} \end{bmatrix} \\ \text{DOM} & \left\langle \begin{bmatrix} \text{PHON} & \text{girl} \\ \text{SYNSEM} & \begin{bmatrix} \text{CAT} & \boxed{13} \\ \text{CONT} & \boxed{14} \end{bmatrix} \end{bmatrix} \right\rangle \end{bmatrix}$$
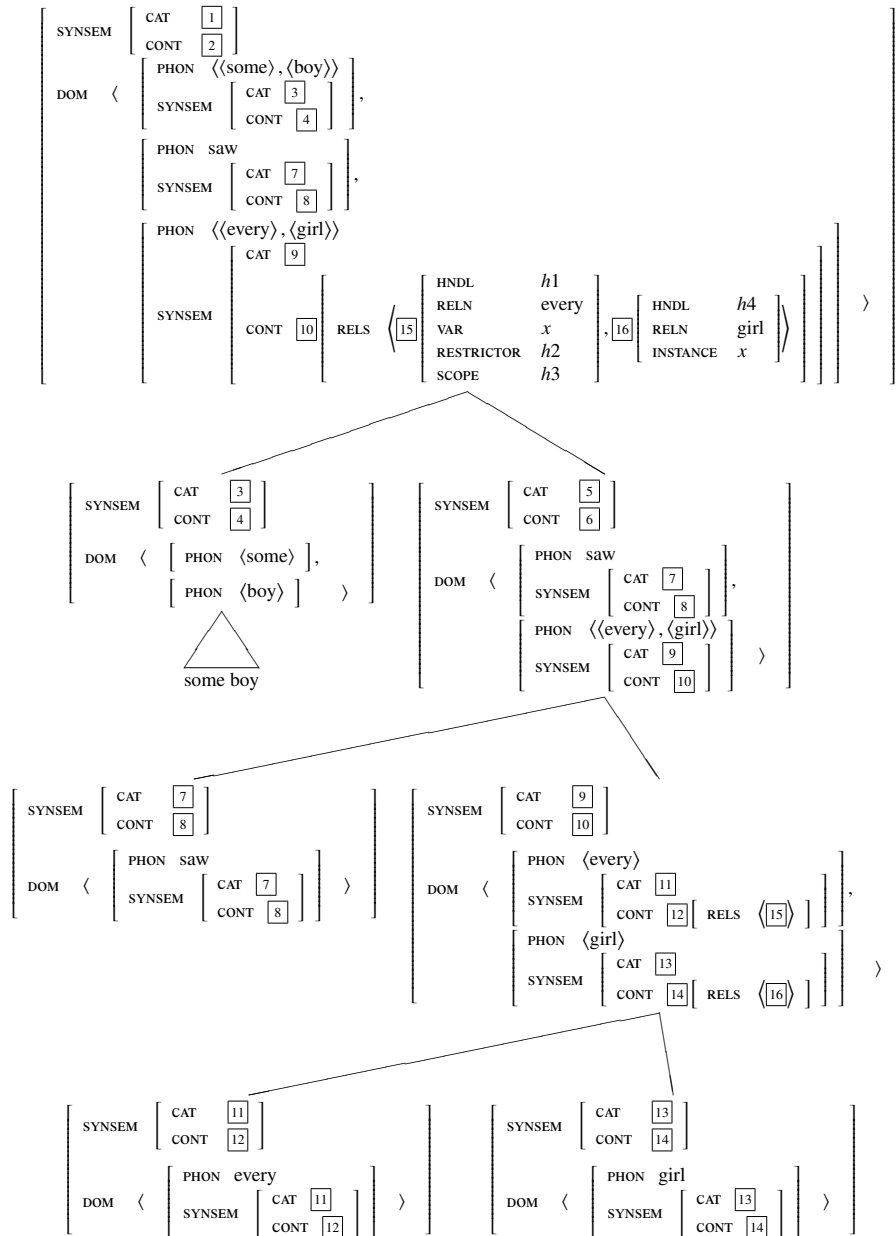
Figure 3: A schematic representation of the structure assigned to the sentence *Some boy saw every girl* in the standard versions of Linearization-based HPSG

letting it simply mirror what takes place in the CONT values of signs. Meaning assembly is compaction-driven in this theory, in the sense that one step of meaning assembly takes place every time a sign undergoes compaction and a new domain object is created. Since domain objects are representations of prosodic constituents, the proposed theory can be regarded as an attempt to modify the HPSG framework to capture the insight, expressed most clearly in Steedman (2000), that the linguistic objects that need to be given semantic interpretation are strings that are viewed in most grammatical theories as prosodic constituents, as opposed to morphosyntactic constituents. The reason why this departure from the standard versions of HPSG is required will become apparent in Section 4 below, where we will compare the proposed theory with the theory presented in Beavers and Sag (2004). And in Section 5, we will compare the proposed theory with CG-based theories like Steedman's, and demonstrate that these two types of theories are not equivalent to each other.

In the theory that we advocate, the value of the SYNSEM|CONTENT feature is a feature structure with the following features: EP, KEY, LTOP, SEMHEAD, INDEX, H-STORE, and H-CONS. Below, we will describe how each of these features is utilized within the CONTENT values of domain objects as well as within the CONTENT values of signs.

The EP value of a domain object is a list of elementary predications that represents the meaning of that domain object. For instance, the EP value of a domain object representing the expression *every girl* would be as shown in (11).

$$(11) \quad \left\langle \begin{bmatrix} \text{HNDL} & h5 \\ \text{RELN} & \text{every} \\ \text{VAR} & y \\ \text{RESTRICTOR} & h6 \\ \text{SCOPE} & h7 \end{bmatrix}, \begin{bmatrix} \text{HNDL} & h12 \\ \text{RELN} & \text{girl} \\ \text{INSTANCE} & y \end{bmatrix} \right\rangle$$

Within each elementary predication, the HNDL value represents the handle of that elementary predication, and the RELN value represents the relation that holds together that elementary predication. We assume that, unlike the EP value of a domain object, the EP value of a sign is always an empty list.

The KEY value of a phrase, which is determined according to the rules in (12), shows the meaning of the head of that phrase. We assume that the KEY value of a word is identical to the EP value of the sole domain object in its order domain.

(12) a. The KEY value of a headed phrase is indentical to the KEY value of the head daughter.

   b. The KEY value of a coordinate structure is the list obtained by concatenating the KEY values of the conjuncts.[1]

The KEY values of signs are used to distinguish intersective modifiers from non-intersective ones (see (13) below) and to distinguish quantificational DPs from non-quantificational DPs (see section 3 and (86) below). Since the KEY feature does not have any role to play inside domain objects, we assume that the KEY value of a domain object is always *none*.

The LTOP value of a sign or domain object is the local top handle of that sign or domain object. For instance, if the EP value of a domain object is like (7) above, then the LTOP value of that domain object is $h0$, the handle of the quantifier that takes widest scope.

---

[1]Following the tradition in formal linguistics, we use the word *conjunct* to refer to each of the expressions that are coordinated inside a coordinate structure, irrespective of whether the coordinator involved expresses conjunction or disjunction. The word *disjunct* will be used as a more restrictive term that can be employed only when the coordinator involved expresses disjunction.

The SEMHEAD value of a node diverges from its LTOP value only when one or more quantifiers are retrieved from quantifier storage and take scope at that node. When the LTOP value and the SEMHEAD value of a node do diverge, the SEMHEAD value of that node is the handle that would have become the local top handle of that node if no quantifier had been retrieved from quantifier storage and taken scope at that node.[2] In other words, the SEMHEAD value of a node is, in most cases, the topmost non-quantificational handle at that node, if we use the term *non-quantificational handles* to refer to handles that do not correspond to quantifiers or to the restrictions of quantifiers. (Nodes that represent quantifiers or the restrictions of quantifiers are exceptions to this statement; at those nodes, the SEMHEAD values are themselves quantificational handles.) For instance, suppose (i) that the EP value of the domain object that is created as a result of compacting a node X looks like (7) above, and (ii) that the quantifier meaning contained in that EP value was retrieved from the quantifier storage and took scope at that node. In that situation, the SEMHEAD value of the sign X is $h2$, the handle of the adverb *probably*, the highest non-quantificational handle in the representation. Since the SEMHEAD feature is meaningful only in the CONTENT value of a sign, we assume that the SEMHEAD value of a domain object is always *none*.

The LTOP value and the SEMHEAD value of a sign are used to maintain the relationship between the HNDL values of elementary predications, i.e. their handles, and they are subject to the following set of constraints.[3]

(13)   a. The LTOP value and the SEMHEAD value of a headed structure whose head is liberated are identical to the LTOP value and the SEMHEAD value of the head respectively.

        b. The SEMHEAD value of a head-complement structure whose head is totally or partially compacted is identical to the LTOP value of the head.

        c. In a head-adjunct structure such that the KEY value of the non-head daughter contains a scopal elementary predication (i.e. an elementary predication that takes a handle as an argument), the SEMHEAD value of the mother is identical to the LTOP value of the non-head daughter.

        d. In a head-adjunct structure such that the KEY value of the non-head daughter does not contain a scopal elementary predication, the SEMHEAD value of the mother, the LTOP value of the non-head daughter, and the LTOP value of the head are identical to each other.

The constraints in (13) constrain the LTOP values and the SEMHEAD values of signs largely as if the signs were given semantic interpretation just as in standard versions of HPSG.

The rule in (13c) is for a head-adjunct structure in which the adjunct is of the non-intersective kind. Take as an example a head-adjunct structure made up of a VP and a non-intersective adverb *probably*. Assuming the standard type of semantic composition, the meaning of the head-adjunct structure as a whole would be probably′(VP′), if no quantifier is retrieved from quantifier storage and takes scope at that node; the meaning of the adverb (i.e. probably′) would be the outermost element of that semantic representation. This means that the topmost non-quantificational handle of this head-adjunct structure (i.e. its SEMHEAD value) is the local top handle of the adverb. Notice that this parallels what is specified in (13c), although in the proposed account the signs are assumed not to be the principal carriers of semantic information.

---

[2]This means that the SEMHEAD feature in this theory has roughly the same function that the LTOP feature does in the version of MRS presented in Copestake *et al.* (2005).

[3]The theory described in Yatabe (2001) did not have a mechanism for interpreting intersective modifiers, a task that is achieved here by (13d).

The constraint in (13d) is for a head-adjunct structure in which the adjunct is intersective. One example of a relevant structure would be *blue sky*, consisting of an intersective adjunct *blue* and a nominal *sky*. Assuming the standard type of semantic composition, the semantic representation for this structure as a whole would be something like blue$'(x) \land$ sky$'(x)$, provided that no quantifier is retrieved from quantifier storage and takes scope at this node; the meaning of the adjunct and that of the head would be the outermost non-quantificational elements of this representation. This parallels what is specified in (13d).

The constraint in (13b) is for a nominal head-complement structure, such as the phrase *mother of Bill*. Assuming the standard type of semantic composition, the semantic representation for the phrase would be something like mother$'($Bill$')$, provided that no quantifier is retrieved from quantifier storage and takes scope at this node; the meaning of the head would be the outermost non-quantificational element of this representation. This parallels what is specified in (13b).

And the constraint in (13a) is for head-subject structures and non-nominal head-complement structures. This category of structures is treated separately from nominal head-complement structures because we assume (as stated in (5)) that the head is liberated in the former but not in the latter type of structure. As we will see shortly, the fact that the head is not compacted means that no quantifier is retrieved from quantifier storage at the head node. Therefore, if a standard kind of semantic interpretation were applied to this type of structure, the meaning of the head would necessarily constitute the outermost element of the resulting semantic representation for the structure as a whole. This is why (13a) requires that the SEMHEAD value of the mother node be identical to the SEMHEAD value of the head daughter. By requiring further that the LTOP value of the mother be equated with the LTOP value of the head daughter, the constraint in (13a) is in effect saying that the mother and the head daughter in this type of structure are indistinguishable as far as scope taking is concerned.

The INDEX value of a sign is used in the grammar the same way that it is used in the standard version of HPSG. The INDEX value of a domain object is required (by the definition of the compaction operation, to be presented shortly) to be identical to the INDEX value of the sign whose compaction has given rise to it.

The H-STORE value of a domain object functions as a quantifier storage; it is a set that consists of the handles of those quantifiers that are contained in that domain object and that are yet to be associated with any constraints as to where to take scope. The H-CONS value of a domain object is a set of constraints that are imposed on the relationship between the handles mentioned in the EP value of that domain object. The values of these two features are determined partly by lexical entries and partly by the definition of the compaction operation. We assume that the H-CONS value and the H-STORE value of a sign (i.e. a node in a syntactic phrase-structure tree) are both always an empty set.

Figures 4, 5, and 6 show part of the lexical entries that we are assuming for the words *saw*, *every*, and *girl*, respectively. In each lexical entry, the SEMHEAD value of the sign is identified with the HNDL value of an elementary predication contained in the EP value of a domain object. The SEMHEAD value of a leaf node is thus always linked to the HNDL value of some elementary predication.

The meaning of a larger prosodic constituent (i.e. a larger domain object) is computed by amalgamating the meaning of the smaller prosodic constituents that make it up (i.e. the smaller domain objects contained in the order domain of the sign whose compaction gave rise to the larger domain object). This is achieved by the compaction operation as it is defined in Figure 7.[4] What this figure means is that, when a sign

---

[4]The definition of compaction given here differs from that given in (24) of Yatabe (2001) in several

$$
\begin{bmatrix}
\text{SYNSEM} &
\begin{bmatrix}
\text{CAT} & \boxed{1} &
\begin{bmatrix}
\text{HEAD} & verb \\
\text{VALENCE} &
\begin{bmatrix}
\text{SUBJ} & \langle[\text{CONT}|\text{INDEX}\ \boxed{2}]\rangle \\
\text{COMPS} & \langle[\text{CONT}|\text{INDEX}\ \boxed{3}]\rangle \\
\text{MOD} & \langle\rangle
\end{bmatrix} \\
\text{QUANTIFIERS} & \{\}
\end{bmatrix} \\
\text{CONT} & [\text{SEMHEAD}\ \boxed{4}]
\end{bmatrix} \\
\text{DOM} & \left\langle
\begin{bmatrix}
\text{PHON} & \text{saw} \\
\text{SYNSEM} &
\begin{bmatrix}
\text{CAT} & \boxed{1} \\
\text{CONT} &
\begin{bmatrix}
\text{EP} & \left\langle
\begin{bmatrix}
\text{HNDL} & \boxed{4} \\
\text{RELN} & \text{saw} \\
\text{ARG1} & \boxed{2} \\
\text{ARG2} & \boxed{3}
\end{bmatrix}\right\rangle \\
\text{H-CONS} & \{\}
\end{bmatrix}
\end{bmatrix}
\end{bmatrix}
\right\rangle
\end{bmatrix}
$$

Figure 4: Part of the lexical entry for *saw*

$$
\begin{bmatrix}
\text{SYNSEM} &
\begin{bmatrix}
\text{CAT} & \boxed{1} &
\begin{bmatrix}
\text{HEAD} & det \\
\text{VALENCE} &
\begin{bmatrix}
\text{SUBJ} & \langle\rangle \\
\text{COMPS} & \left\langle\left[\text{CONT}\begin{bmatrix}\text{LTOP} & \boxed{4} \\ \text{INDEX} & \boxed{3}\end{bmatrix}\right]\right\rangle \\
\text{MOD} & \langle\rangle
\end{bmatrix} \\
\text{QUANTIFIERS} & \{\}
\end{bmatrix} \\
\text{CONT} & \begin{bmatrix}\text{SEMHEAD} & \boxed{2} \\ \text{INDEX} & \boxed{3}\end{bmatrix}
\end{bmatrix} \\
\text{DOM} & \left\langle
\begin{bmatrix}
\text{PHON} & \text{every} \\
\text{SYNSEM} &
\begin{bmatrix}
\text{CAT} & \boxed{1} \\
\text{CONT} &
\begin{bmatrix}
\text{EP} & \left\langle
\begin{bmatrix}
\text{HNDL} & \boxed{2} \\
\text{RELN} & \text{every} \\
\text{VAR} & \boxed{3} \\
\text{RESTRICTOR} & \boxed{4} \\
\text{SCOPE} & \boxed{5}
\end{bmatrix}\right\rangle \\
\text{H-CONS} & \{\}
\end{bmatrix}
\end{bmatrix}
\end{bmatrix}
\right\rangle
\end{bmatrix}
$$

Figure 5: Part of the lexical entry for *every*

$$
\begin{bmatrix}
\text{SYNSEM} &
\begin{bmatrix}
\text{CAT} & \boxed{1} &
\begin{bmatrix}
\text{HEAD} & noun \\
\text{VALENCE} &
\begin{bmatrix}
\text{SUBJ} & \langle\rangle \\
\text{COMPS} & \langle\rangle \\
\text{MOD} & \langle\rangle
\end{bmatrix} \\
\text{QUANTIFIERS} & \{\}
\end{bmatrix} \\
\text{CONT} & \begin{bmatrix}\text{SEMHEAD} & \boxed{2} \\ \text{INDEX} & \boxed{3}\end{bmatrix}
\end{bmatrix} \\
\text{DOM} & \left\langle
\begin{bmatrix}
\text{PHON} & \text{girl} \\
\text{SYNSEM} &
\begin{bmatrix}
\text{CAT} & \boxed{1} \\
\text{CONT} &
\begin{bmatrix}
\text{EP} & \left\langle
\begin{bmatrix}
\text{HNDL} & \boxed{2} \\
\text{RELN} & \text{girl} \\
\text{INSTANCE} & \boxed{3}
\end{bmatrix}\right\rangle \\
\text{H-CONS} & \{\}
\end{bmatrix}
\end{bmatrix}
\end{bmatrix}
\right\rangle
\end{bmatrix}
$$

Figure 6: Part of the lexical entry for *girl*

$$
\begin{bmatrix}
\textit{sign} \\
\text{SYNSEM} \begin{bmatrix} \text{CONT} \begin{bmatrix} \text{LTOP} & \boxed{0} \\ \text{INDEX} & \boxed{1} \\ \text{SEMHEAD} & \boxed{2} \end{bmatrix} \\ \text{CAT} \ \boxed{3} \big[\text{TO-BE-STORED} \ \boxed{4}\big] \end{bmatrix} \\
\text{DOM} \ \left\langle \begin{bmatrix} \text{SYNSEM|CONT} \begin{bmatrix} \text{EP} & \boxed{a_1} \\ \text{H-CONS} & \boxed{b_1} \\ \text{H-STORE} & \boxed{c_1} \end{bmatrix} \\ \text{PHON} \ \boxed{d_1} \end{bmatrix}, \cdots, \begin{bmatrix} \text{SYNSEM|CONT} \begin{bmatrix} \text{EP} & \boxed{a_n} \\ \text{H-CONS} & \boxed{b_n} \\ \text{H-STORE} & \boxed{c_n} \end{bmatrix} \\ \text{PHON} \ \boxed{d_n} \end{bmatrix} \right\rangle
\end{bmatrix}
$$

$$
\Rightarrow \begin{bmatrix}
\textit{dom-obj} \\
\text{SYNSEM} \begin{bmatrix} \text{CONT} \begin{bmatrix} \text{LTOP} & \boxed{0} \\ \text{INDEX} & \boxed{1} \\ \text{SEMHEAD} & \textit{none} \\ \text{KEY} & \textit{none} \\ \text{EP} & \boxed{a_1} \oplus \cdots \oplus \boxed{a_n} \\ \text{H-CONS} & \boxed{b_1} \cup \cdots \cup \boxed{b_n} \cup \left\{ \boxed{0} \geq \left\{ \boxed{2} \right\} \cup \boxed{c_1} \cup \cdots \cup \boxed{c_n} \right\} \\ \text{H-STORE} & \boxed{4} \end{bmatrix} \\ \text{CAT} \ \boxed{3} \end{bmatrix} \\
\text{PHON} \ f\!\left(\boxed{d_1}, \cdots, \boxed{d_n}\right)
\end{bmatrix}
$$

Figure 7: Definition of compaction

that has the form specified in the first line is compacted, the domain object that is produced as a result must have the form specified in the second line. The symbol $\oplus$ used here represents list concatenation. Each time a sign is compacted according to this definition, a new domain object is created whose CONTENT value is the result of putting together the CONTENT value of each domain object in the order domain of that sign. The definition is a specification of what happens to a sign when a node is totally compacted as well as what happens to a sign in the second stage of partial compaction (the first stage being excision of some domain objects from the order domain of the sign); as such, it is meant to replace the simplified description of total compaction shown in (3) as well as part of the description of partial compaction given in (4) above.

When a sign is compacted, the H-CONS value of the newly created domain object contains (i) all the handle constraints that were in the H-CONS sets of the domain objects in the order domain of that sign (i.e. $\boxed{b_1} \cup \cdots \cup \boxed{b_n}$ in Figure 7) and (ii) a new handle constraint of the form $h_0 \geq A$, where h_0 is the LTOP value of the compacted sign (i.e. $\boxed{0}$ in Figure 7) and A is the set consisting of the SEMHEAD value of the compacted sign and the handles contained in the H-STORE sets of the domain objects in the order domain of that sign (i.e. $\left\{ \boxed{2} \right\} \cup \boxed{c_1} \cup \cdots \cup \boxed{c_n}$ in Figure 7). A handle constraint of the form $h_0 \geq A$ is satisfied if and only if, for each h_i in A, either h_0 is identical to h_i or h_0 outscopes h_i. (This semantics of handle constraints is slightly different from what is proposed in Yatabe (2001) and is similar to one of the possibilities considered in Copestake *et al.* (2005).)

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respects. First, the definition used here constrains the SEMHEAD value and the KEY value of the newly created domain object, while the old definition did not. Second, the specification of the H-CONS value of the newly created domain object now utilizes only the canonical kind of set union, without requiring the disjointness of the members of the sets that are put together. And third, the semantics of handle constraints has been altered, as will be explained in the text shortly. While the first two modifications do not have empirical consequences, the third modification does; quantifier lowering is allowed more freely by this new definition.

What compaction does with the ʜ-ᴄᴏɴs values enables the present theory to capture the apparent fact that certain syntactic configurations (such as conjuncts in Japanese (see Yatabe (2007))) function as scope islands.[5] The handle constraint that is created by the compaction operation and added to the ʜ-ᴄᴏɴs set of a newly formed domain object states that the local top handle of the compacted sign must either be identical to or outscope all the handles contained in the ʜ-sᴛᴏʀᴇ sets of the domain objects that underwent compaction. This means that, when a sign is compacted, each quantifier whose handle was in the ʜ-sᴛᴏʀᴇ set of a domain object that underwent compaction is required to take scope within that sign. Therefore, a sign becomes a scope island when it is required to undergo total compaction.

The function f in the definition of compaction is a function that constructs an appropriate prosodic structure out of smaller prosodic constituents. For the sake of concreteness, we assume the following, which is in fact adequate in most cases.

(14) $f\left(\boxed{d_1}, \cdots, \boxed{d_n}\right) = \left\langle \boxed{d_1}, \cdots, \boxed{d_n} \right\rangle$

The value of the ᴛᴏ-ʙᴇ-sᴛᴏʀᴇᴅ feature on a node is the set consisting of the handles representing the quantifiers that are to be put in the quantifier storage through compaction at that node. The way the value of this feature is constrained is presented in Appendix B.

The overall architecture of this theory can be summarized by the following somewhat impressionistic statements. The ʟᴛᴏᴘ value of a node is linked to things that are supposed to outscope it by one of the constraints in (13), by a constraint contained in some lexical entry, or by the quantifier storage mechanism. The sᴇᴍʜᴇᴀᴅ value of a node is linked to things that it is supposed to outscope either by one of the constraints in (13) or by a constraint contained in some lexical entry. And every time a node is either totally or partially compacted, the ʟᴛᴏᴘ value and the sᴇᴍʜᴇᴀᴅ value of the node are linked with each other by a handle constraint produced by the compaction operation (viz. the handle constraint described as $\boxed{0} \geq \left\{\boxed{2}\right\} \cup \boxed{c_1} \cup \cdots \cup \boxed{c_n}$ in Figure 7).

We will illustrate how all this works using Figure 8. This figure shows part of the structure assigned to the sentence *Some boy saw every girl* in the theory under discussion. As in the textbook version of HPSG, a syntactic representation like this is licensed by the grammar if and only if each local subtree in it conforms to the principles in the grammar. We will choose two of the local subtrees in Figure 8 and show how they both conform to the principles in the grammar that have been presented so far.

First, let us examine the local subtree that is at the very bottom, in which the D sign *every* and the N sign *girl* combine to form a DP sign *every girl*. The first daughter node, which is associated with the D sign, satisfies all the constraints embodied in the lexical entry shown in Figure 5. For instance, the sᴇᴍʜᴇᴀᴅ value of this node (namely *h5*) is identical to the handle of the only elementary predication in the order domain of this sign, as required by the lexical entry. The fact that the ʀᴇsᴛʀɪᴄᴛᴏʀ value of this elementary predication (namely *h6*) is identical to the ʟᴛᴏᴘ value of the complement N (i.e. the second daughter of this local subtree) is also in conformity with the lexical entry of the word *every*. (Recall that we are assuming that the D is the head here.) The second daughter node, on the other hand, satisfies all the constraints embodied in the lexical entry shown in Figure 6. For instance, the ɪɴᴅᴇx value of this second daughter is identical to the ɪɴsᴛᴀɴᴄᴇ value of the only elementary predication in its order domain, in accordance with that lexical entry. This local subtree is a

---

[5]In contrast, the version of MRS presented in Copestake *et al.* (2005) is based on the assumption that there are no syntactic configurations that function as scope islands.

$$
\begin{bmatrix}
\text{SYNSEM|CONT} & \begin{bmatrix} \text{LTOP} & h0 \\ \text{SEMHEAD} & h4 \end{bmatrix} \\[2ex]
\text{DOM} & \left\langle
\begin{bmatrix}
\text{PHON} & \langle\langle some\rangle,\langle boy\rangle\rangle \\
\text{SYNSEM|CONT} & \begin{bmatrix}
\text{EP} & \left\langle \boxed{1}\begin{bmatrix} \text{HNDL} & h1 \\ \text{RELN} & some \\ \text{VAR} & x \\ \text{RESTRICTOR} & h2 \\ \text{SCOPE} & h3 \end{bmatrix}, \boxed{2}\begin{bmatrix} \text{HNDL} & h13 \\ \text{RELN} & boy \\ \text{INSTANCE} & x \end{bmatrix} \right\rangle \\
\text{H-CONS} & \{h8 \geq \{h9\}, h9 \geq \{h1\}, h2 \geq \{h13\}\} \\
\text{H-STORE} & \{h8\}
\end{bmatrix}
\end{bmatrix},
\right.
\\
\begin{bmatrix}
\text{PHON} & saw \\
\text{SYNSEM|CONT} & \begin{bmatrix}
\text{EP} & \left\langle \boxed{3}\begin{bmatrix} \text{HNDL} & h4 \\ \text{RELN} & saw \\ \text{ARG1} & x \\ \text{ARG2} & y \end{bmatrix} \right\rangle \\
\text{H-CONS} & \{\}
\end{bmatrix}
\end{bmatrix},
\\
\left.
\begin{bmatrix}
\text{PHON} & \langle\langle every\rangle,\langle girl\rangle\rangle \\
\text{SYNSEM|CONT} & \begin{bmatrix}
\text{EP} & \left\langle \boxed{4}\begin{bmatrix} \text{HNDL} & h5 \\ \text{RELN} & every \\ \text{VAR} & y \\ \text{RESTRICTOR} & h6 \\ \text{SCOPE} & h7 \end{bmatrix}, \boxed{5}\begin{bmatrix} \text{HNDL} & h12 \\ \text{RELN} & girl \\ \text{INSTANCE} & y \end{bmatrix} \right\rangle \\
\text{H-CONS} & \boxed{6}\{h10 \geq \{h11\}, h11 \geq \{h5\}, h6 \geq \{h12\}\} \\
\text{H-STORE} & \boxed{7}\{h10\}
\end{bmatrix}
\end{bmatrix}
\right\rangle
\end{bmatrix}
$$

$$
\begin{bmatrix}
\text{SYNSEM} & \begin{bmatrix}
\text{CONT} & \begin{bmatrix} \text{LTOP} & h8 \\ \text{SEMHEAD} & h9 \\ \text{INDEX} & x \end{bmatrix} \\
\text{CAT} & \begin{bmatrix} \text{QUANTIFIERS} & \{h8\} \\ \text{TO-BE-STORED} & \{h8\} \end{bmatrix}
\end{bmatrix} \\
\text{DOM} & \left\langle \begin{bmatrix} \text{PHON} & \langle some\rangle \\ \text{SYNSEM|CONT|EP} & \langle\boxed{1}\rangle \end{bmatrix}, \begin{bmatrix} \text{PHON} & \langle boy\rangle \\ \text{SYNSEM|CONT|EP} & \langle\boxed{2}\rangle \end{bmatrix} \right\rangle
\end{bmatrix}
\qquad
\begin{bmatrix}
\text{SYNSEM|CONT} & \begin{bmatrix} \text{LTOP} & h0 \\ \text{SEMHEAD} & h4 \end{bmatrix} \\
\text{DOM} & \left\langle \begin{bmatrix} \text{PHON} & saw \\ \text{SYNSEM|CONT|EP} & \langle\boxed{3}\rangle \end{bmatrix}, \begin{bmatrix} \text{PHON} & \langle\langle every\rangle,\langle girl\rangle\rangle \\ \text{SYNSEM|CONT} & \begin{bmatrix} \text{EP} & \langle\boxed{4},\boxed{5}\rangle \\ \text{H-CONS} & \boxed{6} \\ \text{H-STORE} & \boxed{7} \end{bmatrix} \end{bmatrix} \right\rangle
\end{bmatrix}
$$

some boy

$$
\begin{bmatrix}
\text{SYNSEM|CONT} & \begin{bmatrix} \text{LTOP} & h0 \\ \text{SEMHEAD} & h4 \end{bmatrix} \\
\text{DOM} & \left\langle \begin{bmatrix} \text{PHON} & saw \\ \text{SYNSEM|CONT|EP} & \langle\boxed{3}\rangle \end{bmatrix} \right\rangle
\end{bmatrix}
\qquad
\begin{bmatrix}
\text{SYNSEM} & \begin{bmatrix}
\text{CONT} & \begin{bmatrix} \text{LTOP} & h10 \\ \text{SEMHEAD} & h11 \\ \text{INDEX} & y \end{bmatrix} \\
\text{CAT} & \begin{bmatrix} \text{QUANTIFIERS} & \{h10\} \\ \text{TO-BE-STORED} & \{h10\} \end{bmatrix}
\end{bmatrix} \\
\text{DOM} & \left\langle \begin{bmatrix} \text{PHON} & \langle every\rangle \\ \text{SYNSEM|CONT} & \begin{bmatrix} \text{EP} & \langle\boxed{4}\rangle \\ \text{H-CONS} & \{h11 \geq \{h5\}\} \end{bmatrix} \end{bmatrix}, \begin{bmatrix} \text{PHON} & \langle girl\rangle \\ \text{SYNSEM|CONT} & \begin{bmatrix} \text{EP} & \langle\boxed{5}\rangle \\ \text{H-CONS} & \{h6 \geq \{h12\}\} \end{bmatrix} \end{bmatrix} \right\rangle
\end{bmatrix}
$$

$$
\begin{bmatrix}
\text{SYNSEM|CONT} & \begin{bmatrix} \text{LTOP} & h11 \\ \text{SEMHEAD} & h5 \end{bmatrix} \\
\text{DOM} & \left\langle \begin{bmatrix} \text{PHON} & every \\ \text{SYNSEM|CONT|EP} & \langle\boxed{4}\rangle \end{bmatrix} \right\rangle
\end{bmatrix}
\qquad
\begin{bmatrix}
\text{SYNSEM|CONT} & \begin{bmatrix} \text{LTOP} & h6 \\ \text{SEMHEAD} & h12 \\ \text{INDEX} & y \end{bmatrix} \\
\text{DOM} & \left\langle \begin{bmatrix} \text{PHON} & girl \\ \text{SYNSEM|CONT|EP} & \langle\boxed{5}\rangle \end{bmatrix} \right\rangle
\end{bmatrix}
$$

Figure 8: Part of the structure assigned to the sentence *Some boy saw every girl*

head-complement structure whose head is nominal, and thus the first daughter must be totally compacted and the second daughter must be partially compacted, due to (5c). In the structure at hand, both the daughters are totally compacted, satisfying the requirement.[6] The local subtree has to conform to the constraint in (13b) as well, and it does; the SEMHEAD value of the mother (namely $h11$) is identical to the LTOP value of the head D sign. The first domain object in the order domain of the mother DP is the result of totally compacting the first daughter, and the second domain object in that order domain is the result of totally compacting the second daughter. In both cases, the relation between the sign and the domain object conforms to the definition of compaction shown in Figure 7. For instance, the handle constraint requiring the LTOP value of the D node to either outscope or be identical to its SEMHEAD value (i.e. the constraint of the form $h11 \geq \{h5\}$) is in the H-CONS set of the first domain object in the order domain of the mother, as required by the definition. The handle constraint $h11 \geq \{h5\}$ here corresponds to $\boxed{0} \geq \left\{\boxed{2}\right\} \cup \boxed{c_1} \cup \cdots \cup \boxed{c_n}$ in the second line of Figure 7. The handle $h11$ corresponds to $\boxed{0}$, the handle $h5$ corresponds to $\boxed{2}$, and $\boxed{c_1} \cdots \boxed{c_n}$ are all empty sets in the case at hand.

The local subtree in which the V *saw* combines with the DP *every girl* to produce the VP *saw every girl* similarly conforms to all the constraints contained in the grammar. This local subtree is a head-complement structure whose head is not nominal, so it has to satisfy the constraint in (5a), and it does. The head V is liberated, and the domain object inside its order domain is thus inherited unchanged by the order domain of the VP node. The complement DP is required to be partially compacted, and is here totally compacted; the result of that compaction is the domain object to be pronounced "every girl", i.e. the second domain object in the order domain of the mother. Since the head daughter is liberated, this local subtree has to satisfy the condition in (13a), and it does; the LTOP value and the SEMHEAD value of the mother VP node (namely $h0$ and $h4$) are identical to the LTOP and the SEMHEAD value of the head daughter, respectively. The relationship between the second daughter and the second domain object in the order domain of the mother correctly reflects what is specified in the definition of the compaction operation. For instance, the H-CONS set of the second domain object in the order domain of the mother, namely $\{h10 \geq \{h11\}, h11 \geq \{h5\}, h6 \geq \{h12\}\}$, consists of (i) two handle constraints that have been inherited from the H-CONS sets of the domain objects in the order domain of the DP sign whose compaction gave rise to this domain object and (ii) a newly created handle constraint (namely $h10 \geq \{h11\}$) which means that the LTOP value of the DP sign has to either outscope or be identical to its SEMHEAD value. The former corresponds to $\boxed{b_1} \cup \cdots \cup \boxed{b_n}$ in the second line of Figure 7, and the latter corresponds to $\boxed{0} \geq \left\{\boxed{2}\right\} \cup \boxed{c_1} \cup \cdots \cup \boxed{c_n}$ there.

The semantic content of a sentence as a whole is obtained by first totally compacting the top node of the syntactic representation and then resolving the values of the handles in the EP value in conformity with all the grammatical constraints including the handle constraints that have been collected in the H-CONS set. Figure 9 shows the domain object that results when the top node in Figure 8 is totally compacted. Its LTOP value indicates that $h0$ is the top handle. The handle constraints in the H-CONS set, taken together, require, among other things, that $h0 \geq h4$, $h0 \geq h8 \geq h9 \geq h1$, and $h0 \geq h10 \geq h11 \geq h5$, where we use the notation of the form $A \geq B$ to mean that A either outscopes or is identical to B. Since the elementary predication whose handle is $h4$ (viz. the one representing the meaning of the verb *saw*) contains variables that must be bound by the quantifiers whose handles are $h1$ and $h5$, $h4$ needs to be

---

[6]Since the order domains of these two daughters both contain only one domain object, compaction of these daughters can only be total compaction.

$$
\begin{bmatrix}
\text{PHON} & \langle\langle\langle\text{some}\rangle,\langle\text{boy}\rangle\rangle,\text{saw},\langle\langle\text{every}\rangle,\langle\text{girl}\rangle\rangle\rangle \\
\text{SYNSEM}|\text{CONT} &
\begin{bmatrix}
\text{LTOP} & h0 \\
\text{EP} & \langle
\begin{bmatrix}
\text{HNDL} & h1 \\
\text{RELN} & \text{some} \\
\text{VAR} & x \\
\text{RESTRICTOR} & h2 \\
\text{SCOPE} & h3
\end{bmatrix},
\begin{bmatrix}
\text{HNDL} & h13 \\
\text{RELN} & \text{boy} \\
\text{INSTANCE} & x
\end{bmatrix}, \\
& \quad
\begin{bmatrix}
\text{HNDL} & h4 \\
\text{RELN} & \text{saw} \\
\text{ARG1} & x \\
\text{ARG2} & y
\end{bmatrix},
\begin{bmatrix}
\text{HNDL} & h5 \\
\text{RELN} & \text{every} \\
\text{VAR} & y \\
\text{RESTRICTOR} & h6 \\
\text{SCOPE} & h7
\end{bmatrix}, \\
& \quad
\begin{bmatrix}
\text{HNDL} & h12 \\
\text{RELN} & \text{girl} \\
\text{INSTANCE} & y
\end{bmatrix} \rangle \\
\text{H-CONS} & \{\ h0 \geq \{h4, h8, h10\}, \\
& \quad h8 \geq \{h9\}, h9 \geq \{h1\}, h2 \geq \{h13\}, \\
& \quad h10 \geq \{h11\}, h11 \geq \{h5\}, h6 \geq \{h12\}\ \} \\
\text{H-STORE} & \{\}
\end{bmatrix}
\end{bmatrix}
$$

Figure 9: The result of totally compacting the top node of the tree shown in Figure 8

outscoped by $h1$ and $h5$, and thus cannot be identical to $h0$. On the other hand, $h1$ and $h5$ can be identical to $h0$; in fact, $h0$ *must* be identical either to $h1$ or to $h5$, since there is no other handle that could come between $h0$ and $h1$ and between $h0$ and $h5$. If $h0$ is taken to be identical to $h1$, then $h3$ must be taken to be identical to $h5$, yielding the reading in which the subject takes scope over the object; if $h3$ is not taken to be equal to $h5$, then there is no way to obtain a resolved semantic representation in which every handle-argument name has been equated with the handle of some elementary predication. If, on the other hand, $h0$ is taken to be identical to $h5$, then $h7$ must be taken to be identical to $h1$, yielding the reading in which the object takes scope over the subject. The handle $h4$ is identified with $h7$ in the former case and with $h3$ in the latter case. In both cases, $h2$ must be equal to $h13$ and $h6$ must be equal to $h12$. Thus, the only meanings represented by the CONT value of the domain object in Figure 9 are the ones shown in the conventional notation in (15).

(15)   a.   some(x, boy(x), every(y, girl(y), saw(x, y)))
       b.   every(y, girl(y), some(x, boy(x), saw(x, y)))

2.4   Non-constituent coordination in the HPSG-based theory

The mechanism of compaction-driven meaning assembly makes it possible to capture the semantic properties of non-constituent coordination within the HPSG framework without recourse to any ad-hoc machinery.

The theory of non-constituent coordination presented in Yatabe (2001) and modified in later works such as Yatabe (2012) posits that there are two types of right-node raising (RNR) and two types of left-node raising (LNR): a phonological kind of RNR and LNR that is merely prosodic ellipsis and a syntactic kind of RNR and LNR that involves fusion of multiple domain objects that has the potential of affecting semantic interpretation. We will first illustrate roughly how this theory works using the example in (16), before presenting a more general characterization. Figure 10 shows part

$$
\begin{bmatrix}
\text{DOM} & \left\langle \begin{array}{l}
[\text{PHON} \quad \langle \text{drove} \rangle], \\
[\text{PHON} \quad none], \\
[\text{PHON} \quad \langle \langle \text{to}, \langle \text{Chicago} \rangle \rangle, \langle \text{in}, \langle \langle \text{the} \rangle, \langle \text{morning} \rangle \rangle \rangle \rangle], \\
[\text{PHON} \quad \langle \text{and}, \langle \langle \text{Detroit} \rangle \rangle, \langle \text{in}, \langle \langle \text{the} \rangle, \langle \text{afternoon} \rangle \rangle \rangle \rangle]
\end{array} \right\rangle
\end{bmatrix}
$$

$$
\begin{bmatrix}
\text{DOM} & \left\langle \begin{array}{l}
[\text{PHON} \quad \langle \text{drove} \rangle], \\
[\text{PHON} \quad \langle \text{to}, \langle \text{Chicago} \rangle \rangle], \\
[\text{PHON} \quad \langle \text{in}, \langle \langle \text{the} \rangle, \langle \text{morning} \rangle \rangle \rangle]
\end{array} \right\rangle
\end{bmatrix}
\quad
\begin{bmatrix}
\text{DOM} & \left\langle \begin{array}{l}
[\text{PHON} \quad \langle \text{drove} \rangle], \\
[\text{PHON} \quad \langle \text{to}, \langle \text{Detroit} \rangle \rangle], \\
[\text{PHON} \quad \langle \text{in}, \langle \langle \text{the} \rangle, \langle \text{afternoon} \rangle \rangle \rangle]
\end{array} \right\rangle
\end{bmatrix}
$$
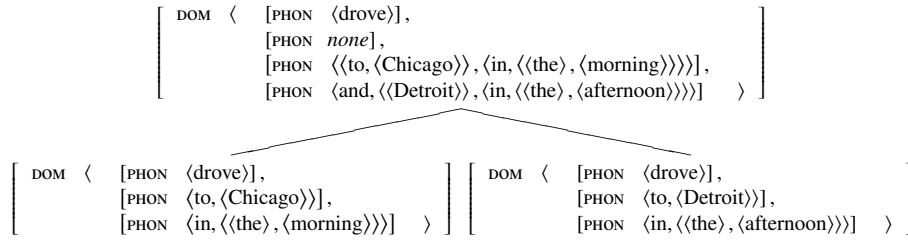
Figure 10: Part of the structure assigned to example (16)

of the structure assigned to this sentence when the verb *drove* is assumed to have been syntactically left-node-raised and the preposition *to* is assumed to have been phonologically left-node-raised. What is shown is the local subtree in which two VPs are conjoined and the verb and the preposition are left-node-raised. Coordinators like *and* are assumed to be introduced into the syntactic structure by a linearization-related mechanism, and does not appear as a node in the syntactic phrase-structure tree (see Yatabe (2012)).

(16) John drove to Chicago in the morning and Detroit in the afternoon.
(from Dowty (1988))

Syntactic LNR (or RNR) excises a list of domain objects from the left (or right, respectively) edge of the order domain of each daughter, fuses those domain objects item by item to create a possibly modified list of domain objects, and places the resulting list of domain objects at the left (or right, respectively) edge of the order domain of the mother. In Figure 10, a domain object corresponding to the verb *drove* is excised from the left edge of the order domain of the first daughter and from the left edge of the order domain of the second daughter. Those two domain objects are then fused with each other to create a new domain object, and that new domain object, which is to be pronounced "drove" like the two domain objects that have given rise to it, is placed at the left edge of the order domain of the mother. Syntactically LNRed or RNRed domain objects continue to exist as separate domain objects in the order domain of the mother, rather than becoming part of some larger domain objects.

The second domain object in the order domain of the mother node in Figure 10 is there to represent the meaning of conjunction and does not have any phonological content. It is added to the order domain of a coordinate structure by the phrase-structure schema that licenses coordinate structures (see Yatabe (2012) for the details of this analysis).

The third domain object in the order domain of the mother node in Figure 10 was created by compacting that portion of the first daughter node that did not undergo syntactic LNR, and the fourth domain object in the order domain of the mother node was created by compacting that portion of the second daughter node that did not undergo syntactic LNR. The PHON value of the fourth domain object was later modified first by applying phonological LNR to its left edge (and thereby eliding the string *to* that was there) and then by adding the string *and* to the left edge. (See Yatabe (2012) for the details of the process that adds a string that corresponds to a coordinator at the beginning of the PHON value of a conjunct.)

Phonological LNR (or RNR) simply deletes some phonological material at the left (or right, respectively) edge of non-initial (or non-final, respectively) daughters, on condition that the same phonological material is contained in the initial (or final,

respectively) daughter. In Figure 10, the phonological material *to* in the second conjunct is allowed to be deleted because (i) it is at the left edge of the second conjunct after the domain object for the verb *drove* is removed by syntactic LNR and (ii) the same phonological material appears in the corresponding position (viz. the left edge, modulo the syntactically left-node-raised material) in the first daughter. Phonologically LNRed (or RNRed respectively) material generally becomes part of the domain object corresponding to the initial (or final respectively) daughter. In Figure 10, *to* becomes part of the domain object that is to be pronounced *to Chicago in the morning*, which corresponds to the first daughter or, more precisely, that part of the first daughter that has not been syntactically left-node-raised or right-node-raised.

Unlike phonologically left- or right-node-raised expressions, syntactically left- or right-node-raised expressions escape compaction and continue to exist (for the time being) as independent domain objects, so there tend to be prosodic boundaries around them, since domain objects inside order domains are, by hypothesis, representations of prosodic constituents. For instance, if the sentence *John was looking for and Mary was running away from those police officers* involves syntactic RNR of the DP *those police officers* and its pronunciation is not perturbed by extraneous factors such as focusing, the prosodic phrasing indicated in (17) will result, in which the right-node-raised string is pronounced as an independent prosodic constituent. On the other hand, if the sentence involves phonological RNR of *those police officers* and its pronunciation is not perturbed by extraneous factors, the prosodic phrasing indicated in (18) will result, in which the right-node-raised string is pronounced as a normal part of the final conjunct.

(17) [John was looking for] [and Mary was running away from] [those police officers]

(18) [John was looking for] [and Mary was running away from those police officers]

(We will come back to the issue of prosodic phrasing in section 4, where we will discuss a Japanese example.)

When two or more identical domain objects are fused together by syntactic LNR or RNR to become a single domain object, the output of the fusion will naturally be a domain object that is identical to the input domain objects in its entirety. That can be regarded as the default type of syntactic LNR and RNR. It turns out, however, that not all instances of syntactic LNR and RNR are of this type. There are two types of exceptions to consider. First, consider the following example, discussed in Postal (1998).

(19) The pilot claimed that the first nurse, and the sailor proved that the second nurse, were spies.

This example cannot be a case of phonological RNR, since the right-node-raised VP does not agree in number with either of its two grammatical subjects and the sentence thus cannot be generated by simple prosodic ellipsis. What is involved here therefore must be syntactic RNR of the VP *were spies*. However, the domain object that represents the VP inside the order domain of the first conjunct cannot be identical to the domain object that represents the VP inside the order domain of the second conjunct; since the VP has combined with different grammatical subjects in the two conjuncts, the domain object for the VP coming from the first conjunct and the one coming from the second conjunct must have different VALENCE values and different CONT values. Deferring the discussion of what happens to the VALENCE values to subsection 5.2, let us

focus here on what should happen to the CONT|EP values of the right-node-raised domain objects when they are fused. The domain object representing the VP in the order domain of the first conjunct has an EP value that expresses the proposition that x is a spy, where x is the referent of the DP *the first nurse*, and the domain object representing the VP in the order domain of the second conjunct has an EP value that expresses the proposition that y is a spy, where y is the referent of the DP *the second nurse*. In order for the sentence as a whole to be given appropriate semantic interpretation, the domain object that results from fusing these two domain objects needs to have an EP value that expresses both these propositions. In other words, the newly created domain object must express the proposition that x is a spy and y is also a spy, as is expected from the fact that the VP exhibits plural agreement.

The second type of exceptions to consider is exemplified by (20), taken from Abbott (1976).

(20)   I borrowed, and my sister stole, a total of $3000 from the bank.

This sentence cannot be an instance of phonological RNR either, because its most salient reading is truth-conditionally different from any of the readings of the sentence *I borrowed a total of $3000 from the bank, and my sister stole a total of $3000 from the bank*. What is involved must be syntactic RNR of the DP and the PP *a total of $3000 from the bank*. Let us focus here on the RNR of the DP *a total of $3000*. Since what the speaker borrowed and what the speaker's sister stole ought to be different from each other, they must be represented by different indices. This means that the domain object for the DP in the order domain of the first conjunct cannot be identical to the domain object for the DP in the order domain of the second conjunct. Moreover, we cannot carry over the analysis of sentence (19) that we suggested above to the example in (20); in the case at hand, the EP value of the domain object that results from fusion cannot simply express each of the propositions expressed by the input domain objects. Supposing that the index for the DP is x in the first conjunct and y in the second conjunct, the domain object for the DP in the order domain of the first conjunct must express the proposition that x is a total of $3000, and the corresponding domain object in the order domain of the second conjunct must express the proposition that y is a total of $3000. Thus, if the domain object that results from fusing these two domain objects simply expressed both these propositions, the sentence would mean "I borrowed x from the bank, my sister stole y from the bank, x is a total of $3000, and y is also a total of $3000," which is one possible reading of the sentence but not its most salient reading.

In light of these considerations, Yatabe (2012) suggests that the grammar should contain the following principle. When syntactic LNR or RNR fuses n domain objects of the form shown in (21) (each coming from a different daughter) to produce a single domain object of the form shown in (22) (to be placed in the order domain of the mother), one of the three conditions shown in (23) must be satisfied. If the local subtree involved is either a coordinate structure whose coordinator is *or* or a non-coordinate structure, then one of the first two conditions has to be satisfied.[7]

---

[7]A more precise definition of this fusion relation is provided in the Appendix of Yatabe (2012), but there were three minor errors in that definition, which have been corrected here. First, the definition of (23b) presented in the 2012 paper required that $\boxed{d_0} = \boxed{d_1} = \cdots = \boxed{d_n}$. Second, the third line of (23b) was not in the version presented in the 2012 paper. And third, the definition of (23c) in the 2012 paper did not require the H-CONS set of each daughter to be identical to that of the mother.

$$(21) \quad \begin{bmatrix} \text{SYNSEM} \mid \text{CONT} & \begin{bmatrix} \text{INDEX} & \boxed{a_1} \\ \text{EP} & \boxed{b_1} \\ \text{H-CONS} & \boxed{c_1} \\ \text{H-STORE} & \boxed{d_1} \end{bmatrix} \end{bmatrix}, \cdots, \begin{bmatrix} \text{SYNSEM} \mid \text{CONT} & \begin{bmatrix} \text{INDEX} & \boxed{a_n} \\ \text{EP} & \boxed{b_n} \\ \text{H-CONS} & \boxed{c_n} \\ \text{H-STORE} & \boxed{d_n} \end{bmatrix} \end{bmatrix}$$

$$(22) \quad \begin{bmatrix} \text{SYNSEM} \mid \text{CONT} & \begin{bmatrix} \text{INDEX} & \boxed{a_0} \\ \text{EP} & \boxed{b_0} \\ \text{H-CONS} & \boxed{c_0} \\ \text{H-STORE} & \boxed{d_0} \end{bmatrix} \end{bmatrix}$$

(23)   a. $\boxed{a_0} = \boxed{a_1} = \cdots = \boxed{a_n} \quad \wedge \quad \boxed{b_0} = \boxed{b_1} = \cdots = \boxed{b_n}$
       $\wedge \quad \boxed{c_0} = \boxed{c_1} = \cdots = \boxed{c_n} \quad \wedge \quad \boxed{d_0} = \boxed{d_1} = \cdots = \boxed{d_n}$

   b. $\boxed{a_0} = none \quad \wedge \quad \boxed{b_0} = \boxed{b_1} \oplus \cdots \oplus \boxed{b_n}$
       $\wedge \quad \boxed{c_0} = \boxed{c_1} \cup \cdots \cup \boxed{c_n} \quad \wedge \quad \boxed{d_0} = \boxed{d_1} \cup \cdots \cup \boxed{d_n}$

       and the n domain objects to be fused are alphabetic variants of each other.

   c. $\boxed{a_0} = \boxed{a_1 + \cdots + a_n} \quad \wedge$
       $\boxed{b_0} = \text{replace}(\boxed{a_1}, \boxed{a_1 + \cdots + a_n}, \boxed{b_1}) = \cdots = \text{replace}(\boxed{a_n}, \boxed{a_1 + \cdots + a_n}, \boxed{b_n})$
       $\wedge \quad \boxed{c_0} = \boxed{c_1} = \cdots = \boxed{c_n} \quad \wedge \quad \boxed{d_0} = \boxed{d_1} = \cdots = \boxed{d_n}$

       (replace(x, y, z) is the result of replacing all occurrences of x with y in z.)

The condition in (23a) licenses the default type of syntactic LNR and RNR in which the domain objects to be fused and the domain object that results from fusing them are all identical.[8] When this condition is applied to syntactically right-node-raised or left-node-raised domain objects representing a quantifier, those domain objects, which are equated with each other, turn out to represent a single quantifier, and that quantifier therefore has to take wide scope over all the daughter nodes, since otherwise some of the variables to be bound by the quantifier would remain unbound, in violation of the variable binding condition. This aspect of this theory makes it somewhat analogous to the theories that analyze right-node raising in terms of multidominance, for example the one proposed in Bachrach and Katzir (2007); in all these theories, a single quantifier that is to be interpreted only once can nevertheless be contained in multiple, distinct syntactic phrases.

The second condition, namely condition (23b), licenses the type of syntactic RNR and LNR exemplified by sentence (19). When the domain objects corresponding to a syntactically right-node-raised or left-node-raised expression obey this condition, the sentence as a whole is given the same interpretation that it would receive if the expression in question did not undergo RNR or LNR. (In the case of (19), the sentence is given the same interpretation as *The pilot claimed that the first nurse was a spy, and the sailor proved that the second nurse was a spy*.) This is because the effect that condition (23b) has on the EP and the H-CONS values parallels what compaction does to those values.

The constraint (23b) does not require the domain objects to be fused to be identical to each other, but it requires the domain objects to be fused to be alphabetic variants of each other. Two domain objects are *alphabetic variants* if (i) they are identical except for their indices and handles and (ii) these indices and handles exhibit the same pattern of links.

---

[8]Whenever the condition in (23a) is invoked, the domain objects that are fused by LNR or RNR are in fact identified with each other in their entirety. See the second line of (46) in Yatabe (2012).

And the condition in (23c) licenses the type of syntactic LNR and RNR exemplified by sentence (20). When a new domain object to be placed in the order domain of the mother is created according to this condition, the newly created domain object is, roughly speaking, the semantic sum of the domain objects coming from the daughter nodes. We use a string of the form $i_1 + \cdots + i_n$ to represent an index whose interpretation is required to be the sum of the interpretations of $i_1, \ldots, i_n$. Additionally, we are assuming that, when the denotation of the tags $\boxed{t_1}, \ldots, \boxed{t_n}$ are indices $i_1, \ldots, i_n$ respectively, the denotation of a tag of the form $\boxed{t_1 + \cdots + t_n}$ is the index $i_1 + \cdots + i_n$.

Let us use an example to illustrate what (23c) does. Suppose the DP *twenty books* in the sentence *Mary borrowed and John stole twenty books* has been syntactically right-node-raised in accordance with the condition (23c). In that case, if the domain object for the DP contained in the order domain of the first conjunct and the domain object for the DP contained in the order domain of the second conjunct are (24) and (25) respectively, the domain object for the DP in the order domain of the matrix node, which is the fusion of the two domain objects, is required to be (26).

(24) The domain object for the DP *twenty books* in the order domain of the first conjunct:

$$
\begin{bmatrix}
\text{SYNSEM|CONT} &
\begin{bmatrix}
\text{INDEX} & x \\
\text{EP} & \left\langle
\begin{bmatrix}
\text{HNDL} & h1 \\
\text{RELN} & \text{twenty} \\
\text{VAR} & x \\
\text{RESTRICTOR} & h2 \\
\text{SCOPE} & h3
\end{bmatrix},
\begin{bmatrix}
\text{HNDL} & h4 \\
\text{RELN} & \text{books} \\
\text{INSTANCE} & x
\end{bmatrix}
\right\rangle \\
\text{H-CONS} & \{h6 \geq \{h5\}, h5 \geq \{h1\}, h2 \geq \{h4\}\} \\
\text{H-STORE} & \{h6\}
\end{bmatrix}
\end{bmatrix}
$$

(25) The domain object for the DP *twenty books* in the order domain of the second conjunct:

$$
\begin{bmatrix}
\text{SYNSEM|CONT} &
\begin{bmatrix}
\text{INDEX} & y \\
\text{EP} & \left\langle
\begin{bmatrix}
\text{HNDL} & h1 \\
\text{RELN} & \text{twenty} \\
\text{VAR} & y \\
\text{RESTRICTOR} & h2 \\
\text{SCOPE} & h3
\end{bmatrix},
\begin{bmatrix}
\text{HNDL} & h4 \\
\text{RELN} & \text{books} \\
\text{INSTANCE} & y
\end{bmatrix}
\right\rangle \\
\text{H-CONS} & \{h6 \geq \{h5\}, h5 \geq \{h1\}, h2 \geq \{h4\}\} \\
\text{H-STORE} & \{h6\}
\end{bmatrix}
\end{bmatrix}
$$

(26) The domain object for the DP *twenty books* in the order domain of the matrix node:

$$
\begin{bmatrix}
\text{SYNSEM|CONT} &
\begin{bmatrix}
\text{INDEX} & x + y \\
\text{EP} & \left\langle
\begin{bmatrix}
\text{HNDL} & h1 \\
\text{RELN} & \text{twenty} \\
\text{VAR} & x + y \\
\text{RESTRICTOR} & h2 \\
\text{SCOPE} & h3
\end{bmatrix},
\begin{bmatrix}
\text{HNDL} & h4 \\
\text{RELN} & \text{books} \\
\text{INSTANCE} & x + y
\end{bmatrix}
\right\rangle \\
\text{H-CONS} & \{h6 \geq \{h5\}, h5 \geq \{h1\}, h2 \geq \{h4\}\} \\
\text{H-STORE} & \{h6\}
\end{bmatrix}
\end{bmatrix}
$$

Apart from the constraint (already mentioned) that prohibits use of condition (23c) in disjunctive coordinate structures and non-coordinate structures, there is no statement in the grammar that specifies which one of the conditions (23a)–(23c) should be invoked in a given situation; any of the conditions can be invoked as long as no constraints in the grammar are violated by the resulting structure. For instance, in fusing

the domain objects shown in (24) and (25), condition (23b) can be invoked instead of condition (23c). Condition (23a) can also be invoked, provided that the indices x and y can be equated with each other.

Whereas phonological LNR and RNR are always meaning-preserving, syntactic LNR and RNR can be either meaning-preserving (due to the existence of the option (23b)) or meaning-changing (due to the existence of the options (23a) and (23c)). Thus, whether a particular instance of RNR or LNR is of the syntactic kind or the phonological kind is not necessarily determined by the semantic interpretation of the sentence involved, while it generally *is* determined by the prosodic phrasing of the sentence involved.

We will now demonstrate that, unlike a theory that views RNR and LNR only as prosodic ellipsis, this theory correctly accounts for the kinds of observations that Kubota and Levine claim are problematic for the HPSG-based theories in general.

2.4.1 Quantifier scope

First, we will illustrate how the theory we have described analyzes the sentence in (1a), which is reproduced below as (27). (Those readers who believe that they already understand how the sentence can be analyzed in our theory might want to skip to the next sub-subsection, i.e. sub-subsection 2.4.2.)

(27) Terry gave no man a book on Friday or a record on Saturday.

Figure 11 shows part of the structure that the theory assigns to the sentence, when the string *gave no man* is taken to have undergone the syntactic type of LNR. What is shown in Figure 11 is the local subtree where the two VPs (viz. *gave no man a book on Friday* and *gave no man a record on Saturday*) are conjoined by the coordinator *or* to become a larger VP (viz. *gave no man a book on Friday or a record on Saturday*). As noted above, coordinators like *or* are assumed to be introduced into the syntactic structure by a linearization-related mechanism, and does not appear as a node in the syntactic phrase-structure tree.

The first domain object in the order domain of the mother represents the verb *gave*, which has been syntactically left-node-raised. This domain object is the result of fusing the first domain object in the order domain of the first daughter and the first domain object in the order domain of the second daughter. The relationship between this domain object and the two domain objects that gave rise to it conforms to the condition in (23b). The two handle constraints listed in the H-CONS value of this domain object (viz. $h17 \geq \{h4\}$ and $h25 \geq \{h5\}$) both arose when a VP to be modified by an adjunct underwent partial compaction in accordance with (5b). Figure 12 depicts the local subtree in which the VP *gave no man a book* combines with the adjunct *on Friday* to become the first conjunct in sentence (27). Although the two daughters in this local subtree are both only required to undergo partial compaction, the second daughter, i.e. *on Friday*, undergoes total compaction. On the other hand, the compaction that the first daughter, i.e. the VP *gave no man a book*, undergoes is not total. The two non-initial domain objects (viz. the one representing *no man* and the one representing *a book*) escape compaction and are inherited by the order domain of the mother. As a consequence of this, a VP sign whose order domain consists only of the domain object representing the verb *gave* undergoes compation, producing a domain object whose H-CONS set contains the handle constraint $h17 \geq \{h4\}$. The constraint $h25 \geq \{h5\}$ was added to an H-CONS set in an analogous fashion in the second conjunct.

As Kubota and Levine do, we treat the meaning of a phrase like *on Friday* as an unanalyzed unit, for the sake of simplicity; we represent it using a single elementary

$$
\begin{bmatrix}
\textsc{synsem|cont} & \begin{bmatrix} \textsc{ltop} & h0 \\ \textsc{semhead} & h1 \end{bmatrix} \\[2ex]
\textsc{dom} \quad \Big\langle & \\
\end{bmatrix}
$$

Top structure:

SYNSEM|CONT [LTOP h0 ; SEMHEAD h1]

DOM ⟨

- PHON ⟨gave⟩
  SYNSEM|CONT
  EP ⟨ ①[HNDL h4 ; RELN gave ; AGENT u ; RECIPIENT v ; THEME w] , ⑦[HNDL h5 ; RELN gave ; AGENT u ; RECIPIENT v ; THEME x] ⟩
  H-CONS {h17 ≥ {h4}, h25 ≥ {h5}}
  H-STORE {}

- PHON ⟨⟨no⟩, ⟨man⟩⟩
  SYNSEM|CONT
  EP ⟨ ②[HNDL h6 ; RELN no ; VAR v ; RESTRICTOR h7 ; SCOPE h8] , ③[HNDL h9 ; RELN man ; INSTANCE v] ⟩
  H-CONS {h10 ≥ {h11}, h11 ≥ {h6}, h7 ≥ {h9}}
  H-STORE {h10}

- PHON *none*
  SYNSEM|CONT
  EP ⟨ [HNDL h1 ; RELN or ; CONJUNCTS ⟨h2, h3⟩] ⟩
  H-CONS {}
  H-STORE {}

- PHON ⟨⟨a⟩, ⟨book⟩, ⟨on-Friday⟩⟩
  SYNSEM|CONT
  EP ⟨ ④[HNDL h12 ; RELN a ; VAR w ; RESTRICTOR h13 ; SCOPE h14] , ⑤[HNDL h15 ; RELN book ; INSTANCE w] , ⑥[HNDL h16 ; RELN onFri ; ARG1 h17] ⟩
  H-CONS {h2 ≥ {h28, h18}, h18 ≥ {h19}, h19 ≥ {h12}, h13 ≥ {h15}, h28 ≥ {h16}}
  H-STORE {}

- PHON ⟨or, ⟨⟨a⟩, ⟨record⟩⟩, ⟨on-Saturday⟩⟩
  SYNSEM|CONT
  EP ⟨ ⑧[HNDL h20 ; RELN a ; VAR x ; RESTRICTOR h21 ; SCOPE h22] , ⑨[HNDL h23 ; RELN record ; INSTANCE x] , ⑩[HNDL h24 ; RELN onSat ; ARG1 h25] ⟩
  H-CONS {h3 ≥ {h29, h26}, h26 ≥ {h27}, h27 ≥ {h20}, h21 ≥ {h23}, h29 ≥ {h24}}
  H-STORE {}

⟩

Left daughter:

SYNSEM [CONT [LTOP h2 ; SEMHEAD h28] ; CAT [TO-BE-STORED {}]]

DOM ⟨
- PHON ⟨gave⟩ ; SYNSEM|CONT [EP ⟨①⟩ ; H-STORE {}] ,
- PHON ⟨⟨no⟩, ⟨man⟩⟩ ; SYNSEM|CONT [EP ⟨②, ③⟩ ; H-STORE {h10}] ,
- PHON ⟨⟨a⟩, ⟨book⟩⟩ ; SYNSEM|CONT [EP ⟨④, ⑤⟩ ; H-STORE {h18}] ,
- PHON ⟨on-Friday⟩ ; SYNSEM|CONT [EP ⟨⑥⟩ ; H-STORE {}]
⟩

Right daughter:

SYNSEM [CONT [LTOP h3 ; SEMHEAD h29] ; CAT [TO-BE-STORED {}]]

DOM ⟨
- PHON ⟨gave⟩ ; SYNSEM|CONT [EP ⟨⑦⟩ ; H-STORE {}] ,
- PHON ⟨⟨no⟩, ⟨man⟩⟩ ; SYNSEM|CONT [EP ⟨②, ③⟩ ; H-STORE {h10}] ,
- PHON ⟨⟨a⟩, ⟨record⟩⟩ ; SYNSEM|CONT [EP ⟨⑧, ⑨⟩ ; H-STORE {h26}] ,
- PHON ⟨on-Saturday⟩ ; SYNSEM|CONT [EP ⟨⑩⟩ ; H-STORE {}]
⟩

Figure 11: Part of the structure that the theory advocated here assigns to sentence (27), when the string *gave no man* is taken to have undergone the syntactic type of LNR

24

$$
\begin{bmatrix}
\text{SYNSEM}|\text{CONT} & \begin{bmatrix} \text{LTOP} & h2 \\ \text{SEMHEAD} & h28 \end{bmatrix} \\[2ex]
\text{DOM} & \Big\langle \\
& \begin{bmatrix}
\text{PHON} & \langle\text{gave}\rangle \\
\text{SYNSEM}|\text{CONT} & \begin{bmatrix}
\text{EP} & \Big\langle \boxed{1}\begin{bmatrix} \text{HNDL} & h4 \\ \text{RELN} & \text{gave} \\ \text{AGENT} & u \\ \text{RECIPIENT} & v \\ \text{THEME} & w \end{bmatrix}\Big\rangle \\
\text{H-CONS} & \{h17 \geq \{h4\}\} \\
\text{H-STORE} & \{\}
\end{bmatrix}
\end{bmatrix}, \\[6ex]
& \boxed{11}\begin{bmatrix}
\text{PHON} & \langle\langle\text{no}\rangle,\langle\text{man}\rangle\rangle \\
\text{SYNSEM}|\text{CONT} & \begin{bmatrix}
\text{EP} & \Big\langle \begin{bmatrix} \text{HNDL} & h6 \\ \text{RELN} & \text{no} \\ \text{VAR} & v \\ \text{RESTRICTOR} & h7 \\ \text{SCOPE} & h8 \end{bmatrix}, \begin{bmatrix} \text{HNDL} & h9 \\ \text{RELN} & \text{man} \\ \text{INSTANCE} & v \end{bmatrix}\Big\rangle \\
\text{H-CONS} & \{h10 \geq \{h11\}, h11 \geq \{h6\}, h7 \geq \{h9\}\} \\
\text{H-STORE} & \{h10\}
\end{bmatrix}
\end{bmatrix}, \\[6ex]
& \boxed{12}\begin{bmatrix}
\text{PHON} & \langle\langle\text{a}\rangle,\langle\text{book}\rangle\rangle \\
\text{SYNSEM}|\text{CONT} & \begin{bmatrix}
\text{EP} & \Big\langle \begin{bmatrix} \text{HNDL} & h12 \\ \text{RELN} & \text{a} \\ \text{VAR} & w \\ \text{RESTRICTOR} & h13 \\ \text{SCOPE} & h14 \end{bmatrix}, \begin{bmatrix} \text{HNDL} & h15 \\ \text{RELN} & \text{book} \\ \text{INSTANCE} & w \end{bmatrix}\Big\rangle \\
\text{H-CONS} & \{h18 \geq \{h19\}, h19 \geq \{h12\}, h13 \geq \{h15\}\} \\
\text{H-STORE} & \{h18\}
\end{bmatrix}
\end{bmatrix}, \\[6ex]
& \begin{bmatrix}
\text{PHON} & \langle\text{on-Friday}\rangle \\
\text{SYNSEM}|\text{CONT} & \begin{bmatrix}
\text{EP} & \Big\langle \boxed{6}\begin{bmatrix} \text{HNDL} & h16 \\ \text{RELN} & \text{onFri} \\ \text{ARG1} & h17 \end{bmatrix}\Big\rangle \\
\text{H-CONS} & \{h28 \geq \{h16\}\} \\
\text{H-STORE} & \{\}
\end{bmatrix}
\end{bmatrix} \Big\rangle
\end{bmatrix}
$$

$$
\begin{bmatrix}
\text{SYNSEM} & \begin{bmatrix} \text{CONT} & \begin{bmatrix} \text{LTOP} & h17 \\ \text{SEMHEAD} & h4 \end{bmatrix} \\ \text{CAT} & \begin{bmatrix} \text{TO-BE-STORED} & \{\} \end{bmatrix} \end{bmatrix} \\[3ex]
\text{DOM} & \Big\langle \begin{bmatrix} \text{PHON} & \text{gave} \\ \text{SYNSEM}|\text{CONT} & \begin{bmatrix} \text{EP} & \langle\boxed{1}\rangle \\ \text{H-CONS} & \{\} \\ \text{H-STORE} & \{\} \end{bmatrix} \end{bmatrix}, \boxed{11}, \boxed{12} \Big\rangle
\end{bmatrix}
\qquad
\begin{bmatrix}
\text{SYNSEM} & \begin{bmatrix} \text{CONT} & \begin{bmatrix} \text{LTOP} & h28 \\ \text{SEMHEAD} & h16 \end{bmatrix} \\ \text{CAT} & \begin{bmatrix} \text{TO-BE-STORED} & \{\} \end{bmatrix} \end{bmatrix} \\[3ex]
\text{DOM} & \Big\langle \begin{bmatrix} \text{PHON} & \text{on-Friday} \\ \text{SYNSEM}|\text{CONT} & \begin{bmatrix} \text{EP} & \langle\boxed{6}\rangle \\ \text{H-CONS} & \{\} \\ \text{H-STORE} & \{\} \end{bmatrix} \end{bmatrix} \Big\rangle
\end{bmatrix}
$$

Figure 12: Part of the structure assigned to the first conjunct of sentence (27)

$$
\begin{bmatrix}
\text{SYNSEM} & \begin{bmatrix}
\text{CAT} & \boxed{1} & \begin{bmatrix}
\text{HEAD} & adv \\
\text{VALENCE} & \begin{bmatrix}
\text{SUBJ} & \langle\rangle \\
\text{COMPS} & \langle\rangle \\
\text{MOD} & \langle[\text{CONT}\ [\text{LTOP}\ \boxed{3}\ ]]\rangle
\end{bmatrix} \\
\text{QUANTIFIERS} & \{\}
\end{bmatrix} \\
\text{CONT} & [\text{SEMHEAD}\ \boxed{2}\ ]
\end{bmatrix} \\[2em]
\text{DOM} & \left\langle \begin{bmatrix}
\text{PHON} & \text{on-Friday} \\
\text{SYNSEM} & \begin{bmatrix}
\text{CAT} & \boxed{1} \\
\text{CONT} & \begin{bmatrix}
\text{EP} & \left\langle \begin{bmatrix}
\text{HNDL} & \boxed{2} \\
\text{RELN} & \text{onFri} \\
\text{ARG}1 & \boxed{3}
\end{bmatrix}\right\rangle \\
\text{H-CONS} & \{\}
\end{bmatrix}
\end{bmatrix}
\end{bmatrix} \right\rangle
\end{bmatrix}
$$

Figure 13: Part of the lexical entry for the expression *on Friday*

predication. Figure 13 shows the lexical entry we are assuming for this expression.

The second domain object in the order domain of the mother in Figure 11 represents the quantifier *no man*, which is also assumed to have been syntactically left-node-raised. This DP is constructed in a way analogous to the way the DP *every girl* is constructed in Figure 8. The sole handle in the H-STORE set of this domain object (viz. $h10$), which will turn out to be identical to $h11$ and $h6$, is the handle of the meaning of the quantifier *no man* itself. This domain object is the result of fusing the second domain object in the order domain of the first daughter and the second domain object in the order domain of the second daughter. It conforms to the condition in (23a) above; the three domain objects involved are identical to each other and represent a single quantifier. Since domain objects rather than signs are the principal carriers of semantic information in this theory, the fact that the order domain of the mother node contains only one set of elementary predications corresponding to this quantifier means that the semantic representation of this sentence is going to contain only one instance of that quantifier, which is thus required to take scope over the entire coordinate structure.

The third domain object in the order domain of the mother node is there to represent the meaning of disjunction, and has no phonological content. This domain object is created by the phrase-structure schema that licenses coordinate structure, as we noted at the outset of this subsection, i.e. subsection 2.4. That phrase-structure schema stipulates (i) that a list consisting of the LTOP values of the conjuncts (viz. $\langle h2, h3\rangle$) be the argument of the meaning of conjunction, and (ii) that the handle of the elementary predication expressing the meaning of conjunction (viz. $h1$) be the SEMHEAD value of the coordinate structure as a whole.

The fourth domain object of the mother node in Figure 11 is the result of compacting the first daughter or, more precisely, the sign that is obtained by excising the first two domain objects of the first daughter, which were syntactically left-node-raised out of it. This means that the sign whose compaction gave rise to this domain object had only two domain objects (viz. the one representing *a book* and the one representing *on Friday*) in its order domain. The first handle constraint in the H-CONS value of this fourth domain object (viz. the constraint $h2 \geq \{h28, h18\}$) was produced by the application of compaction that led to the creation of this domain object; the constraint says that the LTOP value of the first conjunct (i.e. $h2$) has to either outscope or be identical to the SEMHEAD value of the first conjunct (i.e. $h28$) and the handle of the quantifier meaning of *a book* (i.e. $h18$). The second, the third, and the fourth handle constraint in the

$$
\begin{bmatrix}
\text{SYNSEM} & \begin{bmatrix}
\text{CAT} & \boxed{1} & \begin{bmatrix}
\text{HEAD} & noun \\
\text{VALENCE} & \begin{bmatrix}
\text{SUBJ} & \langle\rangle \\
\text{COMPS} & \langle\rangle \\
\text{MOD} & \langle\rangle
\end{bmatrix} \\
\text{QUANTIFIERS} & \{\}
\end{bmatrix} \\
\text{CONT} & \begin{bmatrix}
\text{SEMHEAD} & gtop \\
\text{INDEX} & \boxed{2}
\end{bmatrix}
\end{bmatrix} \\[2em]
\text{DOM} & \left\langle \begin{bmatrix}
\text{PHON} & \text{Terry} \\
\text{SYNSEM} & \begin{bmatrix}
\text{CAT} & \boxed{1} \\
\text{CONT} & \begin{bmatrix}
\text{EP} & \left\langle \begin{bmatrix}
\text{HNDL} & gtop \\
\text{RELN} & \text{identical} \\
\text{ARG1} & \boxed{2} \\
\text{ARG2} & \text{Terry}
\end{bmatrix} \right\rangle \\
\text{H-CONS} & \{\}
\end{bmatrix}
\end{bmatrix}
\end{bmatrix} \right\rangle
\end{bmatrix}
$$
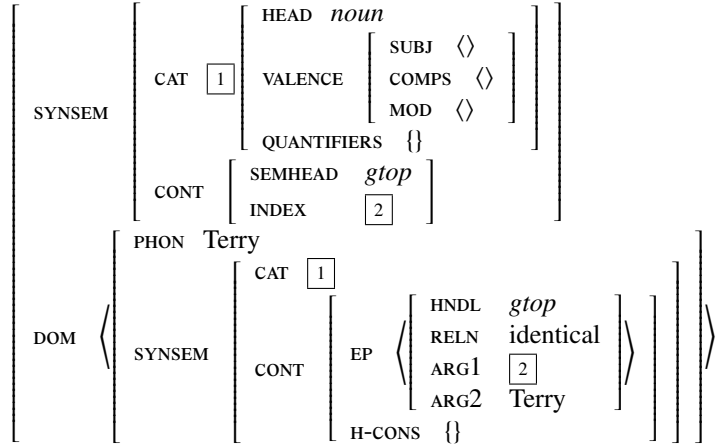
Figure 14: Part of the lexical entry for the proper noun *Terry*

H-CONS value (viz. the constraints $h18 \geq \{h19\}$, $h19 \geq \{h12\}$, and $h13 \geq \{h15\}$) were produced by the three applications of compaction that were involved in generating the DP *a book*. And the fifth handle constraint in this H-CONS value (viz. the constraint $h28 \geq \{h16\}$) was produced when the adjunct *on Friday* was compacted within the first conjunct (see Figure 12).

The fifth domain object of the mother node in Figure 11 is the result of compacting the second daughter or, more precisely, the sign that is obtained by excising the first two domain objects of the second daughter, which were syntactically left-node-raised out of it. The first element of its PHON value, namely "or", was added here after this application of compaction.

The lexical entry we assume for the proper noun *Terry* is shown in Figure 14. The symbol *gtop* used in this lexical entry represents a designated handle that is always identified with the global top handle of an MRS representation.

When the VP shown in Figure 11 is combined with the subject DP *Terry* and the resulting sentential sign is totally compacted, we obtain a domain object whose H-CONS value is (28) (where $h30$ is the LTOP value of the subject DP).

(28) $\{ h0 \geq \{h1, h10\}, h30 \geq \{gtop\}, h17 \geq \{h4\}, h25 \geq \{h5\}, h10 \geq \{h11\}, h11 \geq \{h6\}, h7 \geq \{h9\}, h2 \geq \{h28, h18\}, h18 \geq \{h19\}, h19 \geq \{h12\}, h13 \geq \{h15\}, h28 \geq \{h16\}, h3 \geq \{h29, h26\}, h26 \geq \{h27\}, h27 \geq \{h20\}, h21 \geq \{h23\}, h29 \geq \{h24\} \}$

This means, among other things, that $h2 \geq h18 \geq h19 \geq h12$, which means that the DP *a book* has to take scope within the first disjunct. Likewise, the DP *a record* is required to take scope within the second disjunct. On the other hand, the DP *no man* has to take wide scope over the disjunction because it has to bind all the occurrences of the variable v, which is used in both disjuncts. The scope relation between the DP *a book* and the adjunct *on Friday* is underspecified, as is the scope relation between the DP *a record* and the adjunct *on Saturday*.

The CONT value of the domain object representing the sentence as a whole therefore corresponds to the four representations in (29) in the conventional notation.

(29) a. $u = \text{Terry} \land \text{no}(v, \text{man}(v), \text{onFri}(a(w, \text{book}(w), \text{gave}(u, v, w))) \lor \text{onSat}(a(x, \text{record}(x), \text{gave}(u, v, x))))$

b. $u = \text{Terry} \land \text{no}(v, \text{man}(v), \text{a}(w, \text{book}(w), \text{onFri}(\text{gave}(u, v, w))) \lor \text{onSat}(\text{a}(x, \text{record}(x), \text{gave}(u, v, x))))$

c. $u = \text{Terry} \land \text{no}(v, \text{man}(v), \text{onFri}(\text{a}(w, \text{book}(w), \text{gave}(u, v, w))) \lor \text{a}(x, \text{record}(x), \text{onSat}(\text{gave}(u, v, x))))$

d. $u = \text{Terry} \land \text{no}(v, \text{man}(v), \text{a}(w, \text{book}(w), \text{onFri}(\text{gave}(u, v, w))) \lor \text{a}(x, \text{record}(x), \text{onSat}(\text{gave}(u, v, x))))$

Assuming that the values of free variables are contextually determined, the four representations in (29) are truth-conditionally equivalent to each other and are all adequate representations of the reading of sentence (27) in which the quantifier *no man* takes wide scope over the coordinate structure. Thus, we see that this reading of sentence (27) does not pose a problem for the HPSG-based account.

The other reading of this sentence, in which the quantifier is outscoped by the disjunction, is not a problem for the account either. That reading can be generated in the following two ways. First, if the quantifier *no man* is taken to have undergone phonological LNR, the sentence will be given the same interpretation as *Terry gave no man a book on Friday or no man a record on Saturday*, which is precisely the interpretation in which the quantifier *no man* is interpreted within each disjunct and is outscoped by the disjunction. Second, the same reading can be obtained by taking the quantifier *no man* to have undergone syntactic LNR and utilizing condition (23b) instead of condition (23a) in licensing the fusion of two domain objects corresponding to that left-node-raised quantifier.

Thus, Kubota and Levine's claim that a sentence like (27) poses an empirical challenge to the HPSG-based account is incorrect.

2.4.2 Symmetric predicates

Next, we will illustrate the way the HPSG-based theory analyzes (2a), reproduced below as (30), which is another sentence that Kubota and Levine claim poses a problem for the theory.

(30)   I said different things to Robin on Thursday and Leslie on Friday.

The reading that we are interested in is one where this sentence means that the thing that the speaker said to Robin on Thursday was different from the thing that the speaker said to Leslie on Friday. Kubota and Levine imply that the fact that such a reading exists is not addressed anywhere in the HPSG literature,[9] but it *is* addressed in Yatabe (2012), and we are going to present the analysis that is proposed in that article below, again filling in some details that are left unspecified there. (Those readers who believe that they already understand how the sentence can be analyzed in our theory might want to skip to the preantepenultimate paragraph of the present sub-subsection, which starts with "As we have already noted".)

Figure 15 shows part of the structure that the HPSG-based theory under discussion assigns to this sentence. It depicts the local subtree in which two VPs are conjoined to become a larger VP.

The first domain object in the order domain of the mother node, i.e. the one to be pronounced "said", is the result of fusing the first domain object in the order domain of

---

[9]Here is what is said on p. 538 in Kubota and Levine (2015): "The situation is exactly parallel with symmetrical and summative predicates. In short, with 'respective', symmetrical and summative predicates, essentially the same problem arises as in the case of quantifiers when they interact with coordination, but the situation for the LBE approach is worse: currently, there is not even an attempt at addressing this problem." (LBE stands for Linearization-Based Ellipsis.)

$$
\begin{bmatrix}
\text{SYNSEM}|\text{CONT} & \begin{bmatrix} \text{LTOP} & h0 \\ \text{SEMHEAD} & h1 \end{bmatrix} \\[2mm]
\text{DOM} \quad \Big\langle
\begin{bmatrix}
\text{PHON} \ \langle\text{said}\rangle \\
\text{SYNSEM}|\text{CONT}
\begin{bmatrix}
\text{EP} & \Big\langle \boxed{1}
\begin{bmatrix}
\text{HNDL} & h4 \\ \text{RELN} & \text{said} \\ \text{AGENT} & u \\ \text{RECIPIENT} & v \\ \text{THEME} & w
\end{bmatrix},
\boxed{4}
\begin{bmatrix}
\text{HNDL} & h5 \\ \text{RELN} & \text{said} \\ \text{AGENT} & u \\ \text{RECIPIENT} & x \\ \text{THEME} & y
\end{bmatrix} \Big\rangle \\
\text{H-CONS} & \{h13 \geq \{h4\}, h15 \geq \{h5\}\} \\
\text{H-STORE} & \{\}
\end{bmatrix}
\end{bmatrix},
$$

$$
\begin{bmatrix}
\text{PHON} \ \langle\langle none\rangle, \langle\langle different\rangle, \langle things\rangle\rangle\rangle \\
\text{SYNSEM}|\text{CONT}
\begin{bmatrix}
\text{INDEX} & w+y \\
\text{EP} & \Big\langle
\begin{bmatrix}
\text{HNDL} & h6 \\ \text{RELN} & \text{some} \\ \text{VAR} & w+y \\ \text{RESTRICTOR} & h7 \\ \text{SCOPE} & h8
\end{bmatrix},
\begin{bmatrix}
\text{HNDL} & h20 \\ \text{RELN} & \text{different} \\ \text{INSTANCE} & w+y
\end{bmatrix},
\begin{bmatrix}
\text{HNDL} & h21 \\ \text{RELN} & \text{things} \\ \text{INSTANCE} & w+y
\end{bmatrix} \Big\rangle \\
\text{H-CONS} & \boxed{7}\{h10 \geq \{h11\}, h11 \geq \{h6\}, h7 \geq \{h9\}, h9 \geq \{h20\}, h9 \geq \{h21\}\} \\
\text{H-STORE} & \boxed{8}\{h10\}
\end{bmatrix}
\end{bmatrix},
$$

$$
\begin{bmatrix}
\text{PHON} \ none \\
\text{SYNSEM}|\text{CONT}
\begin{bmatrix}
\text{EP} & \Big\langle
\begin{bmatrix}
\text{HNDL} & h1 \\ \text{RELN} & \text{and} \\ \text{CONJUNCTS} & \langle h2, h3\rangle
\end{bmatrix} \Big\rangle \\
\text{H-CONS} & \{\} \\
\text{H-STORE} & \{\}
\end{bmatrix}
\end{bmatrix},
$$

$$
\begin{bmatrix}
\text{PHON} \ \langle\langle \text{to}, \langle\text{Robin}\rangle\rangle, \langle\text{on-Thursday}\rangle\rangle \\
\text{SYNSEM}|\text{CONT}
\begin{bmatrix}
\text{EP} & \Big\langle \boxed{2}
\begin{bmatrix}
\text{HNDL} & gtop \\ \text{RELN} & \text{identical} \\ \text{ARG1} & v \\ \text{ARG2} & \text{Robin}
\end{bmatrix},
\boxed{3}
\begin{bmatrix}
\text{HNDL} & h12 \\ \text{RELN} & \text{onThu} \\ \text{ARG1} & h13
\end{bmatrix} \Big\rangle \\
\text{H-CONS} & \{h2 \geq \{h16\}, h18 \geq \{h18\}, h18 \geq \{gtop\}, h16 \geq \{h12\}\} \\
\text{H-STORE} & \{\}
\end{bmatrix}
\end{bmatrix},
$$

$$
\begin{bmatrix}
\text{PHON} \ \langle \text{and}, \langle\langle\text{Leslie}\rangle\rangle, \langle\text{on-Friday}\rangle\rangle \\
\text{SYNSEM}|\text{CONT}
\begin{bmatrix}
\text{EP} & \Big\langle \boxed{5}
\begin{bmatrix}
\text{HNDL} & gtop \\ \text{RELN} & \text{identical} \\ \text{ARG1} & x \\ \text{ARG2} & \text{Leslie}
\end{bmatrix},
\boxed{6}
\begin{bmatrix}
\text{HNDL} & h14 \\ \text{RELN} & \text{onFri} \\ \text{ARG1} & h15
\end{bmatrix} \Big\rangle \\
\text{H-CONS} & \{h3 \geq \{h17\}, h19 \geq \{h19\}, h19 \geq \{gtop\}, h17 \geq \{h14\}\} \\
\text{H-STORE} & \{\}
\end{bmatrix}
\end{bmatrix}
\Big\rangle
\end{bmatrix}
$$

Left daughter:

$$
\begin{bmatrix}
\text{SYNSEM} &
\begin{bmatrix}
\text{CONT} & \begin{bmatrix} \text{LTOP} & h2 \\ \text{SEMHEAD} & h16 \end{bmatrix} \\
\text{CAT} & \begin{bmatrix} \text{TO-BE-STORED} & \{\} \end{bmatrix}
\end{bmatrix} \\[2mm]
\text{DOM} \ \Big\langle
\begin{bmatrix}
\text{PHON} \ \langle\text{said}\rangle \\
\text{SYNSEM}|\text{CONT}
\begin{bmatrix} \text{EP} & \langle \boxed{1} \rangle \\ \text{H-STORE} & \{\} \end{bmatrix}
\end{bmatrix},
\begin{bmatrix}
\text{PHON} \ \langle\langle none\rangle, \langle\langle different\rangle, \langle things\rangle\rangle\rangle \\
\text{SYNSEM}|\text{CONT}
\begin{bmatrix} \text{INDEX} & w \\ \text{H-CONS} & \boxed{7} \\ \text{H-STORE} & \boxed{8} \end{bmatrix}
\end{bmatrix}, \\
\begin{bmatrix}
\text{PHON} \ \langle\text{to}, \langle\text{Robin}\rangle\rangle \\
\text{SYNSEM}|\text{CONT}
\begin{bmatrix} \text{EP} & \langle \boxed{2} \rangle \\ \text{H-STORE} & \{\} \end{bmatrix}
\end{bmatrix},
\begin{bmatrix}
\text{PHON} \ \langle\text{on-Thursday}\rangle \\
\text{SYNSEM}|\text{CONT}
\begin{bmatrix} \text{EP} & \langle \boxed{3} \rangle \\ \text{H-STORE} & \{\} \end{bmatrix}
\end{bmatrix}
\Big\rangle
\end{bmatrix}
$$

Right daughter:

$$
\begin{bmatrix}
\text{SYNSEM} &
\begin{bmatrix}
\text{CONT} & \begin{bmatrix} \text{LTOP} & h3 \\ \text{SEMHEAD} & h17 \end{bmatrix} \\
\text{CAT} & \begin{bmatrix} \text{TO-BE-STORED} & \{\} \end{bmatrix}
\end{bmatrix} \\[2mm]
\text{DOM} \ \Big\langle
\begin{bmatrix}
\text{PHON} \ \langle\text{said}\rangle \\
\text{SYNSEM}|\text{CONT}
\begin{bmatrix} \text{EP} & \langle \boxed{4} \rangle \\ \text{H-STORE} & \{\} \end{bmatrix}
\end{bmatrix},
\begin{bmatrix}
\text{PHON} \ \langle\langle none\rangle, \langle\langle different\rangle, \langle things\rangle\rangle\rangle \\
\text{SYNSEM}|\text{CONT}
\begin{bmatrix} \text{INDEX} & y \\ \text{H-CONS} & \boxed{7} \\ \text{H-STORE} & \boxed{8} \end{bmatrix}
\end{bmatrix}, \\
\begin{bmatrix}
\text{PHON} \ \langle\text{to}, \langle\text{Leslie}\rangle\rangle \\
\text{SYNSEM}|\text{CONT}
\begin{bmatrix} \text{EP} & \langle \boxed{5} \rangle \\ \text{H-STORE} & \{\} \end{bmatrix}
\end{bmatrix},
\begin{bmatrix}
\text{PHON} \ \langle\text{on-Friday}\rangle \\
\text{SYNSEM}|\text{CONT}
\begin{bmatrix} \text{EP} & \langle \boxed{6} \rangle \\ \text{H-STORE} & \{\} \end{bmatrix}
\end{bmatrix}
\Big\rangle
\end{bmatrix}
$$

Figure 15: Part of the structure assigned to sentence (30)

the first daughter and the first domain object in the order domain of the second daughter. The relationship between these three domain objects conforms to the constraint stated in (23b).

The second domain object in the order domain of the mother node in Figure 15, i.e. the one to be pronounced "different things", is the result of fusing the second domain object in the order domain of the first daughter and the second domain object in the order domain of the second daughter. The relationship between these three domain objects conforms to the constraint stated in (23c).

Apart from the fact that (23c) was invoked for the second domain object instead of (23a), the way the structure in Figure 15 is licensed is analogous to the way the structure in Figure 11 is licensed. The reason that the domain object corresponding to *said* and the domain object corresponding to *different things* both exist as independent domain objects at this point is that the VP that is modified by the temporal adjunct underwent partial compaction in each conjunct. When the VP *said different things to Robin* was modified by the adjunct *on Thursday* in the first conjunct, the two non-initial domain objects in the order domain of the VP (viz. the one corresponding to *different things* and the one corresponding to *to Robin*) escaped compaction. Likewise, when the VP *said different things to Leslie* was modified by the adjunct *on Friday* in the second conjunct, the two non-initial domain objects in the order domain of the VP (viz. the one corresponding to *different things* and the one corresponding to *to Leslie*) escaped compaction. Partial compaction of the VP *said different things to Robin* in the first conjunct gave rise to the first handle constraint in the H-CONS set of the first domain object in the order domain of the mother node in Figure 15 (viz. $h13 \geq \{h4\}$), while partial compaction of the VP *said different things to Leslie* in the second conjunct gave rise to the second handle constraint in that H-CONS set (viz. $h15 \geq \{h5\}$).

The third domain object in the order domain of the mother node in Figure 15 merely represents the meaning of conjunction, and does not have phonological content.

The fourth domain object, i.e. the one to be pronounced "to Robin on Thursday", is the result of compacting the first daughter or, more precisely, the sign that is obtained by excising the first two domain objects in the order domain of the first daughter, which were syntactically left-node-raised. The first handle constraint in the H-CONS set of this domain object (viz. $h2 \geq \{h16\}$) was created when this compaction took place. The second handle constraint in the set (viz. $h18 \geq \{h18\}$), which is tautological, was created when the PP *to Robin* underwent total compaction. (The lexical entry we assume for the marking preposition *to* is shown in Figure 16.) The third handle constraint (viz. $h18 \geq \{gtop\}$) was created when the DP *Robin* underwent total compaction. And the fourth handle constraint (viz. $h16 \geq \{h12\}$) was created when the adjunct *on Thursday* underwent compaction.

And the fifth domain object in the order domain of the mother node in Figure 15, i.e. the one to be pronounced "Leslie on Friday", is the result of (i) compacting the second daughter or, more precisely, the sign that is obtained by excising the first two domain objects in the order domain of the second daughter, which were syntactically left-node-raised, (ii) applying phonological left-node raising to the left edge of its PHON value and deleting the string "to" there, and (iii) adding the string "and" to the left edge of its PHON value.

Figure 17 shows part of the internal structure of the DP *different things* in the first conjunct of sentence (30). For concreteness, we assume that this DP is headed by a phonologically empty determiner whose semantics is identical to that of *some*. Figure 18 shows part of the lexical entry that we are assuming for the word *different*. The DP *different things* in the second conjunct is generated in an almost identical

SYNSEM [CAT [1] [HEAD *prep* / VALENCE [SUBJ ⟨⟩ / COMPS ⟨[CONT [LTOP [2] / INDEX [3]]]⟩ / MOD ⟨⟩] / QUANTIFIERS {}] / CONT [LTOP [2] / SEMHEAD [2] / INDEX [3]]]

DOM ⟨ [PHON to / SYNSEM [CAT [1] / CONT [EP ⟨⟩ / H-CONS {}]]] ⟩
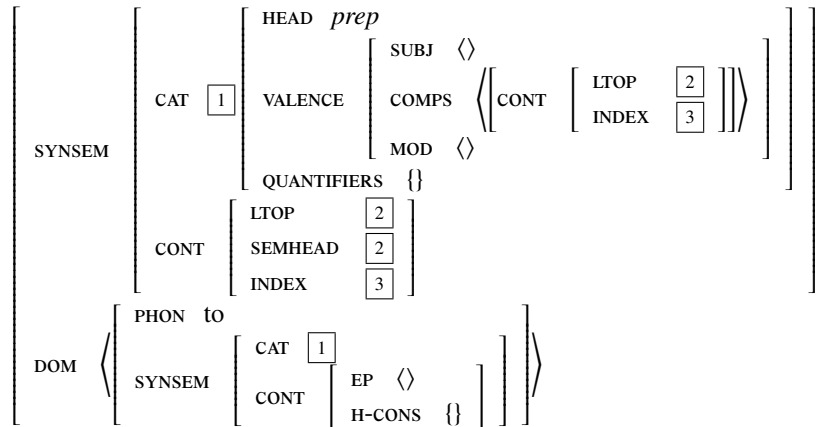
Figure 16: Part of the lexical entry for the marking preposition *to*

SYNSEM|CONT [LTOP $h10$ / SEMHEAD $h11$ / INDEX w]

DOM ⟨ [PHON ⟨*none*⟩ / SYNSEM|CONT [EP [9]⟨ [HNDL $h6$ / RELN some / VAR w / RESTRICTOR $h7$ / SCOPE $h8$] ⟩ / H-CONS {$h11 \geq \{h6\}$} / H-STORE {}]] ,

[PHON ⟨⟨different⟩, ⟨things⟩⟩ / SYNSEM|CONT [EP [10]⟨ [HNDL $h20$ / RELN different / INSTANCE w] , [11][HNDL $h21$ / RELN things / INSTANCE w] ⟩ / H-CONS {$h7 \geq \{h9\}$, $h9 \geq \{h20\}$, $h9 \geq \{h21\}$} / H-STORE {}]] ⟩

SYNSEM [CONT [LTOP $h11$ / SEMHEAD $h6$ / INDEX w]] / DOM ⟨ [PHON *none* / SYNSEM|CONT|EP [9]⟨ ⟩] ⟩

SYNSEM|CONT [LTOP $h7$ / SEMHEAD $h9$] / DOM ⟨ [PHON ⟨different⟩ / SYNSEM|CONT [EP [10] / H-CONS {$h9 \geq \{h20\}$}]] , [PHON ⟨things⟩ / SYNSEM|CONT [EP [11]⟨ ⟩ / H-CONS {$h9 \geq \{h21\}$} / H-STORE {}]] ⟩

SYNSEM|CONT [LTOP $h9$ / SEMHEAD $h20$ / KEY ⟨[10]⟩] / DOM ⟨ [PHON different / SYNSEM|CONT|EP ⟨[10]⟩] ⟩

SYNSEM [CONT [LTOP $h9$ / SEMHEAD $h21$ / INDEX w]] / DOM ⟨ [PHON things / SYNSEM|CONT [EP ⟨[11]⟩ / H-CONS {}]] ⟩

Figure 17: Part of the structure assigned to the DP *different things* in the first conjunct of Figure 15

31
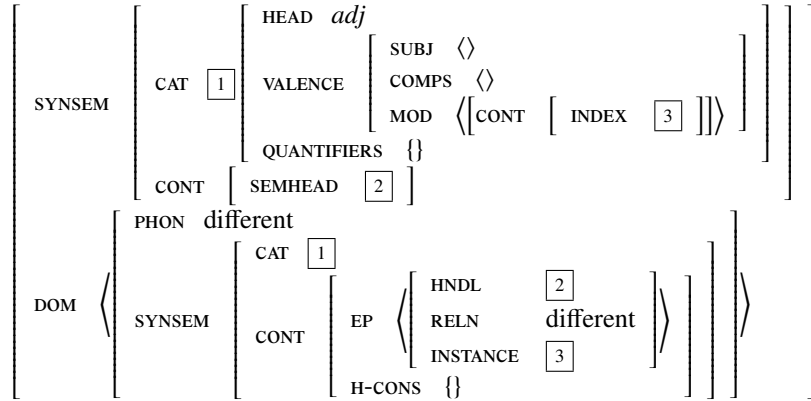
Figure 18: Part of the lexical entry for the adjective *different*

fashion but with a distinct index, namely y instead of w. The second domain object in the order domain of the mother node in Figure 15 has the INDEX feature whose value is $w + y$ because it was created by fusing a domain object whose INDEX value is w and an almost identical domain object whose INDEX value is y in accordance with the condition (23c).

When the VP as a whole is combined with the subject DP *I* and the resulting S is totally compacted, we obtain a domain object whose CONT value represents the meaning of the sentence. That meaning is expressed by the representation in (31) in the conventional notation.

(31) u = Speaker $\wedge$ v = Robin $\wedge$ x = Leslie $\wedge$ some($w+y$, different($w+y$) $\wedge$ things($w+y$), onThu(said(u, v, w)) $\wedge$ onFri(said(u, x, y)))

This is an adequate representation of the reading in question, on the assumption (i) that a variable whose name is of the form $X_1 + \cdots + X_n$ is to denote the set consisting of the denotations of $X_1, \ldots, X_n$ and (ii) that an elementary predication whose RELN value is *different* and whose argument is a variable whose name is of the form $X_1 + \cdots + X_n$ means that the denotations of $X_1, \ldots, X_n$ are different from each other. Kubota and Levine's claim that the HPSG-based theory is incapable of accounting for the interpretation of a sentence like (30) is thus incorrect.

As we have already noted, choice between (23a), (23b), and (23c) is entirely free, apart from the restriction that prevents (23c) from applying to disjunctive coordinate structures and non-coordinate structures. Thus, (23c) can be used not just to fuse domain objects standing for an expression like *different things* that contains a symmetric predicate but also to fuse domain objects standing for an expression like *thirty books*. This allows the theory to deal with a sentence like *Mary borrowed, and Bill stole, thirty books (in total) from the library*.

The condition in (23c) could be used to license fusion of domain objects standing for an expression like *Bill* as well, and this might appear to lead to overgeneration, but it does not. Let us examine the interpretation of the sentence *Mary likes, and Jane dislikes, Bill* as an example. This sentence will be associated with a semantic representation like (32) below, when the domain objects standing for *Bill* are fused according to (23c).

(32) w = Mary $\wedge$ x = Jane $\wedge$ $y + z$ = Bill $\wedge$ and(likes(w, y), dislikes(x, z))

In a sci-fi world in which Bill is made up of two components, this can be interpreted as saying that Mary likes the first component of Bill while Jane dislikes the second component. In a real world, in which a man is difficult to conceive of as being made up of two components, it will be inferred that $y = z = y+z = Bill$, and the sentence will consequently receive the interpretation that Mary likes Bill while Jane dislikes Bill, that is, the same interpretation that the sentence receives when the condition (23a) is used instead of (23c).[10]

Our account of a sentence like (30) may appear overly complicated, in that it relies on the constraint in (23c), which is distinct from the constraint that was invoked to deal with a sentence like (27), namely (23a). In this regard, our theory contrasts with that proposed in Kubota and Levine (2016), in which sentences (27) and (30) are treated in an entirely unified fashion. Kubota and Levine's theory achieves this simplicity by attributing the semantic peculiarity of the internal readings of symmetric and summative predicates in a sentence like (30) to a grammatical mechanism that generates the *respectively* reading of a sentence like *Chris and Alex read Joyce and Greene respectively*. According to their account, sentence (30) involves *respectively* interpretation of the object DP *different things* and the coordinate structure *Robin on Thursday and Leslie on Friday*, as a result of which the first of the two things denoted by the DP *different things* is semantically linked to the meaning of the first conjunct (viz. *Robin on Thursday*) and the second of the two things denoted by *different things* is semantically linked to the meaning of the second conjunct (viz. *Leslie on Friday*). The sentence thus comes to mean "I said a thing X to Robin on Thursday and said a thing Y to Leslie on Friday and X and Y are different from each other".

While Kubota and Levine's theory is indeed simpler than ours in this regard, there are some reasons to believe that their account is in fact too simple to be empirically adequate. We will make our case for this view at the end of section 3, after we have presented our own account of *respectively* readings. It is our contention that our account is only as complicated as facts require it to be.

3   *Respectively* readings

There are two respects in which the HPSG-based theory that has been proposed in the literature has a narrower empirical coverage compared to the theory proposed by Kubota and Levine. First, the theory does not apply to cases of the internal reading of a symmetric predicate that do not involve non-constituent coordination. Second, the theory does not generate *respectively* readings.

We believe that the first issue could be dealt with by incorporating into our theory a semantic theory of symmetric predicates such as that proposed in Brasoveanu (2011). Since the theory presented in Brasoveanu (2011) is likely not to be applicable to a sentence like (30), his theory and ours could complement each other without any redundancy.

On the other hand, the issue involving *respectively* readings cannot be rectified by incorporating some existing theory into our theory. There is no ready-made theory that is compatible with our theory and is capable of dealing with sentences like (33), discussed in Kubota and Levine (2015).

(33)   I bought and sold a car on Thursday and a bike on Friday, respectively.

---

[10]The discussion in the text presupposes that the sum of x and x is necessarily identical to x. Alternatively we could assume that the expression $x+y$ has a denotation only when the denotations of x and y are distinct. On that assumption, the representation in (32) will be interpreted as false in a world in which a man cannot be conceived of as being made up of two distinct components.

Thus, we will sketch below a new account of *respectively* readings, in order to ensure that the viability of our theory is not threatened by this issue.

Since some of the examples that we will discuss involve conjunction of proper names, we will first state what our assumptions are regarding the interpretation of such conjunction. The analysis of coordination that we presented in section 2 relies on an elementary predication whose RELN value is "and" or "or" and which takes as an argument a list of handles. This analysis is adequate for coordination of Ss, VPs, and Vs, but it is not adequate for expressions like *Alex and Chris*, which involve conjunction of non-quantificational nominal signs. We assume that, when two or more non-quantificational nominal signs (i.e. nominals whose KEY values do not contain scopal elementary predications) whose INDEX values are $x_1, \cdots, x_n$ are conjoined using the coordinator *and*, the phrase-structure schema for coordination requires (i) that a phonologically empty domain object of the form

$$\left[\text{SYNSEM}|\text{CONT}|\text{EP} \quad \left\langle \left[\begin{array}{ll} \text{HNDL} & h \\ \text{RELN} & \text{identical} \\ \text{ARG}1 & x_0 \\ \text{ARG}2 & x_1 + \cdots + x_n \end{array} \right] \right\rangle \right]$$

should be placed in the order domain of the coordinate structure, (ii) that the INDEX value and the SEMHEAD value of the coordinate structure should be x_0 and h respectively.[11] We also assume that a non-quantificational NP involving conjunction (such as *Alex and Chris*) is obligatorily preceded by a phonologically empty determiner whose meaning is the same as that of *some*.[12]

Our account of *respectively* readings consists of two components: an annotation mechanism for keeping track of those prosodic constituents that are to be given *respectively* interpretation, and a rewriting mechanism for deriving semantic representations that embody *respectively* readings. In the proposed account, the semantic representations that are initially produced by the grammar merely indicate which portions of the representations are to be given *respectively* interpretation, and do not actually express the truth conditions that are to be arrived at ultimately. This account is based on the view, which we owe to Ivan A. Sag (personal communication), that *respectively* interpretation is something that is acquired relatively late as an add-on to the core grammatical mechanisms.

Let us define some terms that we will use in what follows. First, we will say that in an example like *Mary and Jane saw Bill and Brad respectively*, the subject DP *Mary and Jane* and the object DP *Bill and Brad* are *semantically aligned* with each other. When we say (as we already did above) that an expression is given *respectively* interpretation, what we mean can be that it is semantically aligned with some other expression. Second, we will use the term *semantic coordinator* to refer to the following three things: the symbols "and" and "or" used as the values of the RELN feature, and the symbol "+" that is used as part of the SYNSEM|CONT|EP|FIRST|ARG2 value of a domain object introduced by the phrase-structure schema for coordinate structure. And third, we will say that a given occurrence of a semantic coordinator is the *semantic coordinator of* an expression X when that occurrence of the semantic coordinator is contained in the phonologically empty domain object that was introduced by the particular application of a phrase-structure schema that licensed X.

---

[11] We need to assume that a similar analysis is given to an expression like *the three students*, in order for the present theory to be applicable to sentences like *The three students went to Paris, London, and Berlin, respectively*. We are unable to present the details of such an analysis in the present article.

[12] Given the theory of constituent coordination proposed in Yatabe (2004), NPs that involve conjunction and NPs that do not can be distinguished from each other because they have distinct kinds of HEAD values.

The annotation mechanism optionally assigns subscripts to the semantic coordinators of expressions. Since we are working with a constraint-based framework, this means that the grammar licenses structures in which some occurrences of semantic coordinators have subscripts attached to them. To state this more precisely, we assume (i) that the SYNSEM|CONT|EP|FIRST|RELN value of a domain object that is introduced by the phrase-structure schema for a coordinate structure is allowed to be of the form α_i, where α is either "and" or "or", and (ii) that when two or more non-quantificational nominal signs whose INDEX values are $x_1, \cdots, x_n$ are conjoined using the coordinator *and*, the SYNSEM|CONT|EP|FIRST|ARG2 value of the domain object that is introduced by the phrase-structure schema for a coordinate structure can be of the form $x_1 +_i \cdots +_i x_n$.

Expressions whose semantic coordinators have the same subscript are interpreted as semantically aligned with each other. The annotation mechanism can produce a structure in which only one semantic coordinator has a given subscript. We assume that such a structure is filtered out by the rewriting mechanism, which we will present below.

Assignment of subscripts is subject to the constraint stated in (34), which we call the *i*-within-*i* constraint on *respectively* interpretation. What this constraint states is, roughly, that prosodic constituents that are semantically aligned with each other must not overlap with each other.

(34) The *i*-within-*i* constraint on *respectively* interpretation

    a. Suppose the domain object that has been introduced by the phrase-structure schema for coordinate structure has the following form:

$$\left[\text{SYNSEM|CONT|EP} \quad \left\langle \left[\begin{array}{ll} \text{RELN} & \text{and}_i \vee \text{or}_i \\ \text{CONJUNCTS} & \langle h_1, \cdots, h_n \rangle \end{array} \right] \right\rangle \right]$$

    Then those domain objects in the order domain of the coordinate structure whose LTOP values are $h_1, \cdots, h_n$ (that is, the domain objects that were created by compacting the conjuncts) must not contain a semantic coordinator with the subscript *i*.

    b. Suppose the domain object that has been introduced by the phrase-structure schema for coordinate structure has the following form:

$$\left[\text{SYNSEM|CONT|EP} \quad \left\langle \left[\begin{array}{ll} \text{RELN} & \text{identical} \\ \text{ARG1} & x_0 \\ \text{ARG2} & x_1 +_i \cdots +_i x_n \end{array} \right] \right\rangle \right]$$

    Then those domain objects in the order domain of the coordinate structure whose INDEX values are $x_1, \cdots, x_n$ (that is, the domain objects that were created by compacting the conjuncts) must not contain a semantic coordinator with the subscript *i*.

We assume that the grammar contains the following constraint as well, which means that when a coordinate structure is syntactically left- or right-node-raised, it has to be left- or right-node-raised in its entirety, including the phonologically empty domain object expressing the meaning of the coordinator.[13]

(35)   a. Suppose a given order domain contains a phonological empty domain object δ_0 of the form

$$\left[\begin{array}{ll} \text{PHON} & \textit{none} \\ \text{SYNSEM|CONT|EP} & \left\langle \left[\text{CONJUNCTS} \quad \langle h_1, \cdots, h_n \rangle \right] \right\rangle \end{array} \right]$$

---

[13] This constraint is consistent with the observation in Neijt (1979, pp. 43–44) and McCawley (1982) that conjuncts cannot be right-node-raised in English, although the proposed grammar does not capture the fact that conjuncts cannot even be phonologically right-node-raised in English.

as well as domain objects $\delta_1, \cdots, \delta_n$, whose LTOP values are $h_1, \cdots, h_n$. Then it is not possible to syntactically left-node-raise or right-node-raise some but not all of the domain objects, $\delta_0, \cdots, \delta_n$.

b. Suppose a given order domain contains a phonological empty domain object δ_0 of the form

$$
\begin{bmatrix}
\text{PHON} & \textit{none} \\
\text{SYNSEM|CONT|EP} & \left\langle \begin{bmatrix} \text{RELN} & \text{identical} \\ \text{ARG1} & x_0 \\ \text{ARG2} & x_1 + \cdots + x_n \end{bmatrix} \right\rangle
\end{bmatrix}
$$

or

$$
\begin{bmatrix}
\text{PHON} & \textit{none} \\
\text{SYNSEM|CONT|EP} & \left\langle \begin{bmatrix} \text{RELN} & \text{identical} \\ \text{ARG1} & x_0 \\ \text{ARG2} & x_1 +_i \cdots +_i x_n \end{bmatrix} \right\rangle
\end{bmatrix}
$$

as well as domain objects $\delta_1, \cdots, \delta_n$, whose INDEX values are $x_1, \cdots, x_n$. Then it is not possible to syntactically left-node-raise or right-node-raise some but not all of the domain objects, $\delta_0, \cdots, \delta_n$.

The constraints given in (34) mean that a domain object created by compacting a conjunct of a coordinate structure X cannot contain a semantic coordinator that comes from an expression that is semantically aligned with X. Since the constraints in (35) prevent domain objects representing a coordinate structure from being split apart from each other by syntactic LNR or RNR, this means, among other things, that a domain object created by compacting a conjunct of a coordinate structure X cannot contain any portion of another coordinate structure that is semantically aligned with X.

Let us see what this annotation mechanism can do in the case of the sentence in (33). One way to generate the VP in this sentence is to follow the three steps shown below. In this illustration, each arrow indicates the process of conjoining two VPs, and expressions that are either left- or right-node-raised are italicized.

1. bought *a car on Thursday* + sold *a car on Thursday*
   → bought and sold *a car on Thursday*

2. bought *a bike on Friday* + sold *a bike on Friday*
   → bought and sold *a bike on Friday*

3. *bought and sold* a car on Thursday + *bought and sold* a bike on Friday
   → *bought and sold* a car on Thursday and a bike on Friday

Suppose that each of the three steps involves syntactic RNR or LNR, and that condition (23b) is invoked in each step. In that scenario, the three instances of VP conjunction can each introduce a domain object whose SYNSEM|CONT|EP|FIRST|RELN value is "and_i" without violating the i-within-i constraint in (34a). Step 3 does not violate the constraint in question because the domain object that is created by compacting the first conjunct in Step 3 contains only elementary predications coming from the string *a car on Thursday*, and the domain object that is created by compacting the second conjunct in that step contains only elementary predications coming from the string *a bike on Friday*. Therefore the grammar can produce the following semantic representation for the sentence, ignoring the contribution of the adverb *respectively*.

(36) $s = \text{Speaker} \land$
      $\text{and}_i(\text{and}_i(\text{a}(w, \text{car}(w), \text{onThu}(\text{bought}(s, w))),$

$$\text{a}(x, \text{car}(x), \text{onThu}(\text{sold}(s, x)))),$$
$$\text{and}_i(\text{a}(y, \text{bike}(y), \text{onFri}(\text{bought}(s, y)))),$$
$$\text{a}(z, \text{bike}(z), \text{onFri}(\text{sold}(s, z))))))$$

We submit that the function of the word *respectively* is to signal the need to invoke this annotation mechanism in interpreting the sentence. On this view, the function of *respectively* is analogous to that of the adjective *proverbial* in a sentence like *John kicked the proverbial bucket*, where the adjective signals the need to interpret the immediately following noun as part of an idiom.

The rewriting mechanism, which is the second component of our account of *respectively* readings, turns a representation like (36) into a semantic representation that expresses the actual truth conditions. The workings of this rewriting mechanism are as follows.

(37)   The rewriting mechanism for *respectively* interpretation:
Suppose (i) the given semantic representation (where all the handle values have been resolved) contains more than one semantic coordinator with the subscript i, and (ii) all those semantic coordinators express predicates or operators that take n arguments. Then select a formula X in the semantic representation that contains all the occurrences of i, and replace X with $\text{and}([\![X]\!]^{(i,1)},$ $\cdots, [\![X]\!]^{(i,n)})$.

The function $[\![\bullet]\!]^{(i,p)}$, whose role is to extract the pth argument of each predicate or operator that has the subscript i and discard the other arguments, is defined as follows.

(38)   a. $[\![\alpha]\!]^{(i,p)} \equiv \alpha$, when α is an atomic symbol.
   b. $[\![\alpha(\beta_1, \cdots, \beta_n)]\!]^{(i,p)} \equiv [\![\alpha]\!]^{(i,p)}([\![\beta_1]\!]^{(i,p)}, \cdots, [\![\beta_n]\!]^{(i,p)})$, when α is a predicate with either no subscript or a subscript other than i and $\beta_1, \cdots, \beta_n$ are its arguments.
   c. $[\![\beta_1 + \cdots + \beta_n]\!]^{(i,p)} \equiv [\![\beta_1]\!]^{(i,p)} + \cdots + [\![\beta_n]\!]^{(i,p)}$
   d. $[\![\beta_1 +_j \cdots +_j \beta_n]\!]^{(i,p)} \equiv [\![\beta_1]\!]^{(i,p)} +_j \cdots +_j [\![\beta_n]\!]^{(i,p)}$, when $i \neq j$.
   e. $[\![\beta_1 \wedge \cdots \wedge \beta_n]\!]^{(i,p)} \equiv [\![\beta_1]\!]^{(i,p)} \wedge \cdots \wedge [\![\beta_n]\!]^{(i,p)}$
   f. $[\![\alpha(\beta_1, \cdots, \beta_n)]\!]^{(i,p)} \equiv [\![\beta_p]\!]^{(i,p)}$, when α is a predicate with the subscript i and $\beta_1, \cdots, \beta_n$ are its arguments.
   g. $[\![\beta_1 +_i \cdots +_i \beta_n]\!]^{(i,p)} \equiv [\![\beta_p]\!]^{(i,p)}$

We assume that this rewriting mechanism has to be applied to a given semantic representation until there remains no subscript in the representation, and that a semantic representation that contains subscripts that cannot be eliminated that way is illicit and is not associated with any truth conditions. We also assume that the representations that we manipulate at this stage are no longer MRS representations and thus are not subject to the variable binding condition, described at the end of subsection 2.2.

Here is what happens when this rewriting mechanism is applied to the representation in (36). The portion of this representation that follows the symbol $\wedge$ (i.e. the portion that starts with the first "and_i") contains all the occurrences of i in the representation. Let us represent that portion as A. Since all the symbols with the subscript i in A are "and_i" that conjoin two conjuncts, A in this representation can be replaced by $\text{and}([\![A]\!]^{(i,1)}, [\![A]\!]^{(i,2)})$, according to (37). The values of $[\![A]\!]^{(i,1)}$ and $[\![A]\!]^{(i,2)}$ are as follows, according to (38).

(39) $[\![A]\!]^{(i,1)} = [\![\text{and}_i(\text{and}_i(\text{a}(w, \text{car}(w), \text{onThu}(\text{bought}(s, w)))),$
$$\text{a}(x, \text{car}(x), \text{onThu}(\text{sold}(s, x))))),$$

$$\text{and}_i(a(y, \text{bike}(y), \text{onFri}(\text{bought}(s, y))),$$
$$a(z, \text{bike}(z), \text{onFri}(\text{sold}(s, z))))))]\!]^{(i,1)}$$
$$= [\![\text{and}_i(a(w, \text{car}(w), \text{onThu}(\text{bought}(s, w))),$$
$$a(x, \text{car}(x), \text{onThu}(\text{sold}(s, x))))]\!]^{(i,1)} \qquad (\because (38f))$$
$$= [\![a(w, \text{car}(w), \text{onThu}(\text{bought}(s, w)))]\!]^{(i,1)} \qquad (\because (38f))$$
$$= a(w, \text{car}(w), \text{onThu}(\text{bought}(s, w)))$$

$$[\![A]\!]^{(i,2)} = [\![\text{and}_i(\text{and}_i(a(w, \text{car}(w), \text{onThu}(\text{bought}(s, w))),$$
$$a(x, \text{car}(x), \text{onThu}(\text{sold}(s, x)))),$$
$$\text{and}_i(a(y, \text{bike}(y), \text{onFri}(\text{bought}(s, y))),$$
$$a(z, \text{bike}(z), \text{onFri}(\text{sold}(s, z))))))]\!]^{(i,2)}$$
$$= [\![\text{and}_i(a(y, \text{bike}(y), \text{onFri}(\text{bought}(s, y))),$$
$$a(z, \text{bike}(z), \text{onFri}(\text{sold}(s, z))))]\!]^{(i,2)} \qquad (\because (38f))$$
$$= [\![a(z, \text{bike}(z), \text{onFri}(\text{sold}(s, z)))]\!]^{(i,2)} \qquad (\because (38f))$$
$$= a(z, \text{bike}(z), \text{onFri}(\text{sold}(s, z)))$$

Thus, one possible interpretation of (33) turns out to be the following, which correctly captures the *respectively* reading of the sentence.

(40) $s = \text{Speaker}$
  $\wedge \text{and}(a(w, \text{car}(w), \text{onThu}(\text{bought}(s, w))), a(z, \text{bike}(z), \text{onFri}(\text{sold}(s, z))))$

As noted in Kubota and Levine (2015), a sentence like the following does not have a *respectively* reading, unlike (33).

(41) I bought and sold a car on Thursday and bought and sold a bike on Friday.

This fact is correctly accounted for by the proposed theory. In order for this sentence to have the same *respectively* reading as (33), the three instances of conjunction in this sentence have to be given the same subscript, but that leads to a violation of the *i*-within-*i* constraint on *respectively* readings, formulated in (34) above. When the two VPs *bought and sold a car on Thursday* and *bought and sold a bike on Friday* in this sentence are conjoined, each conjunct is compacted to become a domain object. The constraint in (34a), in conjunction with (35), means that neither domain object is allowed to contain any part of a coordinate structure that is semantically aligned with the coordinated VP *bought and sold a car on Thursday and bought and sold a bike on Friday*. The two domain objects, however, both contain elementary predications coming from a coordinate structure *bought and sold*, which is semantically aligned with the coordinated VP.

Kubota and Levine (2016) claim that a sentence like (42) indicates that the internal readings of symmetric and summative predicates and *respectively* readings should be handled by the same mechanism in the grammar, as in their theory.

(42) John collected, and Mary got pledges for, a total of $10,000 for charity from his family and her clients, respectively.

Sentences like this, however, do not pose any particular problem for our account, where the two types of readings are handled separately. We will demonstrate this using a syntactically somewhat simpler example in (43).

(43) John stole, and Mary borrowed, similar books from Pete and Sue (respectively).

This sentence can be analyzed as involving constituent coordination of two non-quantificational NPs *Pete* and *Sue* and syntactic right-node raising of *similar books from Pete and Sue* out of conjoined sentences. The DP *similar books* here can be treated the same way that the DP *different things* is treated in the sentence (30). Thus the annotation mechanism can produce a semantic representation like the following for this sentence. (Recall that we are assuming that a non-quantificational NP involving conjunction, such as *Pete and Sue*, is obligatorily preceded by a phonologically empty determiner whose meaning is the same as that of *some*.)

(44) $j = \text{John} \quad \wedge \quad m = \text{Mary} \quad \wedge \quad p = \text{Pete} \quad \wedge \quad s = \text{Sue}$
     $\wedge \quad \text{some}(x + y, \text{similar}(x + y) \wedge \text{books}(x + y),$
           $\text{some}(z, \text{identical}(z, p +_i s), \text{and}_i(\text{stole}(j, x, z), \text{borrowed}(m, y, z))))$

The constraint in (34a) is not violated in producing this representation because the syntactically right-node-raised DP (*Pete and Sue*) escapes compaction and thus does not become part of the domain objects representing the conjuncts when the two sentences are coordinated. The third argument of the first instance of "some" in (44) contains all the occurrences of the subscript i in this representation. Let us call it A. Since in A the subscript i is attached to a predicate and an operator taking two arguments, the rewriting mechanism can replace A with and($[\![A]\!]^{(i,1)}$, $[\![A]\!]^{(i,2)}$). The values of $[\![A]\!]^{(i,1)}$ and $[\![A]\!]^{(i,2)}$ are shown in (45).

(45)   a. $[\![A]\!]^{(i,1)}$
         $= [\![\text{some}(z, \text{identical}(z, p +_i s), \text{and}_i(\text{stole}(j, x, z), \text{borrowed}(m, y, z)))]\!]^{(i,1)}$
         $= \text{some}(z, \text{identical}(z, [\![p +_i s]\!]^{(i,1)}), \text{stole}(j, x, z))$
         $= \text{some}(z, \text{identical}(z, p), \text{stole}(j, x, z))$ (∵ (38g) and (38a))
         $= \text{stole}(j, x, p)$
   b. $[\![A]\!]^{(i,2)}$
         $= [\![\text{some}(z, \text{identical}(z, p +_i s), \text{and}_i(\text{stole}(j, x, z), \text{borrowed}(m, y, z)))]\!]^{(i,2)}$
         $= \text{some}(z, \text{identical}(z, [\![p +_i s]\!]^{(i,2)}), \text{borrowed}(m, y, z))$
         $= \text{some}(z, \text{identical}(z, s), \text{borrowed}(m, y, z))$ (∵ (38g) and (38a))
         $= \text{borrowed}(m, y, s)$

Thus the sentence (43) is associated with (46), which is an adequate representation of its most prominent reading.

(46) $j = \text{John} \quad \wedge \quad m = \text{Mary} \quad \wedge \quad p = \text{Pete} \quad \wedge \quad s = \text{Sue}$
     $\wedge \quad \text{some}(x + y, \text{similar}(x + y) \wedge \text{books}(x + y),$
           $\text{and}(\text{stole}(j, x, p), \text{borrowed}(m, y, s)))$

We conclude that the issue of *respectively* readings does not threaten the viability of the HPSG-based theory of non-constituent coordination that we are advocating.

The theory of *respectively* interpretation that we have presented here is arguably empirically superior to the theory presented in Kubota and Levine (2015) and Kubota and Levine (2016). At the end of section 2, we noted that Kubota and Levine's theory achieves a high level of simplicity by using the same mechanism for dealing with internal readings of symmetric and summative predicates and *respectively* readings. It turns out that this simplicity comes with some empirical inadequacies.

First, unlike the account presented in this section, Kubota and Levine's theory fails to take into account the fact that not just *and* and plural DPs but also *or* can give rise to *respectively* interpretation. Gawron and Kehler (2004) suggest that *or* can yield *respectively* interpretation only when the word expresses conjunction rather than disjunction, but this line of analysis seems implausible, given an example like (47), discussed in Eggert (2000).

(47) If the cup is too small or too large, then you should go up or down, respectively, in cup size.

The word *or* can induce *respectively* interpretation in conjunction with another occurrence of *or* in the same sentence, as in (47), in conjunction with an occurrence of *and* elsewhere in the sentence, as in (48), and in conjunction with an occurrence of a plural DP elsewhere in the sentence, as in (49).

(48) The n and N commands repeat the previous search command in the same or opposite direction, respectively. (discussed in Eggert (2000))

(49) These sentences will be true just in case the set of sneezers (represented either by $\hat{x}[\textbf{sneeze}(x)]$ or by **sneeze**) contains some person, every man, or most babies, respectively. (from Barwise and Cooper (1981))

It may be possible to extend Kubota and Levine's theory of *respectively* readings to cover cases like these as well, but if that is done, then their theory will most likely make the incorrect prediction that *or* can license the internal readings of symmetric and summative predicates too. For instance, it will most likely be predicted that (50) should be able to mean something like "What Grant might drink is different from what Camelia might drink", since the corresponding sentence (51), taken from Eggert (2000), allows *respectively* interpretation.

(50) Grant or Camelia might drink different things.

(51) Grant or Camelia might drink beer or wine respectively.
(as a response to "Will anybody be drinking at the party?")

Secondly, but not unrelatedly, our theory can provide a better characterization of the constraints on *respectively* interpretation, compared to Kubota and Levine's theory. Both their theory and our theory as it has been described so far predict that *respectively* interpretation can be given to any expressions in any positions, but this prediction is incorrect. There are certain restrictions on the availability of *respectively* interpretation. For instance, the sentence in (51) above contrasts with the sentence in (52) below, as noted by Eggert (2000).

(52) *Grant or Camelia drinks beer or wine respectively.

Likewise, the *respectively* interpretation becomes unavailable when *or* is replaced by *and* in (47), as shown below.

(53) *If the cup is too small and too large, then you should go up and down, respectively, in cup size.

In the theory that we have proposed, these contrasts can be explained by making reference to the preliminary interpretations that are assigned to the sentences, that is, the interpretations that are initially computed by the grammar and are given as input to the rewriting mechanism specified in (37). We submit that the following principle constrains the availability of *respectively* interpretation.

(54) When the rewriting mechanism specified in (37) replaces a formula *X* that contains subscript *i* with another formula *Y* that does not contain *i*, there must exist a truth-condition-preserving paraphrase of *X* that satisfies the following conditions.

1. The paraphrase can be obtained by combining the *i*-components of *X* using conjunction and disjunction.

2. Deletion of some of the *i*-components of *X* in the paraphrase yields *Y*.

(55) Suppose that *X* is a formula that contains subscript α. We say that a formula *F* is an α-*component* of *X* if and only if *F* is the result of selecting one arbitrary semantic conjunct of (and deleting all the other conjuncts of) each semantic coordinate structure with the subscript α in *X*.

(For instance, saw(*a*, *c*), saw(*b*, *c*), saw(*a*, *d*), and saw(*b*, *d*) are each an *i*-component of the formula

$$\text{or}_i(\text{saw}(a +_i b, c), \text{saw}(a +_i b, d)),$$

and nothing else is.)

Given this principle, (33) is correctly allowed to have a *respectively* reading. The portion of the preliminary interpretation of (33) that is rewritten by the rewriting mechanism can be paraphrased as follows, combining its *i*-components. We represent the content of the paraphrase in English for the sake of readability.

(56) [I bought a car on Thursday], [I sold a car on Thursday], [I bought a bike on Friday], and [I sold a bike on Friday].

If two of the *i*-components are deleted, the final interpretation of (33) that is produced by the rewriting mechanism will result. Therefore this *respectively* reading is licensed by (54).

The principle in (54) captures the contrast between (47) and (53) as follows. The preliminary interpretation of one possible reading of (47) can be paraphrased by (57), which can be obtained by combining the four *i*-components of the preliminary interpretation using conjunction and disjunction. (Here and below we assume that the coordinate structures that are semantically aligned are all given the subscript *i*.) Again, we express the content of the paraphrase using English.

(57) [[If the cup is too small, then you should go up in cup size], or
    [if the cup is too small, then you should go down in cup size]], and
    [[if the cup is too large, then you should go up in cup size], or
    [if the cup is too large, then you should go down in cup size]].

The final interpretation produced for this sentence by the rewriting mechanism results if two of the *i*-components are deleted in (57), assuming that, for any formula *X*, or(*X*) is equivalent to *X*. Thus, the *respectively* reading of this sentence is correctly licensed by (54). On the other hand, the preliminary interpretation of (53), which says that the addressee should go up and down in cup size when faced with a contradictory situation in which the cup is simultaneously too large and too small, does not have a paraphrase that can be obtained by combining its *i*-components using conjunction and disjunction.

The contrast between (51) and (52) can be understood analogously. The preliminary interpretation of (51) can be paraphrased by the following, using its *i*-components.

(58) [Grant might drink beer], [Grant might drink wine], [Camelia might drink beer], and [Camelia might drink wine].

Deletion of two of the *i*-components leads to the final interpretation produced by the rewriting mechanism. Thus the *respectively* reading is licensed by (54). In contrast, the preliminary interpretation of (52) does not have the type of paraphrase required by (54). The preliminary interpretation in question can be paraphrased by (59), but the *respectively* reading produced by the rewriting mechanism, which says that Grant drinks beer *and* Camelia drinks wine, cannot be obtained by deleting any part of (59).

(59) [Grant drinks beer] or [Grant drinks wine] or [Camelia drinks beer] or [Camelia drinks wine].

Thus, the contrast between sentences that allow *respectively* interpretation and ones that do not is correctly captured by (54). This explanation relies on the existence of what we called preliminary interpretations, and is thus not compatible with theories like those proposed in Gawron and Kehler (2004), Chaves (2012), and Kubota and Levine (2016), in which *respectively* readings are computed directly.

Like the first consideration above, this second consideration is problematic not just for Kubota and Levine's theory of *respectively* readings itself but also for their view that the grammatical mechanism that produces *respectively* readings underlies the internal readings of symmetric and summative predicates. The apparent fact that preliminary interpretations of sentences involving *respectively* interpretation affect the acceptability of the sentences is a strong indication that the mechanism that produces *respectively* readings does not belong to the core part of grammar. If that assessment is correct, then the mechanism that induces *respectively* readings cannot be assumed to underlie other grammatical phenomena unless there is a reason to believe that those phenomena likewise lie outside the core part of grammar.

4   Comparison with Beavers and Sag (2004)

Unlike our theory, the theory proposed in Beavers and Sag (2004) retains the standard view that signs, rather than domain objects, are the principal carriers of semantic information, and it licenses the wide scope reading for a quantifier in a sentence like (27) by allowing what happens in order domains to affect semantic interpretation. The mechanism they add to their theory in order to obtain this outcome is called Optional Quantifier Merger, and is described as in (60).

(60) Optional Quantifier Merger:
For any elided phrase denoting a generalized quantifier in the domain of either conjunct, the semantics of that phrase may optionally be identified with the semantics of its non-elided counterpart.

According to this theory, there are two separate occurrences of the quantifier *no man* in sentence (27), but these two distinct syntactic objects are allowed to share one and the same quantifier meaning, on account of the phonological disappearance of one of them. The sole quantifier meaning necessarily takes wide scope over the entire sentence because otherwise the quantifier would not outscope everything that it is required to outscope in the setting of Minimal Recursion Semantics. In this section, we will argue that this analysis has several shortcomings and that a theory like ours is required to overcome those shortcomings.

First, Optional Quantifier Merger is ad hoc, unlike the account we advocate. The crucial difference between the two theories is that semantic interpretation is carried out in the CONT values of signs in Beavers and Sag's theory whereas it is carried out mostly in the CONT values of domain objects in our theory. In our account, syntactic

LNR and RNR involve fusion of two or more domain objects, and since the meaning of expressions is represented primarily inside domain objects, it is natural for such fusion to have semantic effects. For example, when two domain objects representing the same quantifier meaning are fused with each other, it is natural for the resulting structure to contain only one instance of that quantifier meaning, as in Figure 11 above. In Beavers and Sag's account, LNR and RNR involve manipulation of domain objects, as in ours. In their theory, however, the semantic representations that are relevant for the computation of the meaning of the entire sentence are located *outside* those domain objects. Thus, as Kubota and Levine claim, there is in fact no reason to expect LNR and RNR in Beavers and Sag's account to be able to affect semantic interpretation, even though it is possible to make this theory conform to the facts by adding Optional Quantifier Merger to it.

Another way to say this is the following: Beavers and Sag's account involves subtractive meaning manipulation, as claimed in Kubota and Levine (2015), whereas our account does not. The description in (60), which is a verbatim quotation from Beavers and Sag (2004), is in fact not an accurate description of what Optional Quantifier Merger does. If it were an accurate description, then addition of Optional Quantifier Merger to the grammar would not change what the grammar does at all, since in HPSG any two objects can optionally be identified with each other, unless there is some constraint that prohibits that identification. A more accurate description of Optional Quantifier Merger, which is formulated in (36) of Beavers and Sag (2004), is (61).

(61)   For any elided phrase denoting a generalized quantifier in the domain of either conjunct, the semantics of that phrase may optionally be deleted, if it is identical with the semantics of its non-elided counterpart.

Consequently, Optional Quantifier Merger generates structures that do not obey the otherwise exceptionless Semantic Compositionality Principle (see Sag *et al.* (2003)), according to which the list of elementary predications that represents the meaning of the mother node should be the concatenation of the lists of elementary predications that represent the meaning of the daughter nodes. In contrast, in the account described in section 2 above, there is no such subtractive meaning manipulation; once two or more domain objects representing a quantifier are fused with each other by syntactic LNR or RNR in the default fashion, the wide-scope reading of that quantifier is derived automatically. In our theory, the meaning of successively larger domain objects is always computed in accordance with the definition of compaction given in (7). As specified in the definition, the EP value of a newly created domain object (i.e. the list of elementary predications that represents the meaning of the domain object) is, without exception, a concatenation of the EP values of the domain objects that were in the order domain of the sign whose compaction gave rise to that domain object. Computation of the H-CONS value and the H-STORE value likewise never involves any subtractive meaning manipulation. Thus, there is a sense in which LNR and RNR can be viewed as a normal part of the grammar in our account but not in Beavers and Sag's account.

It might seem possible to improve Beavers and Sag's theory by representing the meaning of each sign with a *set* of elementary predications rather than a *list* of elementary predications, but such a modification will create a new problem for the theory. If the meaning of each sign is represented with a set of elementary predications, then it does become unnecessary to employ subtractive meaning manipulation, because in such a system, the number of elementary predications contained in a semantic representation will automatically decrease whenever some of them are equated with each

other. However, such a system will predict incorrectly that a sentence like (1b) can express the same meaning as a sentence like (1a), since two elementary predications can optionally be equated with each other, irrespective of whether the expressions that are associated with them are pronounced as separate expressions (as in (1b)) or fused into one by LNR or RNR (as in (1a)).

The second problem with Beavers and Sag's theory is that it fails to capture the correlation between interpretation and intonation. A left-node-raised expression can be pronounced as a normal part of the initial conjunct (or, more generally, the leftmost of the phrases that share the expression) or as a separate intonational unit, and a right-node-raised expression can likewise be pronounced as a normal part of the final conjunct (or, more generally, the rightmost of the phrases that share the expression) or as a separate intonational unit. However, when a left-node-raised or right-node-raised expression is a quantifier that takes wide scope over the phrases out of which it has been left-node-raised or right-node-raised, it has to be pronounced as a separate intonational unit, not as a normal part of the first or the last of the phrases that share the expression.

We illustrate this point using a Japanese example in (62).

(62) Keito wa Furansu, Biru wa Doitsu   e [sanjû-nin no gakusei o]
      Kate TOP France   Bill TOP Germany to [30 people GEN student ACC]
      tsureteitta.
      took
      'Kate took to France and Bill took to Germany 30 students.'

This sentence is ambiguous, and can mean both "Kate took 30 students to France and Bill took 30 students to Germany" and "There were 30 students such that Kate took some of them to France and Bill took the rest to Germany". The grammatical object takes scope over the coordinate structure in the second reading but not in the first. When the sentence is pronounced with the first reading in mind, the grammatical object *sanjû-nin no gakusei o* may or may not be downstepped; it may be pronounced at the same pitch as the immediately preceding expression, but it may also be pronounced at a higher pitch than the immediately preceding expression. When the sentence is pronounced with the second reading in mind, however, the grammatical object cannot be downstepped; at least a part of it has to be pronounced at a higher pitch than the immediately preceding expression (namely the postposition *e*). This means that in the latter case, where the quantifier takes wide scope, there has to be a major-phrase boundary between the quantifier and the immediately preceding expression (see Kubozono (1993)).

In order to capture a correlation like this between interpretation and intonation in Beavers and Sag's theory, it would be necessary to add one more ad-hoc machinery to the grammar. The machinery involved is bound to be ad hoc because in this theory there is no reason why intonation and interpretation have to affect each other, although it is possible to stipulate (as Optional Quantifier Merger does) that something should happen to one when something happens to the other.

In contrast, in the theory described in section 2, all this is expected. A quantifier can take scope over the coordinate structure out of which it has been left- or right-node-raised only if it has been syntactically (as opposed to phonologically) left- or right-node-raised. When something is syntactically left- or right-node-raised out of a coordinate structure and escapes compaction at that stage, it has to be pronounced as a prosodic constituent separate from the conjuncts out of which it has been left- or right-node raised, since domain objects are, by hypothesis, representations of prosodic

constituents. Thus, it is correctly predicted that the wide scope of a quantifier in a sentence like (62) requires the presence of a prosodic boundary.

The third problem with Beavers and Sag's theory is that it makes it difficult to formulate a reasonable account of *respectively* readings. More specifically, their theory makes it difficult to understand the contrast between (33) and (41), pointed out by Kubota and Levine. In our theory, this contrast is captured by the *i*-within-*i* constraint on *respectively* readings, given in (34), as noted in the previous section. In Beavers and Sag's theory, on the other hand, there does not appear to be a simple way to capture the contrast, because in their theory sentence (33) has the same syntactic structure as sentence (41), except that prosodic ellipsis has applied in the former but not in the latter. We concur with Kubota and Levine that this is another indication that RNR and LNR are not to be viewed as mere prosodic ellipsis.

5 Problems with Kubota and Levine's theory of non-constituent coordination

Now we will argue that there are several empirical problems with Kubota and Levine's theory of non-constituent coordination, apart from those issues with their account of *respectively* interpretation that were discussed in section 3 above. We will first show in subsection 5.1 that there are instances of RNR and LNR that can only be analyzed as cases of ellipsis. Then in subsection 5.2 we will make our case that it is not possible to remedy this problem by simply adding to Kubota and Levine's theory a mechanism for ellipsis.

5.1 Instances of RNR and LNR that can only be analyzed as cases of ellipsis

We take it that Kubota and Levine (2015) are advocating the view that ellipsis is not involved in any kind of non-constituent coordination, since they consistently compare what they call the ellipsis-based approach with what they call the direct coordination approach, arguing for the latter and titling their article "Against Ellipsis". This view of non-constituent coordination is untenable; there are reasons to believe that at least some cases of non-constituent coordination involve ellipsis.

First, as shown in Abeillé and Mouret (2011) and Abeillé and Shiraishi (2016), there are acceptable instances of right-node raising in which the right-node-raised expression has a form that is appropriate for the second, final conjunct but not for the first conjunct. (63) is one such example.

(63)   Ce parti ne parvient pas, voire ne souhaite pas, surmonter les contradictions idéologiques qui entravent son action et rendent ses choix confus.
(Cf. Ce parti ne parvient pas *[surmonter ses contradictions idéologiques] / [à surmonter ses contradictions idéologiques].)
(from Abeillé and Mouret (2011))

In an HPSG-based theory, an example like this can be generated if one type of right-node raising is assumed to be prosodic ellipsis (like what is called phonological RNR in our theory) that disregards minor differences in pronunciation between two occurrences of the expression that is to be right-node-raised; one concrete instantiation of this type of theory is proposed in Abeillé and Shiraishi (2016). CG-based theories, on the other hand, seem incapable of generating such examples in a principled way.

Second, there are instances of RNR and LNR in which the right-node-raised or left-node-raised expression is pronounced at a location other than the right or left edge of the coordinate structure involved. (64) is one such example involving RNR. The phenomenon exemplified by this example, which we call medial RNR, has been discussed in the context of CG in works such as Whitman (2009), Kubota (2014), and Warstadt (2015), but it can be shown that this particular example is problematic for all these CG-based theories.

(64)   Are you talking about a new or that ex-boyfriend you used to date?
(from Chaves (2014))

In (64), the right-node-raised expression *boyfriend* is pronounced at a medial position within the second conjunct, rather than at its right edge. Appendix C presents the result of a small questionnaire study concerning the acceptability of this example, which showed that it is acceptable if not perfect. Since the slight awkwardness of the sentence can plausibly be ascribed to the degraded parallelism between conjuncts that always accompanies medial RNR, we regard the sentence as grammatical.

If we are to apply one of the CG-based theories to this example, we need to view the prepositional object in this example (viz. *a new or that ex-boyfriend you used to date*) as the result of combining a coordinate structure of the form *a new or that ex- you used to date* with a noun *boyfriend* and then phonologically infixing the latter into the former. As noted in Yatabe (2015), such an analysis requires the assumption that a sequence of prenominal modifiers like *that ex-* and a postnominal modifier like *you used to date* can form a constituent in English, and once we make such an assumption, it is no longer obvious how we can rule out an ill-formed phrase like (65), which the theory predicts could be generated by combining [*a new* [*who you're dating now*]] *or* [*that ex-* [*you used to date*]] and *boyfriend* and then phonologically infixing the latter into the former.

(65)   *a new [who you're dating now] or that ex-boyfriend [you used to date]

Thus, an example like (64) appears to be a genuine problem for what Kubota and Levine call the direct coordination approach. Yatabe (2016) notes the existence of similarly problematic examples involving LNR.

The partially ellipsis-based theory like ours, on the other hand, has no problem explaining why (64) is possible while (65) is not. (65) is illicit because it violates the constraint stated in (84a), which says that the order of strings can never be reversed once it is fixed inside some order domain. (65) is the result of conjoining (66) and (67) and right-node-raising the noun *boyfriend*.

(66)   a new boyfriend who you're dating now

(67)   that ex-boyfriend you used to date

In the order domain of the first conjunct, the string *boyfriend* precedes the string *who you're dating now*. However, in the order domain of the coordinate structure as a whole, the string *boyfriend* follows the string *who you're dating now*, thus violating the constraint in question. In contrast, (64) is licit because it does not violate this or any other constraint in the grammar. (64) is the result of combining (68) and (69) and right-node-raising *boyfriend*.

(68)   a new boyfriend

(69)   that ex-boyfriend you used to date

The string *a new* precedes the string *boyfriend* throughout, that is, both in the order domain of the first conjunct and in the order domain of the coordinate structure as a whole. Similarly, *that ex-* precedes *boyfriend*, and *boyfriend* precedes *you used to date* throughout, that is, both in the order domain of the second conjunct and in the order domain of the coordinate structure as a whole. Thus, there are no two strings whose order is reversed in violation of the constraint in (84a).

These considerations indicate that, at the very least, Kubota and Levine's theory of LNR and RNR needs to be supplemented with a separate mechanism for ellipsis.

5.2 Summative agreement

The fact that a given theory needs to be supplemented by some additional machinery does not necessarily mean that the theory is incorrect; it only means that it is incomplete. In the case of the CG-based theory of non-constituent coordination, however, there is a reason to believe that the theory is not just incomplete but incorrect. The theory is arguably incapable of capturing a pattern of grammatical agreement that we will refer to as summative agreement, even when it is supplemented with additional mechanisms such as prosodic ellipsis. Summative agreement is a pattern of agreement in which a predicate that has two or more subjects (or objects in the case of languages like Basque that have object-verb agreement) as a result of having been right- or left-node-raised out of two or more clauses fails to agree with any of those subjects (or objects) and instead appears to agree with a nonexistent DP (or NP) that would be formed by conjoining all those subjects (or objects, respectively). The sentence in (70), discussed in section 2, exemplifies the phenomenon in question.

(70)   The pilot claimed that the first nurse, and the sailor proved that the second nurse, were spies.

In this sentence, the right-node-raised VP *were spies* has the form that it takes when it agrees with a plural subject DP, despite the fact that the VP takes a singular subject both in the first conjunct and in the second.

The availability of summative agreement is affected by the type of coordinator involved, as shown by (71), and by the kinds of subject DPs involved, as shown by (72) and (73). (See Yatabe (2003) for questionnaire results that support the factual claims being made here.)

(71) ??The pilot claimed that the first nurse, or the sailor proved that the second nurse, were spies.

(72)   The pilot claimed that the nurse from the United States, and the sailor also claimed that the nurse from the United States, $\left\{ \begin{array}{l} \text{?*were spies.} \\ \text{was a spy.} \end{array} \right\}$

(73)   The pilot claimed that the nurse from the United States, and the sailor claimed that no one, $\left\{ \begin{array}{l} \text{?*were spies.} \\ \text{was a spy.} \end{array} \right\}$

Intuitively, the verb *were* is agreeing, or is failing to agree, with a nonexistent DP of the form *the first nurse and the second nurse* in (70), *the first nurse or the second nurse* in (71), *the nurse from the United States and the nurse from the United States* in (72), and *the nurse from the United States and no one* in (73).

Examples involving summative agreement cannot be viewed as results of simple prosodic ellipsis, and at the same time, they do not seem to be amenable to a CG-based

account either. The contrast between (70) and (71) can be captured by somehow stipulating that summative agreement is licensed by conjunction but not by disjunction. However, the contrast between (70) on the one hand and (72) and (73) on the other is problematic. When sentences like (70), (72), and (73) are analyzed in a CG-based theory, information about the semantic content of each subject DP in the embedded clauses becomes unavailable before coordination takes place. In each of these three sentences, the expressions that are conjoined would belong to a syntactic category like S/VP$_{sing}$, where VP$_{sing}$ is the category for those VPs that take singular subject DPs. There is nothing in this category that indicates anything about the semantic content of the subject DPs in the embedded clauses, over and above the fact that those DPs must mean something that can be denoted by grammatically singular DPs. Thus, in this line of analysis, there is no grammatical reason to expect there to be any difference between (70) on one hand and (72) and (73) on the other.

It might seem that a purely semantic theory of subject-verb agreement would make it unnecessary to say anything special about summative agreement and thus make it possible to maintain a CG-based theory of non-constituent coordination. More specifically, it might seem possible to capture the observed patterns of summative agreement as well as non-summative agreement by saying that the plural form of a verb phrase is used if and only if that verb phrase is predicated of two or more objects. For instance, the example in (70) states that there are *two* people who were either claimed or proven to be spies, and this semantic fact could be taken to be the reason why the verb appears in the plural form. If such a semantic account turns out to be appropriate in all cases, then it will not even be necessary to distinguish summative agreement from non-summative agreement.

This line of analysis is ultimately not tenable, however. For one thing, the semantic representation for the sentence in (70) must mean "The pilot claimed that the first nurse was a spy, and the sailor proved that the second nurse was a spy". Nowhere in such a representation will the VP meaning be predicated of a plural entity. Furthermore, subject-verb agreement in English cannot be regarded as a purely semantic phenomenon. This can be seen from the following examples, the first three of which are taken from Morgan (1984).

(74)   a.   More than one student has passed the exam.

b.   No student $\left\{ \begin{array}{c} \text{has} \\ \text{*have} \end{array} \right\}$ failed the exam.

c.   No students $\left\{ \begin{array}{c} \text{*has} \\ \text{have} \end{array} \right\}$ failed the exam.

d.   Alex and Chris swim and run, respectively.

In (74a), the singular form of the verb is used despite the fact that the sentence claims that the number of students who have passed the exam is two or more. (74b) and (74c) both claim that the number of students who have failed the exam is zero, but the singular form of the verb is used in (74b) and the plural form is used in (74c). And in (74d), the two verbs are each predicated of a single individual, although they both are in the plural form.

It is claimed in Beavers and Sag (2004) that summative agreement is a result of some kind of performance error. This view would also make it possible to maintain the CG-based theory of LNR and RNR, but there are two reasons to reject such an analysis. First, as noted in Yatabe (2007), this type of analysis predicts that summative agreement must always be optional, and this prediction turns out not to be entirely correct. According to Kazenin (2002), summative agreement is obligatory in Russian.

This is illustrated by the contrast between (75) and (76), both taken from Kazenin (2002).

(75) Zavtra   poedut: Kolja v Moskvu, a Vasja v Peterburg.
      tomorrow will.go.PL Kolja to Moscow but Vasja to StPetersburg
      'Tomorrow Kolja will go to Moscow, but Vasja to StPetersburg.'

(76) *Zavtra   poedet: Kolja v Moskvu, a Vasja v Peterburg.
      tomorrow will.go.SG Kolja to Moscow but Vasja to StPetersburg
      'Tomorrow Kolja will go to Moscow, but Vasja to StPetersburg.'

In both sentences, the verb is left-node-raised out of two clauses, and takes a singular subject in each conjunct. The sentence is acceptable when the verb is in the plural but not when it is in the singular. Second, it has been noted by Grosz (2015) that summative agreement is allowed in some languages but banned in others. This also suggests that summative agreement is a matter of competence grammar.

Another theory that would make it possible to maintain the CG-based theory is provided by Chaves (2014). According to Chaves's theory, when eventuality-denoting expressions like VPs are right-node-raised, the surface form of those right-node-raised expressions could be different from the pre-RNR forms of those expressions, as long as (i) the eventuality denoted by the surface form is the sum of the eventualities denoted by the pre-RNR forms and (ii) the surface form expresses everything expressed by the pre-RNR forms and, possibly, some additional information supplied by the context. For instance, in this theory, RNR of the VP *has problems* out of two clauses could result in a surface form exhibiting summative agreement, as shown in (77).

(77) I think that Robert has problems and you think that Bill has problems.
      ↓
      I think that Robert and you think that Bill have similar problems.

This RNR is allowed in the theory because (i) the surface form of the right-node-raised VP *have similar problems* could be taken to denote the sum of the eventualities denoted by the two pre-RNR forms (namely the two occurrences of *has problems*) and (ii) the surface form expresses everything the two pre-RNR forms express as well as the additional information (supplied by the context) that Robert's problem and Bill's problem are similar.

This analysis of summative agreement is arguably not adequate either, however. First of all, this analysis is as ad hoc as Beavers and Sag's theory, discussed in section 4. It is not clear why the kind of transfiguration of a VP is licensed just when another VP with the same PHON value undergoes prosodic ellipsis elsewhere in the sentence. Moreover, Chaves's analysis overgenerates. There is nothing in the theory that prevents RNR from deriving a sentence like (78) from the pre-RNR form shown at the top of (77) above.

(78) *I think that Robert and you think that Bill they have problems.

We could rule out (78) by augmenting Chaves's theory with a constraint that says that the surface form of right-node-raised VPs must be a VP. The augmented version of the theory, however, still does not prevent RNR from deriving a sentence like (79) from the pre-RNR form shown in (80). Note that the surface VP in (79), namely *was seen by Robert and Bill*, can mean the sum of the eventualities denoted by the two occurrences of *saw her* in (80), which express the eventuality of Robert seeing her and the eventuality of Bill seeing her respectively, provided that the unexpressed

grammatical subject of the surface VP is interpreted as referring to the same individual as the pronoun *her*. Note also that, given that interpretation of the unexpressed subject, the surface VP *was seen by Robert and Bill* expresses everything expressed by the pre-RNR forms, namely the two occurrences of *saw her*; the pre-RNR forms express "x (= Robert) saw z (=her)" and "y (= Bill) saw z (= her)", and the surface form expresses "z (=her) was seen by x (= Robert) and y (=Bill)". The fact that the subject of the surface VP needs to be interpreted as different from either of the subjects of the two pre-RNR forms should not be a problem because the same is true in the case of (77).

(79) *I think that Robert and you think that Bill was seen by Robert and Bill.
       (The intended meaning: "I think that she was seen by Robert, and you think
       that she was seen by Bill.")

(80)   I think that Robert saw her and you think that Bill saw her.

We tentatively conclude that there is no easily conceivable analysis of summative agreement that is compatible with the CG-based theory of non-constituent coordination. In our view, this is a major embarrassment for the theory since summative agreement is a widely attested phenomenon, having been shown to exist in Western Armenian (Grosz (2015)), Basque (McCawley (1988, p. 533), citing Rudolf de Rijk), Dargwa (Kazenin (2002)), English (McCawley (1988, p. 532); Postal (1998, p. 173); Levine (2001)), French (Mouret (2006)), German (Schwabe (2001); Schwabe and von Heusinger (2001)),[14] Standard Gujarati (Grosz (2015)), Hebrew (Grosz (2015)), Italian (Grosz (2015)), and Russian (Kazenin (2002)).

Unlike the CG-based account, the HPSG-based theory of RNR and LNR provides a simple way to characterize the phenomenon of summative agreement. This has been shown in Yatabe (2003). In the theory proposed in that work, when two or more domain objects representing predicates are syntactically left- or right-node-raised together and thus fused together, information as to which *synsem* objects the predicates have combined with in each conjunct (or, more generally, each phrase that shares the left- or right-node-raised predicate) is collected and stored in the VALENCE values of the newly created domain object, so to speak. This process, which produces what might be called phantom coordinate structures inside the VALENCE lists of domain objects, is illustrated in (81). Here SYNSEM and VALENCE are abbreviated as ss and VL respectively. (The definitions of functions and relations that are needed to implement the proposed analysis are given in Yatabe (2003).)

(81)
$$
\begin{bmatrix} \textit{dom-obj} \\ \text{SS|CAT|VL} \begin{bmatrix} \text{SUBJ} & \langle \boxed{1}\,NP_i \rangle \\ \text{COMPS} & \langle \boxed{2}\,NP_j \rangle \end{bmatrix} \end{bmatrix}
+
\begin{bmatrix} \textit{dom-obj} \\ \text{SS|CAT|VL} \begin{bmatrix} \text{SUBJ} & \langle \boxed{1}\,NP_i \rangle \\ \text{COMPS} & \langle \boxed{3}\,NP_k \rangle \end{bmatrix} \end{bmatrix}
$$

$$
\longrightarrow
\begin{bmatrix} \textit{dom-obj} \\ \text{SS|CAT|VL} \begin{bmatrix} \text{SUBJ} & \langle \boxed{1}\,NP_i \rangle \\ \text{COMPS} & \left\langle \begin{bmatrix} \text{CONJ} & \text{and} \\ \text{ARGS} & \langle \boxed{2}\,NP_j,\ \boxed{3}\,NP_k \rangle \end{bmatrix} \right\rangle \end{bmatrix} \end{bmatrix}
$$

Depicted in the first line of (81) are two domain objects that are to be fused together by LNR or RNR, and what is shown in the second line is the result of the fusion. It is assumed here that the coordinator involved is *and*. In this example, the two domain objects that are to be fused together have identical SUBJ lists, although they have non-identical COMPS lists. In this case, as shown in the second line, the SUBJ list

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[14]It has been noted in Grosz (2015) that speakers of Northern German do not allow for summative agreement, as opposed to speakers of Southern dialects.
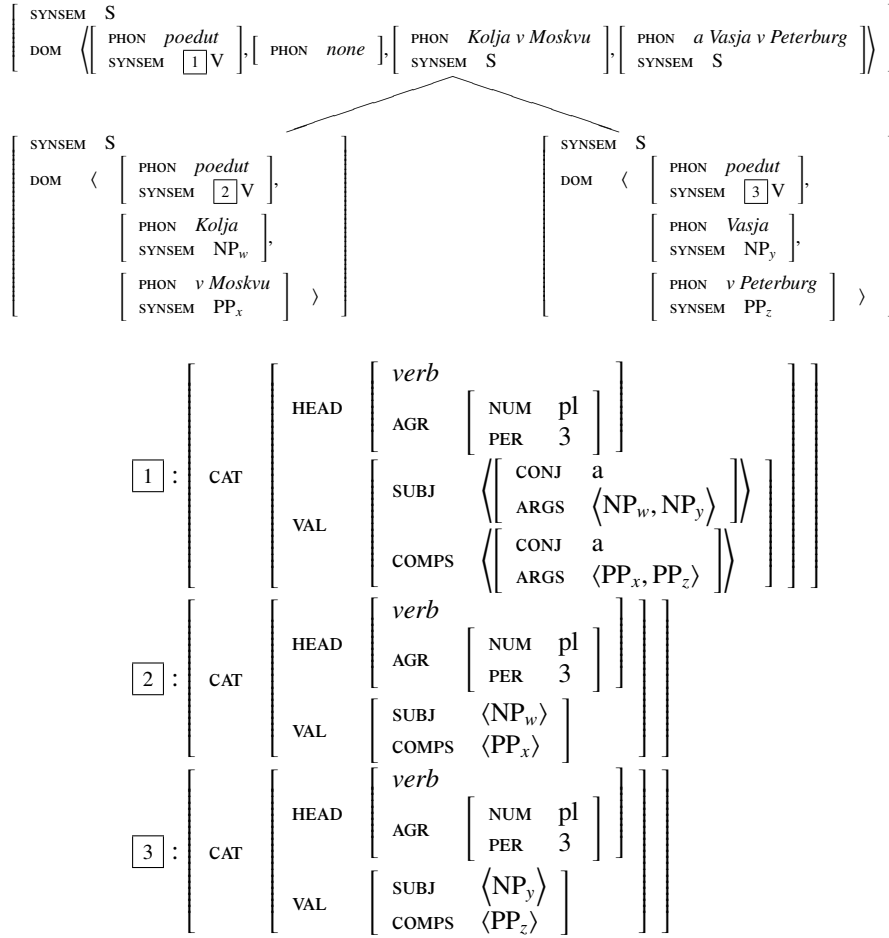
$$
\begin{bmatrix}
\text{SYNSEM} & S \\
\text{DOM} & \left\langle \begin{bmatrix} \text{PHON} & \textit{poedut} \\ \text{SYNSEM} & \boxed{1}\,V \end{bmatrix},\ \begin{bmatrix} \text{PHON} & \textit{none} \end{bmatrix},\ \begin{bmatrix} \text{PHON} & \textit{Kolja v Moskvu} \\ \text{SYNSEM} & S \end{bmatrix},\ \begin{bmatrix} \text{PHON} & \textit{a Vasja v Peterburg} \\ \text{SYNSEM} & S \end{bmatrix} \right\rangle
\end{bmatrix}
$$

$$
\begin{bmatrix}
\text{SYNSEM} & S \\
\text{DOM} & \left\langle \begin{bmatrix} \text{PHON} & \textit{poedut} \\ \text{SYNSEM} & \boxed{2}\,V \end{bmatrix},\ \begin{bmatrix} \text{PHON} & \textit{Kolja} \\ \text{SYNSEM} & NP_w \end{bmatrix},\ \begin{bmatrix} \text{PHON} & \textit{v Moskvu} \\ \text{SYNSEM} & PP_x \end{bmatrix} \right\rangle
\end{bmatrix}
\qquad
\begin{bmatrix}
\text{SYNSEM} & S \\
\text{DOM} & \left\langle \begin{bmatrix} \text{PHON} & \textit{poedut} \\ \text{SYNSEM} & \boxed{3}\,V \end{bmatrix},\ \begin{bmatrix} \text{PHON} & \textit{Vasja} \\ \text{SYNSEM} & NP_y \end{bmatrix},\ \begin{bmatrix} \text{PHON} & \textit{v Peterburg} \\ \text{SYNSEM} & PP_z \end{bmatrix} \right\rangle
\end{bmatrix}
$$

$$
\boxed{1}: \begin{bmatrix}
\text{CAT} & \begin{bmatrix}
\text{HEAD} & \begin{bmatrix} \textit{verb} \\ \text{AGR} & \begin{bmatrix} \text{NUM} & \text{pl} \\ \text{PER} & 3 \end{bmatrix} \end{bmatrix} \\
\text{VAL} & \begin{bmatrix}
\text{SUBJ} & \left\langle \begin{bmatrix} \text{CONJ} & a \\ \text{ARGS} & \langle NP_w, NP_y \rangle \end{bmatrix} \right\rangle \\
\text{COMPS} & \left\langle \begin{bmatrix} \text{CONJ} & a \\ \text{ARGS} & \langle PP_x, PP_z \rangle \end{bmatrix} \right\rangle
\end{bmatrix}
\end{bmatrix}
\end{bmatrix}
$$

$$
\boxed{2}: \begin{bmatrix}
\text{CAT} & \begin{bmatrix}
\text{HEAD} & \begin{bmatrix} \textit{verb} \\ \text{AGR} & \begin{bmatrix} \text{NUM} & \text{pl} \\ \text{PER} & 3 \end{bmatrix} \end{bmatrix} \\
\text{VAL} & \begin{bmatrix}
\text{SUBJ} & \langle NP_w \rangle \\
\text{COMPS} & \langle PP_x \rangle
\end{bmatrix}
\end{bmatrix}
\end{bmatrix}
$$

$$
\boxed{3}: \begin{bmatrix}
\text{CAT} & \begin{bmatrix}
\text{HEAD} & \begin{bmatrix} \textit{verb} \\ \text{AGR} & \begin{bmatrix} \text{NUM} & \text{pl} \\ \text{PER} & 3 \end{bmatrix} \end{bmatrix} \\
\text{VAL} & \begin{bmatrix}
\text{SUBJ} & \langle NP_y \rangle \\
\text{COMPS} & \langle PP_z \rangle
\end{bmatrix}
\end{bmatrix}
\end{bmatrix}
$$

Figure 19: Part of the structure assigned to the Russian sentence in (75)

of the resultant domain object will be identical to the SUBJ list of each of the two input domain objects, and the COMPS list of the resultant domain object will consist of a phantom coordinate structure in which the sole element of the COMPS list of the first input domain object and the sole element of the COMPS list of the second input domain object appear to have been coordinated by *and*.[15]

Using this mechanism that creates phantom coordinate structures inside VALENCE lists, the grammar generates a structure like Figure 19, which shows part of the structure assigned to the Russian sentence in (75).[16] Shown here is the local subtree in which two Ss are conjoined to become a larger S, and in which the verb is syntactically left-node-raised. (The sentence-initial adverbial can be regarded as part of the left-node-raised string, but here we are assuming that the adverbial is outside the coordinate structure.) Left-node raising has fused two domain objects, viz. the first domain object in the order domain of the first daughter and the first domain object in the order domain of the second daughter, and the result of that fusion is the first domain object in the order domain of the mother. As a result of this left-node raising, information

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[15]The SYNSEM|CONT value of the resultant domain object will be determined according to the constraint in (23b), since the other two constraints cannot be satisfied in this case.

[16]We assume that the grammatical subjects in this sentence are NPs rather than DPs.

as to the arguments that the verb has combined with in each conjunct has been collected and stored in the VALENCE lists of the first domain object in the order domain of the mother. The SUBJ list of ① shows that this verb takes as its subject an NP whose index is *w* in the first conjunct and an NP whose index is *y* in the second conjunct, and the COMPS list shows that this verb takes as its complement a PP whose index is *x* in the first conjunct and a PP whose index is *z* in the second conjunct. In addition, ① contains information as to the coordinator that was used to join the first clause and the second clause; in this case, the SUBJ list and the COMPS list of ① both indicate that the two clauses were joined together by the coordinator *a* 'but'.

In this theory, verbs are given a HEAD feature called AGR, as in Kathol (1999), and subject-verb agreement in languages like English and Russian is encoded as a non-lexical constraint that is imposed on the relation between the AGR value of a domain object representing a verb and the content of its SUBJ list. (Here we disregard object-verb agreement and focus on subject-verb agreement.) The constraint in question has to be a non-lexical one since it should be invoked only after the sole element in the SUBJ list of a verb takes its final form, one that will not be replaced by a new phantom coordinate structure. The principle stated in (82) is that non-lexical constraint.

(82)   When (i) a domain object δ with a non-empty SUBJ list undergoes compaction, and (ii) the SUBJ list of the domain object newly created by the compaction is not identical to the SUBJ list of δ, the *subj_verb_agreement* relation must hold between the SYNSEM|CAT|HEAD|AGR value of δ and the sole element in the SUBJ list of δ.

This can be informally paraphrased as in (83).

(83)   Agreement between the SYNSEM|CAT|HEAD|AGR value of a domain object and the sole element in the SUBJ list of that domain object is enforced at the point (in a bottom-up tree construction) where the SUBJ list of the domain object either is emptied or disappears altogether.

The *subj_verb_agreement* relation, which is mentioned in (82), is defined for each language. The version for English is presented in Yatabe (2003), and is partially reproduced in Appendix D below. Given this setup, summative agreement will be licensed whenever the *subj_verb_agreement* relation in a given language allows a situation in which (i) the AGR value of a verb is that which is associated with canonical plural agreement and (ii) the SUBJ list of the verb contains a phantom coordinate structure of some sort.

Let us describe in informal terms what this theory claims is taking place in the example illustrated in Figure 19. In this example, the verb *poedut* is not required to agree with the subject NP of the first conjunct or that of the second conjunct because the SUBJ list of the domain object representing this verb is not emptied or made to disappear while we are constructing this coordinate structure; note that the SUBJ list of the verb still has one element in it at the top node in the figure. This top node is required to undergo total compaction so that the meaning of the matrix clause can be computed (see subsection 2.3), and the SUBJ list of the domain object representing the verb *poedut* is emptied when this compaction takes place; the domain object created by the compaction will have an empty SUBJ list because the sign associated with the top node has an empty SUBJ list. Thus, the compaction of the top node is licensed by the constraint in (82) only if the SYNSEM|CAT|HEAD|AGR value of the domain object representing the verb *poedut* in the order domain of the top node is in the *subj_verb_agreement* relation with the sole element in the SUBJ list of that domain object, which is a phantom

coordinate structure consisting of the two subject NPs. To recapitulate, the verb is required to agree with the sole element in its SUBJ list when the top node in the figure undergoes total compaction, but not at earlier stages, and since the sole element in the SUBJ list is a phantom coordinate structure involving the coordinator *a* 'but' at that point, the verb exhibits summative agreement.

One reason why this account of summative agreement can be formulated the way it is here is that HPSG is a constraint-based framework in which information as to the arguments of a predicate is represented inside (the VALENCE lists of) the predicate itself. As far as we can see, this account therefore cannot be transplanted into a CG-based theory, where information as to the content of the arguments is not represented inside predicates.

6 Conclusion

We have shown that Kubota and Levine's characterization of the HPSG-based theory of non-constituent coordination proposed in Yatabe (2001) and later works is inaccurate, and that the theory in question is consistent with the long-known fact that right-node raising and left-node raising can affect semantic interpretation. In the course of demonstrating this, we have filled in some details of this HPSG-based theory that were left unspecified in the previous literature, and we have also corrected some minor errors in that literature. Next, we formulated an analysis of *respectively* interpretation that is compatible with this theory of non-constituent coordination, in order to ensure that our theory has the same empirical coverage that Kubota and Levine's theory does. We noted that Kubota and Levine's theory of *respectively* interpretation has some empirical inadequacies and that their account of the internal readings of symmetric and summative predicates is invalidated by those inadequacies. We then compared our theory with another HPSG-based theory proposed by Beavers and Sag, and argued that, unlike our theory, their theory does suffer from the kinds of problems that Kubota and Levine have pointed out. Finally, we showed that, pace Kubota and Levine, there are instances of LNR and RNR that can only be analyzed as cases of ellipsis, and argued that the phenomenon of summative agreement poses a problem for CG-based theories of LNR and RNR even if they are supplemented with a mechanism for ellipsis.

Although what we have done in this article is to argue for an HPSG-based account of non-constituent coordination while arguing against CG-based accounts, it should be noted that the theory we have proposed shares an important feature with some CG-based theories of syntax and semantics. Like the theory that has been developed by Steedman and others within the framework of Combinatory Categorial Grammar, our theory embodies the view that semantic composition is performed on the basis of structures that are regarded as the prosodic structures of sentences in most standard theories of syntax. We noted in section 2 that our theory is in a sense an attempt to incorporate this insight into the HPSG framework.

The view that semantic composition is performed on the basis of prosodic structures is supported not just by facts involving non-constituent coordination but also by the fact that semantic interpretation can be affected by prosodic phrasing. For instance, Kayne (1998) notes that, in SVO sentences in English, "the wide-scope reading for the object tends to be associated with an intonation pattern reminiscent of that of Heavy-NP Shift…This supports the idea that wide scope for the object in such sentences depends on (a particular combination of) overt movements…— if it were just a question of covert movement (whether of a phrase or of a feature), no effect at all on intonation would be expected." Our theory may make it possible to explain a fact like

this without adopting the arguably questionable hypothesis that quantifiers in English undergo overt movement which somehow never affects the surface word order. This prospect is still speculative at the moment, but seems to us to merit further inquiry.

Appendix

A The relation between syntactic trees and order domains

We assume that the correspondence between syntactic phrase-structure trees and order domains is subject to the following constraints.

(84) Principles governing the order of domain objects:

    a. If a string *s* precedes another string *t* in the order domain of a sign that is not the top node, *s* must precede *t* in the order domain of the mother of that sign as well.
    (Here we are using the term *string* to refer to the PHON value or a part of the PHON value of a domain object.)

    b. Suppose that signs *B* and *C* are both daughters of a sign *A*, and that *B* precedes *C*. Then, in the order domain of *A*, non-extraposable domain objects that come from *B* but not from *C* must each precede all the non-extraposable domain objects that come from *C* but not from *B*.
    (Here, we say that a domain object *x* contained in the order domain of a sign *comes from* a daughter *y* of that sign if and only if either (i) *x* is also contained in the order domain of *y* or (ii) *x* is a domain object that is newly created by compacting *y*. And we say that a domain object is *non-extraposable* if its SYNSEM|CAT|EXTRAPOSITION value is −.)

To simplify slightly, (84a) says that the order of strings cannot be reversed once it is fixed in some order domain, and (84b) says that, apart from the effects of extraposition, the order of strings in an order domain reflects the order of those strings in the phrase-structure tree. (84a) is a slightly generalized version of what is called the Persistence Constraint in Kathol (1995).

B Quantifier storage

We employ two features, the QUANTIFIERS feature and the TO-BE-STORED feature, to place the handle of each quantifier into the quantifier storage at an appropriate location. The value of the QUANTIFIERS feature on a sign is the set consisting of the handles representing all the quantifiers contained in that sign that have yet to be put in the quantifier storage. The value of the TO-BE-STORED feature on a sign is the set consisting of the handles representing all the quantifiers that are to be put into storage at that node. (See how the TO-BE-STORED feature is used in the definition of compaction in Figure 7.) The values of the TO-BE-STORED and the QUANTIFIERS feature are subject to the following set of constraints.

(85) Principles governing the value of the TO-BE-STORED feature

    a. The TO-BE-STORED value of a sign must be a subset of its QUANTIFIERS value.

    b. The TO-BE-STORED value of a sign that is not totally or partially compacted must be an empty set.

(86) Principles governing the value of the QUANTIFIERS feature

    a. The QUANTIFIERS value of a phrasal sign that is not a DP (i.e. a saturated phrase headed by a determiner) is the set obtained by subtracting the union of the TO-BE-STORED values of its daughters from the union of the QUANTIFIERS values of those same daughters.

    b. The QUANTIFIERS value of a DP whose KEY value contains a scopal elementary predication is the union of (i) the singleton consisting of its LTOP value and (ii) the set obtained by subtracting the union of the TO-BE-STORED values of its daughters from the union of the QUANTIFIERS values of those same daughters.

    c. The QUANTIFIERS value of a DP whose KEY value does not contain a scopal elementary predication is the set obtained by subtracting the union of the TO-BE-STORED values of its daughters from the union of the QUANTIFIERS values of those same daughters.

    d. The QUANTIFIERS value of a phrase headed by a verb or an adjective must be an empty set.

In this theory, a handle corresponding to a quantificational determiner like *every* does not 'start out' in a quantifier storage. Figure 20 shows how the two quantifiers in the sentence *One apple in every basket was rotten* enter into storage in accordance with the principles in (85) and (86). The handles for the two quantifiers are both put into storage (i.e. placed in the H-STORE set) at the top node in the figure. They are 'retrieved' from the quantifier storage when the top node undergoes compaction, as are the two quantifiers in Figure 8.

    The reason that we need the features like QUANTIFIERS and TO-BE-STORED has to do with our decision to define the compaction operation the way we did in Figure 7. As noted in subsection 2.3, when a sign is compacted, each quantifier whose handle was in the H-STORE set of a domain object that underwent compaction is required to take scope within that sign. This prevents us from assuming that the handle of a quantifier starts out in an H-STORE set; if it were in an H-STORE set at the word level, then the quantifier would have to take scope within the D node, since that node is required to undergo total compaction (by (5c)).

C   Collection of acceptablity judgments on example (64)

We used the method described in Sprouse (2011) to test the acceptability of example (64) on the Amazon Mechnical Turk (AMT) platform.

    We included a total of 11 test sentences including (64) in our questionnaire, published on the AMT platform. The other 10 test sentences were also examples of RNR taken from the literature. Besides the test sentences, we also included three questions for (i) verifying that our participants were native speakers of English, (ii) checking whether they were monolingual, and (iii) finding out whether they had the experience of studying linguistics. Every participant was shown the same set of test sentences but in a different, randomized order. Each sentence was followed by a parenthesized sentence that indicated what the intended meaning of the preceding sentence was, and the participants were instructed to rate each of the sentences on a 4-point scale, with 1 meaning "perfectly natural under the intended interpretation", 2 meaning "slightly unnatural under the intended interpretation", 3 meaning "considerably unnatural under the intended interpretation", and 4 meaning "impossible under the intended interpretation". The participants were each paid three US dollars.
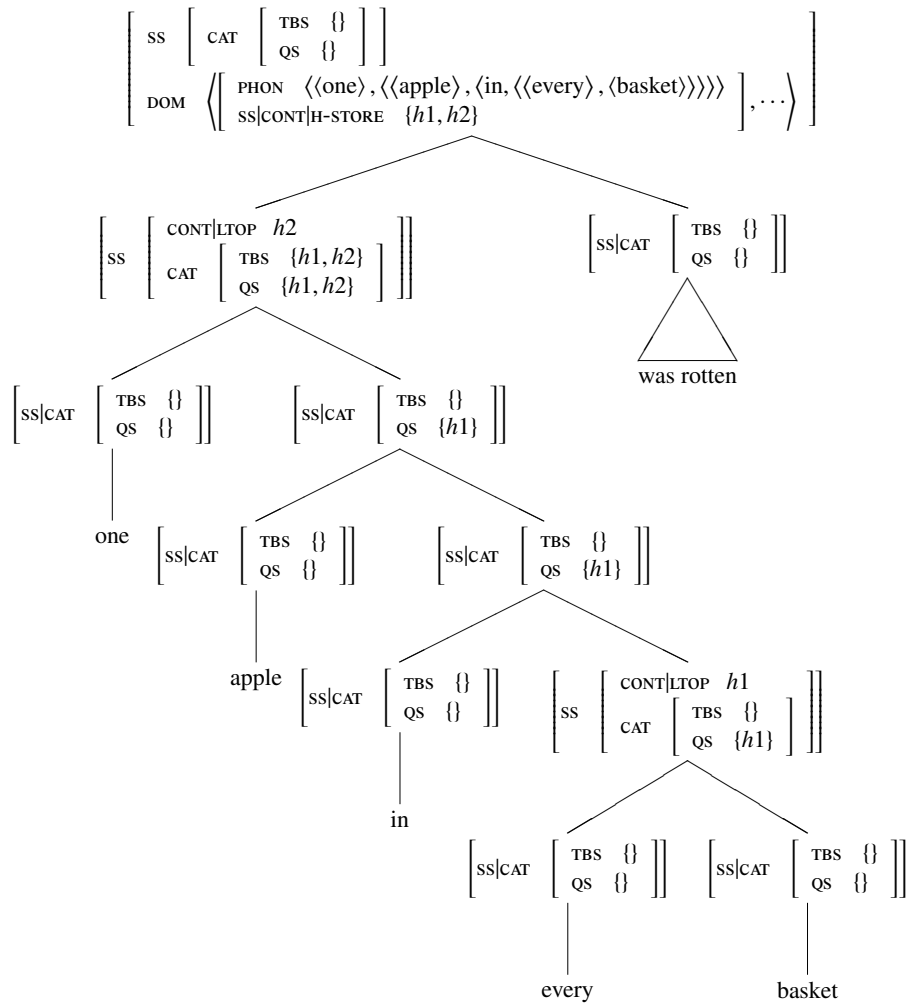
$$\begin{bmatrix} \text{SS} & \begin{bmatrix} \text{CAT} & \begin{bmatrix} \text{TBS} & \{\} \\ \text{QS} & \{\} \end{bmatrix} \end{bmatrix} \\ \text{DOM} & \left\langle \begin{bmatrix} \text{PHON} & \langle\langle\text{one}\rangle, \langle\langle\text{apple}\rangle, \langle\text{in}, \langle\langle\text{every}\rangle, \langle\text{basket}\rangle\rangle\rangle\rangle\rangle \\ \text{SS}|\text{CONT}|\text{H-STORE} & \{h1, h2\} \end{bmatrix}, \ldots \right\rangle \end{bmatrix}$$

$$\begin{bmatrix} \text{SS} & \begin{bmatrix} \text{CONT}|\text{LTOP} & h2 \\ \text{CAT} & \begin{bmatrix} \text{TBS} & \{h1, h2\} \\ \text{QS} & \{h1, h2\} \end{bmatrix} \end{bmatrix} \end{bmatrix} \qquad \begin{bmatrix} \text{SS}|\text{CAT} & \begin{bmatrix} \text{TBS} & \{\} \\ \text{QS} & \{\} \end{bmatrix} \end{bmatrix}$$

was rotten

$$\begin{bmatrix} \text{SS}|\text{CAT} & \begin{bmatrix} \text{TBS} & \{\} \\ \text{QS} & \{\} \end{bmatrix} \end{bmatrix} \qquad \begin{bmatrix} \text{SS}|\text{CAT} & \begin{bmatrix} \text{TBS} & \{\} \\ \text{QS} & \{h1\} \end{bmatrix} \end{bmatrix}$$

one

apple

$$\begin{bmatrix} \text{SS}|\text{CAT} & \begin{bmatrix} \text{TBS} & \{\} \\ \text{QS} & \{\} \end{bmatrix} \end{bmatrix} \qquad \begin{bmatrix} \text{SS}|\text{CAT} & \begin{bmatrix} \text{TBS} & \{\} \\ \text{QS} & \{h1\} \end{bmatrix} \end{bmatrix}$$

in

$$\begin{bmatrix} \text{SS}|\text{CAT} & \begin{bmatrix} \text{TBS} & \{\} \\ \text{QS} & \{\} \end{bmatrix} \end{bmatrix} \qquad \begin{bmatrix} \text{SS} & \begin{bmatrix} \text{CONT}|\text{LTOP} & h1 \\ \text{CAT} & \begin{bmatrix} \text{TBS} & \{\} \\ \text{QS} & \{h1\} \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

$$\begin{bmatrix} \text{SS}|\text{CAT} & \begin{bmatrix} \text{TBS} & \{\} \\ \text{QS} & \{\} \end{bmatrix} \end{bmatrix} \qquad \begin{bmatrix} \text{SS}|\text{CAT} & \begin{bmatrix} \text{TBS} & \{\} \\ \text{QS} & \{\} \end{bmatrix} \end{bmatrix}$$

every

basket

Figure 20: How the quantifiers enter into storage in the sentence *One apple in every basket was rotten*. The feature names SYNSEM, TO-BE-STORED, and QUANTIFIERS are abbreviated as SS, TBS, and QS, respectively.

Our questionnaire was completed by 10 participants. It turned out that all our participants had some experience of studying linguistics. We excluded from analysis two participants who did not choose the answer yes for the question of whether they were native speakers of English (and who, incidentally, both rated the sentence (64) as 1).

The result for sentence (64) was as follows: it was rated as 1 by two people, as 2 by three people, as 3 by two people, and as 4 by one person.

D   Definition of the *subj_verb_agreement* relation

The English version of the *subj_verb_agreement* relation, which is employed in (82), is defined as follows.[17]

(87)   subj_verb_agreement$\left(\boxed{1}, \boxed{2} \right) \equiv$

$$\left(\begin{array}{l} \left(\boxed{1} : \begin{bmatrix} \text{PER} & \boxed{3} \\ \text{NUM} & \boxed{4} \end{bmatrix} \wedge \boxed{2} : \begin{bmatrix} \text{CAT|HEAD|AGR} & \begin{bmatrix} \text{PER} & \boxed{3} \\ \text{NUM} & \boxed{4} \end{bmatrix} \end{bmatrix} \right) \\ \vee \left(\begin{array}{ll} \boxed{2} : \begin{bmatrix} \text{ARGS} & \left\langle \boxed{a_1}, \ldots, \boxed{a_n} \right\rangle \end{bmatrix} \\ \wedge & \text{subj\_verb\_agreement} \left(\boxed{1}, \boxed{a_1} \right) \\ \wedge & \cdots \\ \wedge & \text{subj\_verb\_agreement} \left(\boxed{1}, \boxed{a_n} \right) \end{array} \right) \\ \vee \left(\begin{array}{ll} \boxed{1} : \begin{bmatrix} \text{NUM} & \text{pl} \end{bmatrix} \\ \wedge & \boxed{2} : \begin{bmatrix} \text{CONJ} & \boxed{5} \end{bmatrix} \\ \wedge & \boxed{5} \neq \text{or} \\ \wedge & \cdots \end{array} \right) \end{array} \right)$$

As mentioned in subsection 5.2, the *subj_verb_agreement* relation is a relation that may or may not hold between the ss|CAT|HEAD|AGR value ($\boxed{1}$), and the ss|CAT|VAL|SUBJ|FIRST value ($\boxed{2}$) of a domain object standing for a VP. (The ss|CAT|VAL|SUBJ|FIRST value of a domain object is the sole element in its SUBJ list.) The first disjunct in the right-hand side of the definition of this relation (i.e. line 2 of (87)) deals with cases that do not involve phantom coordinate structures. The second disjunct (i.e. lines 3–6) deals with cases in which a predicate agrees with each 'conjunct' of a phantom coordinate structure. The Russian version of this relation should not have this second disjunct, since Russian does not allow the kind of non-summative agreement that is licensed by this disjunct. And the third disjunct (i.e. lines 7–10), which is only partly shown here, specifies constraints on summative agreement, whose details are presented in Yatabe (2003).

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[17]This definition will have to be modified slightly if the analysis of coordination of unlikes that is proposed in Yatabe (2004) is to be adopted.

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