Underspecification and NP Coordination in Constraint-based Grammar

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Abstract

This paper presents a uniform semantic underspecification account of conjunctive NP coordination phenomena, with particular focus on scope and plural ambiguities. We propose a compositional and constraint-based approach for processing pluralities within an integrated UDRT (Reyle, 1993) and HPSG (Pollard and Sag, 1994) framework, with the goal of capturing complex semantic interactions that can arise in such structures.

1 Introduction

Semantic Underspecification has been successfully employed to avoid the combinatorial explosion caused by scope ambiguities (e.g. QLF (Alshawi and Crouch, 1992), UDRSs (Reyle, 1993), MRS (Copestake et al., 1995), Hole Semantics (Bos, 1996), CLLS (Egg et al., 2001) and LRS (Richter and Sailer, 2001) among others). Still, the underspecification literature has been relatively silent regarding NP coordination phenomena, most likely because of the complex issues raised about conjunction and the semantics of pluralities, as these are still the topic of much linguistic debate. However, recent efforts to deal with scopal phenomena and coordination in underspecified semantics seem to challenge strict compositionality, by making use of copying operations. We will in turn argue against such analysis and propose a compositional and underspecified constraint-based account of scope ambiguities as well as distributive and collective readings triggered by pluralities.

Section 2 overviews a previous underspecification proposal on NP coordination and points out some of the linguistic problems and computational issues. In section 3 a uniform and compositional account for the fragment under discussion is proposed, dealing with scope and plural ambiguities in a general way. Several related issues concerning anaphora, reciprocity and model theory are also briefly discussed. Finally, section 4 concludes.

2 NP Coordination

In early Transformational Grammar, coordination structures like the one in (1) were analyzed via a transformation known as Conjunction Reduction (CR) to yield a sentential coordination:

(1) John and Mary smiled.
$(\exists x\, \mathsf{John}(x) \wedge \mathsf{smiled}(x)) \wedge (\exists y\, \mathsf{Mary}(y) \wedge \mathsf{smiled}(y))$

However, Lakoff and Peters (1969), Massey (1976), Roberts (1987), and others noted that some NP coordinations cannot be reduced to sentential coordination:

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(2) a. Tom, Dick and Harry are similar.
b. John and Mary are a happy couple.
c. Tom, Dick and Harry lifted the piano.
d. John and Mary praised each other.
e. A car and a bike collided.

In the examples above, the subject NP is a *conjoined plurality* which is taken in a collective state-of-affairs. Conjoined NPs can also yield scope ambiguities, and Babko-Malaya (2004) recently proposed a LTAG grammar account using an underspecification language similar to Hole Semantics (following Kallmeyer and Joshi (2003)), with the goal of dealing with scope ambiguities triggered by the coordination of quantificational NPs such as the one in (3):

(3) Every man and every woman solved a puzzle.

However, this account assumes an approach similar to (1) since the disambiguation process copies-out several items (in this case, the verbal head and the object NP), in order to produce the representations in (4) (Babko-Malaya 2004):

(4) a. $\mathsf{every}(\mathsf{x}, \mathsf{man}(\mathsf{x}), \mathsf{some}(\mathsf{z}, \mathsf{puzzle}(\mathsf{z}), \mathsf{solve}(\mathsf{x}, \mathsf{z}))) \wedge$
$\mathsf{every}(\mathsf{y}, \mathsf{woman}(\mathsf{y}), \mathsf{some}(\mathsf{z}, \mathsf{puzzle}(\mathsf{z}), \mathsf{solve}(\mathsf{y}, \mathsf{z})))$

b. $\mathsf{some}(\mathsf{z}, \mathsf{puzzle}(\mathsf{z}), \mathsf{every}(\mathsf{x}, \mathsf{man}(\mathsf{x}), \mathsf{solve}(\mathsf{x}, \mathsf{z})) \wedge$
$\mathsf{every}(\mathsf{y}, \mathsf{woman}(\mathsf{y}), \mathsf{solve}(\mathsf{y}, \mathsf{z})))$

Copying-out over conjuncts is computationally costly since it is associated to the possible scope disambiguations, which are exponential (Dik 1968:78). This can be observed in (5) where the entire relative clause as well as the VP have to be copied in order to obtain narrow scope readings of both indefinite NPs:

(5) Every man and every woman who solved a puzzle won a prize.

This kind of CR analysis also fails to obtain *collective* interpretations for (2). One should not use a coordination rule just for quantificational NPs because these can also yield collective readings (Roberts 1987:166; Hoeksema 1988; Lønning 1989):

(6) a. Every soldier and every officer met.
b. Every man and every woman praised each other.
c. Every professor and every student of his wrote a paper (together).
d. Actually, every proton and every neutron collided in the chamber.

Mixed coordinations of different kinds of NPs can be collectively targeted by anaphoric expressions, as seen below:

(7) [The reverend and every member of the congregation]$_i$ crossed themselves$_i$ as the soldiers filed past.

Analyzing these data as elliptical thus comes at the cost of both parsimony and computational efficiency, even though such constructions do not occur very often. According to informants, some cases actually require very specific pragmatic contexts (e.g. to emphasize that each and every entity is involved in the event) in order to be acceptable. Yet we believe there is nothing ungrammatical about the above, and that any processing difficulties are due to their structural complexity, which as we shall see, entail a significant degree of semantic ambiguity.

There are other cases of coordinated quantificational NPs which should also be considered, namely ones involving a kind of *Hydra* (Link, 1984) where the same NP is interpreted distributively as well as collectively:

(8) a. Every woman and every child gathered at the embassy will be assisted by a red cross medic.

b. Each boy and each girl holding a card with the same number will have to kiss.

c. Every landlord and every tenant who hate each other end up shouting during meetings.

In (8a) the relative clause headed by *gather* requires a collective reading, while the main predicate *be assisted* ranges over individuals. Example (8b) pertains to the context of a child play where each boy and each girl draws a card from two decks respectively, such that the couples with matching cards are dared to kiss.

Carpenter (1997:325) notes yet another source of ambiguity, which we believe cannot easily be addressed in a copy-out approach such as the one in Babko-Malaya (2004), arising from scope interactions *between* conjuncts:

(9) a. Every student and a friend can come to the party.
b. Every inmate and a guard must enter the X-ray room.
c. Every lawyer and each client must wait in line.
d. Each student and his or her advisor should meet once a week.

In (9a,b) the indefinite determiner can have wide or narrow scope relatively to the universal quantifier, yielding a specific or a non-specific reading respectively. The latter allows a different friend or guard for each student or inmate, respectively. (9d) is similar, where in addition the anaphora may or not be local.

The above data are also problematic for branching quantification accounts such as Barwise (1979) and Lønning (1989). An important generalization is also missed in these proposals because several reciprocal predicates are assumed. For instance, a binary $agree_1$ for 'every linguist and every logician agree' as seen in (10), a unary $agree_2$ for 'the linguists agree', a ternary $agree_3$ for 'every linguist, every philosopher and every logician agree', and so on.

(10) $\left(\begin{array}{c} \text{every x linguist(x)} \\ \text{every y logician(y)} \end{array} \right) \text{agree(x,y)}$

In the next section we propose an account of NP Coordination which is consistent with all of the above phenomena, using the same underlying semantic construction, regardless whether the NP conjuncts are quantificational or not.

3 Underspecifying NP Coordination

In the fragment under consideration, NP coordination always yields a non-atomic entity (a *plurality*) which may be interpreted collectively or distributively. There is little agreement on the exact linguistic and philosophical nature of such entities, and for now we will agnostically steer away from the controversy by assuming a 'set formation' operation which may be formalized in many different ways,[1] and concentrate on the goal of providing a general semantic construction constraint that uniformly captures scopal and plural interpretations for such structures.

We start by illustrating our proposal with an example, using standard subordination relations to encode scopal restrictions. Below is depicted the underspecified structure of a sentence that includes a non-trivial NP coordination, where arrows correspond to scope subordination relations ('$\leq$'):

(11) Every lawyer and his secretary will meet tomorrow.

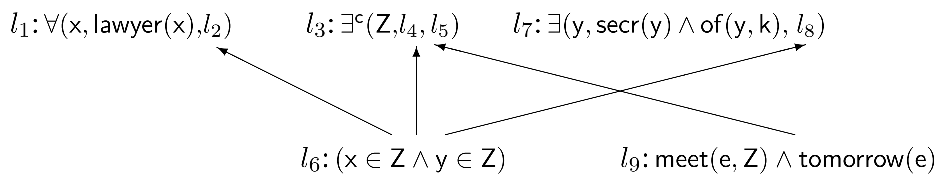

Figure 1: NP Coordination Underspecification

This underspecified structure allows conjuncts to outscope the coordinator, as well as each other: each conjunct outscopes the conjunction l_6, but remains underspecified relatively to the set-formation ($\exists^c$) introduced by the coordinator in l_3. Thus if l_2 is disambiguated as outscoping l_7 as well as the set-formation, one obtains a pair reading where each lawyer meets the respective secretary:[2]

(12) $\forall(\mathsf{x}, \mathsf{lawyer}(\mathsf{x}), \exists(\mathsf{y}, \mathsf{secr}(\mathsf{y}) \wedge \mathsf{of}(\mathsf{y}, \mathsf{x}), \exists^c(\mathsf{Z}, \mathsf{x} {\in} \mathsf{Z} \wedge \mathsf{y} {\in} \mathsf{Z}, \mathsf{meet}(\mathsf{e}, \mathsf{Z}) \wedge \mathsf{tomr}(\mathsf{e}))))$

In that case, the nested indefinite NP is interpreted non-specifically, a suitable referent is locally accessible ($\mathsf{k} = \mathsf{x}$), and external anaphora are blocked:

(13) Every lawyer$_i$ and his$_i$ secretary$_j$ met yesterday. *She$_j$ was worried.

However, if the set-formation is disambiguated as outscoping both conjuncts, a reading obtains where everyone is meeting (including lawyers meeting lawyers and secretaries meeting secretaries), since Z contains every individual introduced by each NP conjunct:

(14) $\exists^c(\mathsf{Z}, \forall(\mathsf{x}, \mathsf{lawyer}(\mathsf{x}), \exists(\mathsf{y}, \mathsf{secr}(\mathsf{y}) \wedge \mathsf{of}(\mathsf{y}, \mathsf{x}), \mathsf{x} {\in} \mathsf{Z} \wedge \mathsf{y} {\in} \mathsf{Z}, \mathsf{meet}(\mathsf{e}, \mathsf{Z}) \wedge \mathsf{tomr}(\mathsf{e}))))$

[1] E.g. as a first-order or as a second-order entity. See §3.4 for more on this discussion.

[2] Henceforth the semantics of *meet* is abbreviated, as it should lexically distribute over the members of Z reciprocally, e.g. l_9:$\forall(\mathsf{k}, \mathsf{k} {\in} \mathsf{Z}, \forall(\mathsf{w}, \mathsf{w} {\in} \mathsf{Z} \wedge \mathsf{k} {\neq} \mathsf{w}, \mathsf{meet}'(\mathsf{e}, \mathsf{k}, \mathsf{w})))$.

Note that the latter reading is quite salient in the child play lottery context of (8b) above. This kind of ambiguity is also visible in the example below, where either everyone meets, or only pairs of a man and a woman meet:

(15) Every man and every woman shall meet in the temple tonight.

a. $\forall(\mathsf{x}, \mathsf{man}(\mathsf{x}), \forall(\mathsf{y}, \mathsf{woman}(\mathsf{y}), \exists^{\mathsf{c}}(\mathsf{Z}, \mathsf{x} \in \mathsf{Z} \wedge \mathsf{y} \in \mathsf{Z}, \mathsf{meet}(\mathsf{e}, \mathsf{Z}) \wedge \mathsf{ton}(\mathsf{e}) \wedge \ldots)))$
b. $\exists^{\mathsf{c}}(\mathsf{Z}, \forall(\mathsf{x}, \mathsf{man}(\mathsf{x}), \forall(\mathsf{y}, \mathsf{woman}(\mathsf{y}), \mathsf{x} \in \mathsf{Z} \wedge \mathsf{y} \in \mathsf{Z})), \mathsf{meet}(\mathsf{e}, \mathsf{Z}) \wedge \mathsf{ton}(\mathsf{e}) \wedge \ldots)$

Conversely, if the indefinite determiner is disambiguated as outscoping the universal quantifier ($l_8 = l_1$), then *his secretary* may be interpreted specifically provided that a suitable binding referent is accessible in the discourse:[3]

(16) The office director$_i$ scheduled an extra meeting this afternoon. Every lawyer and his$_i$ secretary will also be required to attend.

Note that intermediate scopings yield equivalent readings, e.g. $every_x > exists_Z > every_y$ corresponds to each man meeting the members of the set of women. Similarly, scope interactions between existentially quantified conjuncts do not result in distinct readings.

(17) John and Mary met.
$\exists^{\mathsf{c}}(\mathsf{Z}, \exists(\mathsf{x}, \mathsf{John}(\mathsf{x}), \exists(\mathsf{y}, \mathsf{Mary}(\mathsf{y}), \mathsf{x} \in \mathsf{Z} \wedge \mathsf{y} \in \mathsf{Z})), \mathsf{meet}(\mathsf{e}, \mathsf{Z}))$

This is a well known side-effect of scope processing. For example, 10 of the representations usually obtained for the sentence below in most formalisms (underspecified or not) are logically equivalent:[4]

(18) Every man in a bar bought a woman a drink.

3.1 Formalization

We now formalize the coordination clause for the underspecified representation in (11). In HPSG, syntactic and semantic structures are construed via independent implicational constraints which mutually express different kinds of information associated to the same complex linguistic entities. Our semantics constraint should thus be grounded in syntactic structure, and for this purpose we adopt the coordination constraint proposed in Beavers and Sag (2004).

In terms of the semantic framework, we adopt in general terms the Underspecified DRT/HPSG interface in Frank and Reyle (1995).[5] NP Coordination is captured with two different constraints: a conjunction-marking base structure (*hd-mk-cx* in (19)) and a recursive NP conjunction structure (*cnj-cx* in (20)):

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[3]In fact, an alternative way to capture the scopal flexibility between conjuncts could be through presupposition projection and accommodation, as in van der Sant (1992).

[4]See Chaves (2003) for techniques to avoid this problem in an underspecification setting.

[5]For technical reasons our representation of determiners is slightly different from the original, as it singles out the arguments explicitly, similarly to MRS and LUD (Bos, 1999), as discussed below. Also, we employ lists rather than sets, since these are computationally much simpler, and no linguistic requirement exists for using sets presently.

(19)
$$\begin{bmatrix} \textit{hd-mk-cxt} & \\ \text{MTR} \mid \text{SEM} & \begin{bmatrix} \text{INDEX} & \boxed{Z}_{non-at} \\ \text{LS} & \begin{bmatrix}\text{L-MAX} & \boxed{l} \\ \text{L-MIN} & \boxed{l2}\end{bmatrix} \\ \text{SUBORD} & \left\langle \boxed{l_3} \leq \boxed{l_1}, \boxed{l_3} \leq \boxed{l_4} \right\rangle \oplus \boxed{4} \\ \text{CONDS} & \left\langle \begin{bmatrix} \text{LABEL} & \boxed{l_3} \\ \text{REL} & \in \\ \text{ARG1} & \boxed{x} \\ \text{ARG2} & \boxed{Z}\end{bmatrix}, \begin{bmatrix} \text{LABEL} & \boxed{l} \\ \text{REL} & \textit{exists\_cnj} \\ \text{DREF} & \boxed{Z} \\ \text{RES} & \boxed{l_1} \\ \text{SCOPE} & \boxed{l_2}\end{bmatrix}\right\rangle \oplus \boxed{5} \end{bmatrix} \\ \text{DTRS} & \left\langle \begin{bmatrix}\textit{conj-lxm} \\ \text{SYN} \mid \text{SPEC } \boxed{1} \\ \text{CRD} + \end{bmatrix}, \boxed{1}\text{NP}_{CRD-}\begin{bmatrix} \text{INDEX} & \boxed{x} \\ \text{LS} \mid \text{L-MIN} & \boxed{l_4} \\ \text{SUBORD} & \boxed{4} \\ \text{CONDS} & \boxed{5}\end{bmatrix}\right\rangle \end{bmatrix}$$

The above NP conjunction marking constraint roughly corresponds to a schema $\text{NP}_{CRD+} \rightarrow$ *conj* NP_{CRD-}. Note that all semantic information is introduced constructionally by the mother node, allowing the same lexical entry for the conjunction *and* to be used in the coordination of other categories (verbal, adjectival, etc.).

The construction in (20) captures the recursive case $\text{NP} \rightarrow \text{NP}\ \text{NP}_{CRD+}$. Here, the extra conjoined NP triggers the introduction of an additional '$\boxed{y}\in\boxed{Z}$' constraint between the nominal referent $\boxed{y}$ and the conjoined non-atomic referent $\boxed{Z}$, as well as the respective subordination constraints:

(20)
$$\begin{bmatrix} \textit{cnj-cx} & \\ \text{MTR} \mid \text{SEM} & \begin{bmatrix} \text{INDEX} & \boxed{Z}_{non-at} \\ \text{LS} & \boxed{1} \\ \text{SUBORD} & \left\langle \boxed{l_5} \leq \boxed{l_4}, \boxed{l_5} = \boxed{l_3} \right\rangle \oplus \boxed{2} \oplus \boxed{4} \\ \text{CONDS} & \left\langle \begin{bmatrix} \text{LABEL} & \boxed{l_5} \\ \text{REL} & \in \\ \text{ARG1} & \boxed{y} \\ \text{ARG2} & \boxed{Z}\end{bmatrix}\right\rangle \oplus \boxed{3} \oplus \boxed{5} \end{bmatrix} \\ \text{DTRS} & \left\langle \text{NP}\begin{bmatrix} \text{INDEX} & \boxed{y} \\ \text{LS} \mid \text{L-MIN} & \boxed{l_4} \\ \text{SUBORD} & \boxed{4} \\ \text{CONDS} & \boxed{5}\end{bmatrix}, \text{NP}_{CRD+}\begin{bmatrix} \text{INDEX} & \boxed{Z} \\ \text{LS} & \boxed{1} \\ \text{SUBORD} & \boxed{2}\left\langle \boxed{l_3} \leq \boxed{l_1} \mid \ldots \right\rangle \\ \text{CONDS} & \boxed{3}\end{bmatrix}\right\rangle \end{bmatrix}$$

The types *hd-mk-cxt*, *cnj-cx*, and *conj-lxm* can be extended to allow disjunctive coordinations and other kinds of conjunctions (e.g. appositive NP coordination).

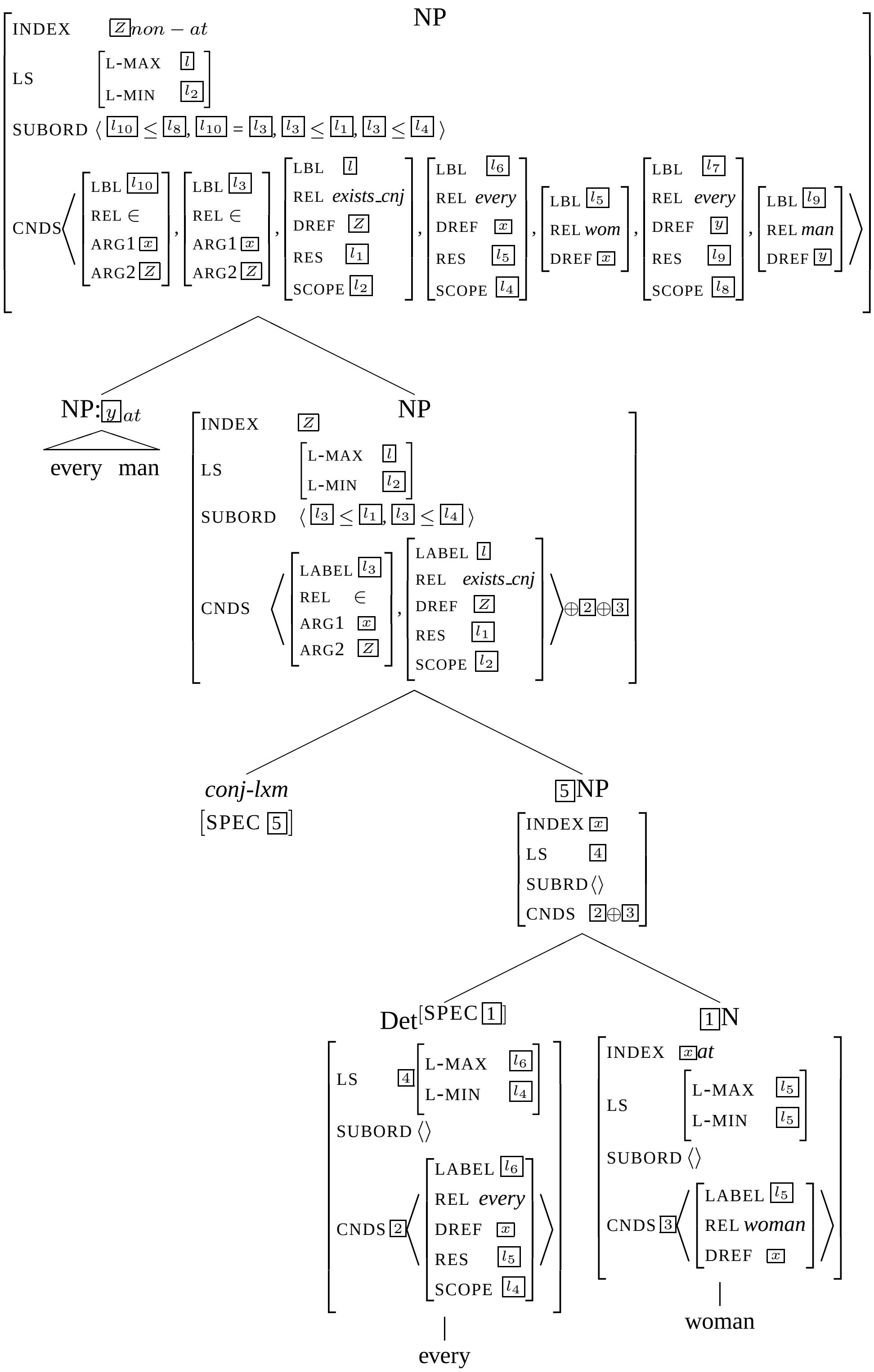


Figure 2: NP Coordination Semantic Construction

The structure in Figure 2 illustrates how the semantic composition of ‘every man and every woman’ proceeds in our grammar fragment (‘a man and a woman’ or ‘each lawyer and an assistant’ are obtained similarly). The resulting NP makes available a non-atomic referent $\boxed{Z}$ which may be taken by a collective predicate such as *meet* and *agree*, regardless of how the conjuncts scopally interact.

We opted for a uniform representation of existential and quantificational determiners which explicitly encodes the arguments in RESTR and SCOPE. This notation prevents scopal interactions between the two arguments (e.g. a distribution introduced by a relative clause cannot outscope the main verb) given the negative constraints stated in Reyle (1996:345,ft.3). Once scope is resolved, existential determiners can be interpreted in the usual way, by having the argument DRSs merged into the main DRS introduced by the determiner. For instance, via equality subordination constraints between the respective labels:

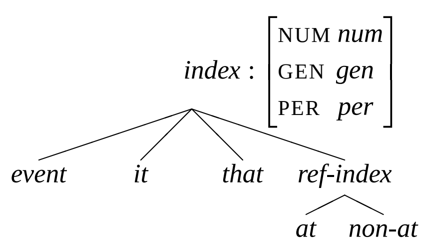
(21) $$\begin{bmatrix} \text{LABEL} & \boxed{l} \\ \text{REL} & \textit{exists} \\ \text{DREF} & \boxed{x} \\ \text{RES} & \boxed{l1} \\ \text{SCOPE} & \boxed{l2} \end{bmatrix} \equiv \quad l{:}\begin{array}{|c|}\hline x \\ \hline \\ \hline \end{array} \text{ where } l = l_1 = l_2$$

Here we assume generalized quantifiers correspond to standard duplex conditions in Kamp and Reyle (1993). After the equality subordination constraints are factored out, the underspecified DRS in Figure 2 boils down to the depicted below:

(22) $$\langle l_3 \leq l, l_3 \leq l_8, l_3 \leq l_4 \rangle$$
$$\langle l_3{:}\begin{array}{|c|}\hline x \in Z \\ y \in Z \\ \hline \end{array},\ l{:}\begin{array}{|c|}\hline Z \\ \hline \\ \hline \end{array},\ l_6{:}\begin{array}{|c|}\hline x \\ \hline \text{woman}(x) \\ \hline \end{array} \Rightarrow \boxed{l_4},\ l_7{:}\begin{array}{|c|}\hline y \\ \hline \text{man}(y) \\ \hline \end{array} \Rightarrow \boxed{l_8} \rangle$$

For the typing of pluralic and atomic indices in INDEX and ARG, we will assume the following *index* type hierarchy based on Pollard and Sag (1994):

(23)



This signature allows to distinguish between several different kinds of nouns: singular atomic (e.g. *student*), singular non-atomic (e.g. *herd*), plural atomic (e.g. *trousers*), and plural non-atomic (e.g. *students*, composed of pure atoms or *herds*, composed of group atoms). Thus a collective verb can select NPs that introduce non-atomic referents, without the need to distinguish complex NPs like ‘John and a student’ (where INDEX is typed *non-at* by the clause in (19)) from simple plural NPs like ‘some students’ (where INDEX is lexically typed *non-at* by the noun):

(24)
$$\left\langle \textit{met}, \begin{bmatrix} \text{ARG-ST} \left\langle \text{NP:}\begin{bmatrix} \text{INDEX } \boxed{1}\textit{non-at} \\ \text{LS} \mid \text{L-MIN } \boxed{l1} \end{bmatrix} \right\rangle \\ \text{SEM} \begin{bmatrix} \text{INDEX } \boxed{e} \\ \text{LS} \begin{bmatrix} \text{L-MAX } \boxed{l2} \\ \text{L-MIN } \boxed{l2} \end{bmatrix} \\ \text{SUBORD} \left\langle \boxed{l2} \leq \boxed{l1} \right\rangle \\ \text{CONDS} \left\langle \begin{bmatrix} \text{LABEL} & \boxed{l2} \\ \text{REL} & \textit{meet} \\ \text{ARG0} & \boxed{e} \\ \text{ARG1} & \boxed{1} \end{bmatrix} \right\rangle \end{bmatrix} \end{bmatrix} \right\rangle$$

Conversely, the typing on the subject index rules out atomic subjects (*iff* the structure is intransitive and not an instance of null complement ellipsis):

(25) a. # Each student met / gathered.
b. # A student met / gathered.

In *head-subject* and *head-complement* constructions semantic composition is rather straightforward, following closely from the Semantics Principle in Frank and Reyle (1995), with the following monotonic constraint:

(26)
$$\begin{bmatrix} \text{MTR} \mid \text{SEM} & \begin{bmatrix} \text{INDEX} & \boxed{1} \\ \text{LS} & \boxed{2} \\ \text{SUBORD} & \boxed{s_1} \oplus \boxed{s_2} \oplus \ldots \oplus \boxed{s_n} \\ \text{CONDS} & \boxed{c_1} \oplus \boxed{c_2} \oplus \ldots \oplus \boxed{c_n} \end{bmatrix} \\ \text{HD-DTR} \mid \text{SEM} & \begin{bmatrix} \text{INDEX} & \boxed{1} \\ \text{LS} & \boxed{2} \\ \text{SUBORD} & \boxed{s_1} \\ \text{CONDS} & \boxed{c_1} \end{bmatrix} \\ \text{DTRS} & \left\langle \begin{bmatrix} \text{SEM} \begin{bmatrix} \text{SUBORD} & \boxed{s_2} \\ \text{CONDS} & \boxed{c_2} \end{bmatrix} \end{bmatrix}, \ldots, \begin{bmatrix} \text{SEM} \begin{bmatrix} \text{SUBORD} & \boxed{s_n} \\ \text{CONDS} & \boxed{c_n} \end{bmatrix} \end{bmatrix} \right\rangle \end{bmatrix}$$

The semantics of each daughter is appended in the mother node, while the distinguishing labels of the head daughter are identified with the mother's. A similar constraint is used for *head-adjunct* and *head-specifier* constructions (cf. Richter and Sailer (1999) and Copestake et al. (2003) for example).

By adopting Beavers and Sag (2004) we are also able to cope with (27), as NP coordination with determiner ellipsis (as opposed to true N' coordination where other kinds of readings emerge):

(27) Every linguist, logician and philosopher agreed (with each other).

3.2 Underspecified Distributivity

The conjunctive coordination constraint we have proposed introduces an existentially quantified non-atomic referent. This pluralic referent must be able to be interpreted distributively as well as collectively, similarly to what occurs to other kinds of pluralities in general:

(28) a. The students / John and Mary smiled. *(Distributive)*
b. Some lawyers / A man and a woman met in the bar. *(Collective)*

In our account, the verb will interact with a pluralic argument in exactly the same way, whether the NP is a simple plural (e.g. *the students*) or complex (e.g. *John and Mary*). If a verb is distributive as in (28a), it will simply force a distributive reading of the NP. If collective, as in (28b), the argument can be taken directly.

It is also known that in the case of 'mixed' (or 'neutral') predicates like *hire*, *buy*, and *carry*, both kinds of readings can arise on each argument:

(29) a. Two lawyers/ Jim and Will have hired a detective before. *(C/D)*
b. As far as I know, Sue only hired two lawyers / Tom and Mia. *(C/D)*
c. The kids / Jimmy and Dan took a toy upstairs. *(C/D)*

Note also that pluralities can be simultaneously interpreted collectively and distributively (Massey, 1976; Link, 1984; Dowty, 1986):

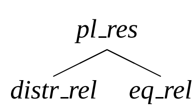
(30) a. The boy and the girl kissing in the park are students. *(C&D)*
b. Some students nodded and gathered around the teacher. *(D&C)*
c. The students who failed the exam agreed to meet in the gym. *(D&C)*

To cope with these cases we follow Link (1983), Roberts (1987), Landman (1989), Hendriks (1997), and many others in assuming a distribution operation which can be triggered by predicates with pluralic arguments. Such distribution however, does not prevent other predicates from accessing the plurality referent once again:

(31) John and Mary smiled and kissed.
$\exists^c(\mathsf{Z}, \exists(\mathsf{x}, \mathsf{J}(\mathsf{x}), \exists(\mathsf{y}, \mathsf{M}(\mathsf{y}), \mathsf{x}\in\mathsf{Z} \wedge \mathsf{y}\in\mathsf{Z})),\ \forall(\mathsf{k}, \mathsf{k}\in\mathsf{Z}, \mathsf{smile}(\mathsf{e}, \mathsf{k})) \wedge \mathsf{kiss}(\mathsf{e}', \mathsf{Z}))$

Following Chaves (2005), verbs lexically introduce a *pl(ural) res(olution)* relation:

(32) $\begin{bmatrix} \text{LABEL} & \boxed{l} \\ \text{REL} & \textit{pl\_res} \\ \text{ARG1} & \textit{ref-index} \\ \text{ARG2} & \textit{ref-index} \\ \text{SCOPE} & \boxed{l'} \end{bmatrix}$



The type *pl_res* introduces two subtypes, *distr_rel* and *eq_rel*. If *pl_res* is resolved as *eq_rel* then the referents are simply 'equated' (i.e. unified), but if *pl_res* resolved as *distr_rel* then a distributive interpretation is obtained. The two possibilities are captured by the Plural Resolution constraint given below:

(33)
$$\begin{bmatrix}\text{REL} & \textit{pl\_res}\end{bmatrix} \Rightarrow \begin{bmatrix}\text{REL} & \textit{eq\_rel}\\ \text{ARG1} & \boxed{1}\textit{ref-index}\\ \text{ARG2} & \boxed{1}\end{bmatrix} \vee \begin{bmatrix}\text{REL} & \textit{distr\_rel}\\ \text{ARG1} & \textit{ref-index}\\ \text{ARG2} & \textit{non-at}\end{bmatrix}$$

In order to allow semantic representations to be underspecified in respect to plural as well as scope ambiguities, we view the application of this constraint as ‘delayed’, on a par with scope disambiguation. This can be implemented in different ways, for instance with a delaying function (cf. *pl_dis* in Frank and Reyle (1995)), with a persistent default constraint, or as an optional processing constraint.

Take for instance the past tense of a distributive verb such as *smile*, *snore* or *die*, which is compatible with plural and singular subjects alike:

(34) A dog and a cat / Some patients / Every plant / Kenny died.

$$\left\langle \textit{died}, \begin{bmatrix}\text{ARG-ST} & \left\langle \text{NP:}\begin{bmatrix}\text{INDEX} & \boxed{1}\\ \text{LS} \mid \text{L-MIN} & \boxed{l1}\end{bmatrix}\right\rangle\\ \text{SEM} & \begin{bmatrix}\text{INDEX} & \boxed{e}\\ \text{LS} & \begin{bmatrix}\text{L-MAX} & \boxed{l4}\\ \text{L-MIN} & \boxed{l3}\end{bmatrix}\\ \text{SUBORD} & \left\langle \boxed{l4} = \boxed{l1}, \boxed{l3} \leq \boxed{l5} \right\rangle\\ \text{CONDS} & \left\langle \begin{bmatrix}\text{LABEL} & \boxed{l4}\\ \text{REL} & \textit{pl\_res}\\ \text{ARG1} & \boxed{3}\\ \text{ARG2} & \boxed{1}\\ \text{SCOPE} & \boxed{l5}\end{bmatrix}, \begin{bmatrix}\text{LABEL} & \boxed{l3}\\ \text{REL} & \textit{die}\\ \text{ARG0} & \boxed{e}\\ \text{ARG1} & \boxed{3}\textit{at}\end{bmatrix} \right\rangle\end{bmatrix}\end{bmatrix} \right\rangle$$

The above lexical entry is able to account for all the possible subjects. While no constraints are imposed on the NP, the predicate argument $\boxed{3}$ is typed as *at(omic)*. This means that no collective readings are allowed. If $\boxed{1}$ is an atomic referent (as in ‘Kenny’ or ‘every plant’) then the signature in (33) forces the non-distributive *eq_rel* resolution, unifying $\boxed{1}$ and $\boxed{3}$. This is the only possible solution because the *distr_rel* disjunct in (33) is restricted to distribute over non-atomic referents only. The distributive relation is interpreted as seen below:[6]

(35)
$$\begin{bmatrix}\text{LABEL} & \boxed{l}\\ \text{REL} & \textit{distr\_rel}\\ \text{ARG1} & \boxed{\alpha}\\ \text{ARG2} & \boxed{X}\textit{non-at}\\ \text{SCOPE} & \boxed{l'}\end{bmatrix} \equiv l\text{:}\begin{array}{|c|}\hline \alpha \\ \hline \alpha \in X \\ \hline\end{array} \Rightarrow \boxed{l'}$$

If $\boxed{1}$ is non-atomic (as in ‘some patients’ or ‘Jim and Sue’) then the typing in $\boxed{3}$*at* and the constraint in (33) force a distributive disambiguation. The non-distributive resolution *eq_rel* is not possible because the types *at* and *non-at* do not unify.

[6]Capitalized characters stand for non-atomic referents, non-capitalized characters for atomic ones, and greek characters for referents that can be either.

Note that the verbal predicate of the lexical entry in (34) is weakly subordinate to the plural resolution ($l_3 \leq l_5$). This allows to capture scope ambiguities in distributive resolutions. For instance, adjuncts outscope the head l_3 but remain underspecified relatively to the distribution. For example, due to traffic jams:

(36) ... some patients died in an ambulance (on the way to a hospital).

a. $\exists(\mathsf{y}, \mathsf{ambulance}(\mathsf{y}), \exists(\mathsf{X}, \mathsf{patients}(\mathsf{X}), \forall(\mathsf{k}, \mathsf{k} \in \mathsf{X}, \mathsf{die}(\mathsf{e}, \mathsf{k}) \wedge \mathsf{in}(\mathsf{e}, \mathsf{y}))))$

b. $\exists(\mathsf{X}, \mathsf{patients}(\mathsf{X}), \forall(\mathsf{k}, \mathsf{k} \in \mathsf{X}, \exists(\mathsf{y}, \mathsf{ambulance}(\mathsf{y}), \mathsf{die}(\mathsf{e}, \mathsf{k}) \wedge \mathsf{in}(\mathsf{e}, \mathsf{y}))))$

This technique thus allows to decouple scope and plural underspecification. For distributive verbs bearing plural inflection (e.g. ‘The students smile’ vs. ‘*John smile’) one uses the type *distr_rel* in the lexical entry instead of using *pl_res*.

Mixed predicates present an interesting case because these can yield collective or distributive readings on each of the plural NP arguments as in (29). We capture this with a single underspecified lexical entry, in relation on both arguments:

(37)

$$\left\langle \textit{hired}, \begin{bmatrix} \text{ARG-ST} \left\langle \text{NP:}\begin{bmatrix} \text{INDEX} & \boxed{1} \\ \text{LS} \mid \text{L-MIN} & \boxed{l3} \end{bmatrix}, \text{NP:}\begin{bmatrix} \text{INDEX} & \boxed{2} \\ \text{LS} \mid \text{L-MIN} & \boxed{l8} \end{bmatrix} \right\rangle \\ \text{SEM} \begin{bmatrix} \text{LS} \mid \text{L-MIN}\ \boxed{l} \\ \text{SUBORD} \left\langle \boxed{l4} = \boxed{l3}, \boxed{l} \leq \boxed{l5}, \boxed{l9} = \boxed{l8}, \boxed{l} \leq \boxed{l10} \right\rangle \\ \text{CONDS} \left\langle \begin{bmatrix} \text{LABEL} & \boxed{l4} \\ \text{REL} & \textit{pl\_res} \\ \text{ARG1} & \boxed{3} \\ \text{ARG2} & \boxed{1} \\ \text{SCOPE} & \boxed{l5} \end{bmatrix}, \begin{bmatrix} \text{LABEL} & \boxed{l9} \\ \text{REL} & \textit{pl\_res} \\ \text{ARG1} & \boxed{4} \\ \text{ARG2} & \boxed{2} \\ \text{SCOPE} & \boxed{l10} \end{bmatrix}, \begin{bmatrix} \text{LABEL} & \boxed{l} \\ \text{REL} & \textit{hire} \\ \text{ARG1} & \boxed{3} \\ \text{ARG2} & \boxed{4} \end{bmatrix} \right\rangle \end{bmatrix} \end{bmatrix} \right\rangle$$

As before, the above lexical entry is underspecified in the sense that both argument NPs can be singular or plural, and take wide or narrow scope over the predicate. However, no constraint is now placed on the arguments of the predicate, as these may be atomic or not. Take for example a simple plural subject in sentence (38), and the respective underspecified representation:

(38) Some lawyers hired a secretary.

$$\begin{bmatrix} \text{SUBORD} \left\langle \boxed{l4} = \boxed{l3}, \boxed{l} \leq \boxed{l5}, \boxed{l9} = \boxed{l8}, \boxed{l} \leq \boxed{l10} \right\rangle \\ \text{CONDS} \left\langle \begin{matrix} \begin{bmatrix} \text{LABEL} & \boxed{l1} \\ \text{REL} & \textit{some} \\ \text{DREF} & \boxed{1}\textit{non-at} \\ \text{RES} & \boxed{l2} \\ \text{SCOPE} & \boxed{l3} \end{bmatrix}, \begin{bmatrix} \text{LABEL} & \boxed{l2} \\ \text{REL} & \textit{lawyers} \\ \text{DREF} & \boxed{1} \end{bmatrix}, \begin{bmatrix} \text{LABEL} & \boxed{l6} \\ \text{REL} & \textit{a} \\ \text{DREF} & \boxed{2}\textit{at} \\ \text{RES} & \boxed{l7} \\ \text{SCOPE} & \boxed{l8} \end{bmatrix}, \begin{bmatrix} \text{LABEL} & \boxed{l7} \\ \text{REL} & \textit{secretary} \\ \text{DREF} & \boxed{2} \end{bmatrix}, \\ \begin{bmatrix} \text{LABEL} & \boxed{l4} \\ \text{REL} & \textit{pl\_res} \\ \text{ARG1} & \boxed{3} \\ \text{ARG2} & \boxed{1} \\ \text{SCOPE} & \boxed{l5} \end{bmatrix}, \begin{bmatrix} \text{LABEL} & \boxed{l9} \\ \text{REL} & \textit{pl\_res} \\ \text{ARG1} & \boxed{4} \\ \text{ARG2} & \boxed{2} \\ \text{SCOPE} & \boxed{l10} \end{bmatrix}, \begin{bmatrix} \text{LABEL} & \boxed{l} \\ \text{REL} & \textit{hire} \\ \text{ARG0} & \boxed{e} \\ \text{ARG1} & \boxed{3} \\ \text{ARG2} & \boxed{4} \end{bmatrix} \end{matrix} \right\rangle \end{bmatrix}$$

In the above representation, scope remains underspecified and the interpretation of the plural subject is still unresolved. A distributive reading is obtained in case the Plural Resolution Principle in (33) further instantiates the *pl_res* relation labeled by l_4 as a distribution:

(39)
$$\left[\begin{array}{l} \text{SUBORD}\ \langle \boxed{l4} = \boxed{l3}, \boxed{l} \leq \boxed{l5}, \boxed{l9} = \boxed{l8}, \boxed{l} \leq \boxed{l10} \rangle \\ \text{CONDS} \left\langle \begin{array}{l} \left[\begin{array}{ll} \text{LABEL} & \boxed{l1} \\ \text{REL} & \textit{some} \\ \text{DREF} & \boxed{1}\textit{non-at} \\ \text{RES} & \boxed{l2} \\ \text{SCOPE} & \boxed{l3} \end{array}\right], \left[\begin{array}{ll} \text{LABEL} & \boxed{l2} \\ \text{REL} & \textit{lawyers} \\ \text{DREF} & \boxed{1} \end{array}\right], \left[\begin{array}{ll} \text{LABEL} & \boxed{l6} \\ \text{REL} & \textit{a} \\ \text{DREF} & \boxed{2}\textit{at} \\ \text{RES} & \boxed{l7} \\ \text{SCOPE} & \boxed{l8} \end{array}\right], \left[\begin{array}{ll} \text{LABEL} & \boxed{l7} \\ \text{REL} & \textit{secretary} \\ \text{DREF} & \boxed{2} \end{array}\right], \\ \left[\begin{array}{ll} \text{LABEL} & \boxed{l4} \\ \text{REL} & \textit{distr\_rel} \\ \text{ARG1} & \boxed{3} \\ \text{ARG2} & \boxed{1} \\ \text{SCOPE} & \boxed{l5} \end{array}\right], \left[\begin{array}{ll} \text{LABEL} & \boxed{l9} \\ \text{REL} & \textit{eq\_rel} \\ \text{ARG1} & \boxed{4} \\ \text{ARG2} & \boxed{2} \\ \text{SCOPE} & \boxed{l10} \end{array}\right], \left[\begin{array}{ll} \text{LABEL} & \boxed{l} \\ \text{REL} & \textit{hire} \\ \text{ARG0} & \boxed{e} \\ \text{ARG1} & \boxed{3} \\ \text{ARG2} & \boxed{4} \end{array}\right] \end{array}\right\rangle \end{array}\right]$$

Since the semantic representation is still scopally underspecified, the indefinite can have a wide or narrow scope relative to the distribution. The typing *at(omic)* of the complement NP 'a secretary' forces it to be resolved non-distributively as *eq_rel*, regardless of how the subject is resolved, since that is the only resolution consistent with the constraints in (33).

Conversely, the collective reading obtains if *pl_res* is resolved as *eq_rel*:

(40)
$$\left[\begin{array}{l} \text{SUBORD}\ \langle \boxed{l4} = \boxed{l3}, \boxed{l} \leq \boxed{l5}, \boxed{l9} = \boxed{l8}, \boxed{l} \leq \boxed{l10} \rangle \\ \text{CONDS} \left\langle \begin{array}{l} \left[\begin{array}{ll} \text{LABEL} & \boxed{l1} \\ \text{REL} & \textit{some} \\ \text{DREF} & \boxed{1}\textit{non-at} \\ \text{RES} & \boxed{l2} \\ \text{SCOPE} & \boxed{l3} \end{array}\right], \left[\begin{array}{ll} \text{LABEL} & \boxed{l2} \\ \text{REL} & \textit{lawyers} \\ \text{DREF} & \boxed{1} \end{array}\right], \left[\begin{array}{ll} \text{LABEL} & \boxed{l6} \\ \text{REL} & \textit{a} \\ \text{DREF} & \boxed{2}\textit{at} \\ \text{RES} & \boxed{l7} \\ \text{SCOPE} & \boxed{l8} \end{array}\right], \left[\begin{array}{ll} \text{LABEL} & \boxed{l7} \\ \text{REL} & \textit{secretary} \\ \text{DREF} & \boxed{2} \end{array}\right], \\ \left[\begin{array}{ll} \text{LABEL} & \boxed{l4} \\ \text{REL} & \textit{eq\_rel} \\ \text{ARG1} & \boxed{3} \\ \text{ARG2} & \boxed{1} \\ \text{SCOPE} & \boxed{l5} \end{array}\right], \left[\begin{array}{ll} \text{LABEL} & \boxed{l9} \\ \text{REL} & \textit{eq\_rel} \\ \text{ARG1} & \boxed{4} \\ \text{ARG2} & \boxed{2} \\ \text{SCOPE} & \boxed{l10} \end{array}\right], \left[\begin{array}{ll} \text{LABEL} & \boxed{l} \\ \text{REL} & \textit{hire} \\ \text{ARG0} & \boxed{e} \\ \text{ARG1} & \boxed{3} \\ \text{ARG2} & \boxed{4} \end{array}\right] \end{array}\right\rangle \end{array}\right]$$

Our proposal thus decouples scope interactions from plural interpretation by locating the collective/distributive potential in the lexical entry of predicates. This is desirable since a NP can simultaneously be interpreted collectively and distributively without altering the possible scopal ambiguities that arise in relation to other arguments (Hoeksema 1983; Dowty 1986; Roberts 1987:121-122):

(41) a. The boys met at the pub and had a beer.
b. Some kids gathered around her, closed their eyes, and made a wish.
c. The kids surrounded the magician and thought of a number.

Since *pl_res* relations are lexically merged to the nominal DRSs, verbal conjuncts cannot scopally interact (note that collective verbs can also distribute, see §3.4 (52)). Also, we believe VP coordination does not establish a scope island, as generalized quantifiers are able to outscope an external argument:[7]

(42) a. The White House is very careful about this. An official representative will personally read each document and reply to every letter.

b. We had to do this ourselves. By the end of the year, some student had proof-read every document and corrected each theorem.

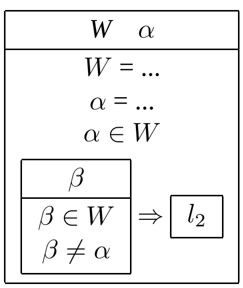
In relative clauses, we assume that these can attach to full NPs and access the restrictor label of the modified NP, so that the relativized argument is semantically identified with the restrictor (e.g. NP[RESTR [1]] and RelC[MOD|L-MIN [1]]).[8]

3.3 Reciprocal Anaphora

Reciprocals like *each other* are often seen as second-order operators that yield pairs of distinct, universally quantified referents. Instead of redefining our notions of subcategorization and variable binding entirely, we follow Heim et al. (1991) and propose an alternative account where reciprocals are regular arguments.

In van der Sant (1992) anaphora are processed in the semantics, through accommodation and resolution. Inspired by this insight, we suggest that *each other* introduces two anaphoric referents which must be locally accommodated and bound, W and α below, as well as a series of semantic conditions:

(43) l_1:



The above conditions force a distributive reading of the binder of W, by also requiring that a member α be locally accessible. The distribution over members distinct from α interacts with the distribution of the binder of W, yielding reciprocation:

(44) The boys hate each other.

$\exists(\mathsf{X}, \mathsf{boys}(\mathsf{X}), \forall(\mathsf{k}, \mathsf{k}\in\mathsf{X}, l_1))$ $\quad$ $\exists(\mathsf{W}, \mathsf{W}{=}..., \exists(\mathsf{z}, \mathsf{z}{=}...\wedge \mathsf{z}\in\mathsf{W} \wedge \forall(\mathsf{w}, \mathsf{w}\in\mathsf{W} \wedge \mathsf{w}\neq\mathsf{z}, l_2)))$

$l_3\colon \mathsf{hate}(\mathsf{e}, \mathsf{k}, \mathsf{w})$

A plural local o-commander will be the binder for W, taking wide scope. A binder for α is found under the scope of the distribution introduced by the verb:

[7] I owe these examples to Ivan Sag (p.c.).

[8] For scope islands for generalized quantifiers see the feature TOP in Chaves (2002).

(45) $\exists(X, boys(X), \forall(k, k{\in}X,$
$\quad\exists(W, W{=}X, \exists(z, z{=}k \wedge z{\in}W \wedge \forall(w, w{\in}W \wedge w{\neq}z, hate(e, k, w))))))$

The verb predicate needs only to access the main discourse referent w, just like in other argument NPs. Different conditions might be adopted to cope with well-known vagueness effects of reciprocity (see Dalrymple et al. (1998)). This approach works similarly for mixed predicates and reciprocal transitive collectives, by forcing a distributive reading of the binder. The AVM corresponding to (43) is:

$$\begin{bmatrix} \textit{recip} \\ \text{INDEX}\ \boxed{w} \\ \text{LS}\ \begin{bmatrix} \text{L-MAX}\ \boxed{l1} \\ \text{L-MIN}\ \boxed{l7} \end{bmatrix} \\ \text{SUBORD}\ \langle\rangle \\ \text{CNDS}\left\langle \begin{bmatrix} \text{LBL}\ \boxed{l1} \\ \text{REL}\ \textit{exists} \\ \text{DREF}\ \boxed{W}\textit{non-at} \\ \text{RSTR}\ \boxed{l2} \\ \text{SCOP}\ \boxed{l3} \end{bmatrix}, \begin{bmatrix} \text{LBL}\ \boxed{l2} \\ \text{REL}\ = \\ \text{ARG1}\ \boxed{W} \end{bmatrix}, \begin{bmatrix} \text{LBL}\ \boxed{l3} \\ \text{REL}\ \textit{exists} \\ \text{DREF}\ \boxed{z} \\ \text{REST}\ \boxed{l4} \\ \text{SCOP}\ \boxed{l5} \end{bmatrix}, \begin{bmatrix} \text{LBL}\ \boxed{l4} \\ \text{REL}\ = \\ \text{ARG1}\ \boxed{z} \end{bmatrix}, \begin{bmatrix} \text{LBL}\ \boxed{l4} \\ \text{REL}\ \in \\ \text{ARG1}\ \boxed{z} \\ \text{ARG2}\ \boxed{W} \end{bmatrix}, \begin{bmatrix} \text{LBL}\ \boxed{l5} \\ \text{REL}\ \textit{every} \\ \text{DREF}\ \boxed{w} \\ \text{REST}\ \boxed{l6} \\ \text{SCOP}\ \boxed{l7} \end{bmatrix}, \begin{bmatrix} \text{LBL}\ \boxed{l6} \\ \text{REL}\ \in \\ \text{ARG1}\ \boxed{w} \\ \text{ARG2}\ \boxed{W} \end{bmatrix}, \begin{bmatrix} \text{LBL}\ \boxed{l6} \\ \text{REL}\ \neq \\ \text{ARG1}\ \boxed{w} \\ \text{ARG2}\ \boxed{z} \end{bmatrix} \right\rangle \end{bmatrix}$$

Since this a semantic-based approach, it is necessary to reformulate HPSG's Binding Theory in order to allow the interleaving of accommodation constraints and o-command constraints. We cannot pursue this issue presently, and will raise the suggestion that Principle A be extended so that locally o-commanded *recip* pronouns have the respective '=' binding restrictions locally accommodated and bound.

Note that wide or narrow scope of set-formation in 'every man and every woman hate each other' yields *all-on-all* or *pair* reciprocal readings respectively. For instance, in the hydra in (46) the distribution outscoping the reciprocal is triggered by *pl_res* of the distributive verb *hate* (below, $recip(w, \ldots)$ abbreviates (43)):

(46) Every gangster and every drug dealer who hate each other argued.
$\forall(x, gangster(x), \forall(y, drugdealer(y),$
$\quad\exists^c(Z,\ x \in Z \wedge y \in Z \wedge \forall(k, k \in Z, recip(w, hate(e, k, w)))\ ,\ argue(e', Z))\ ))$

In this reading, the gangsters that hate mobsters (and vice-versa) argued. Other difficult cases like the one below can also be captured:

(47) The linguists quoted each other's paper.
$\exists(X, linguists(X), \forall(k, k \in X, \exists(y, paper(y) \wedge recip(w, of(y, w)), quote(e, k, y))))$

Higginbotham (1980) and others note an ambiguity in (48), where either John and Mary think to be in love with each other, or each thinks himself in love:

(48) John and Mary think they love each other.

We disagree that this effect is due to *each other*, since the same readings arise without the reciprocal. Like (48), (49) has a second reading where each individual thinks himself to be smart (a *de se* reading of *they* in indirect discourse):

(49) John and Mary think they are smart.

3.4 Intermediate Level Readings

Kamp and Reyle (1993) adopt a lattice-theoretical model theory for plurals, based in Link's mereologic logic, originally intended as a first-order account of pluralities. Link (1984) raises several objections against using sets and higher-order logic to represent plurals, most of which are philosophical, but one which is semantic: using sets leads to the wrong predictions such as the truth of (50) below.

(50) Peter, Paul, and Mary have three elements.

We reject this argument because it seems to mix natural language with metalanguage (see Lønning (1997:1050)).[9] However Link (1998a) shows that his logical framework is actually powerful enough to represent second-order sentences. The mereology account is further complicated by additional operations such as group formation (Hoeksema, 1983; Link, 1984; Landman, 1989) or second-order *cover* operators (Gillon, 1987; Schwarzschild, 1990), required to deal with intermediate-level readings of well-known examples like the ones seen in (51):

(51) a. The boys and the girls were separated.
b. [Blücher] and [Napoleon and Wellington] fought against each other.
c. The boys and the girls got $10.000 for the match.
d. The landlords and the tenants who hate each other argued endlessly.

The above can be interpreted distributively over the conjunct members or over the collection of atomic individuals (e.g. separating boys from girls vs. separating kids). The group approach can become formally very complex and somewhat redundant (Landman 1989; Krifka 1991; Landman 2000:162-164). For instance Link (1998b:30) notes that in Landman's system, iterative group formation generates a structure with $2^{33\,000}$ nodes out of just 4 base atom types. Type-shifting operations over the nodes of such vast lattices only make matters worse. We believe that the domain should allow processing to be computationally tractable for psycholinguistic plausibility reasons: when someone utters a sentence about most, few or all of the books and magazines on a shelf, no cognitive pitfall is apparent. Similar problems have been raised concerning the various proposals of covers and partitions, criticized in Lønning (1991), Krifka (1991), and Lasersohn (1995:132-141) for their linguistic inadequacy and/or their combinatorial explosion of readings.

Since we have adopted set-formation, we can capture the two kinds of distributivity required for (51) straightforwardly. In intermediate readings, our distributive relation with '$\in$' picks up the immediate members of a (simple or complex) non-atomic referent. In full distributive readings the complex plurality Z is reinterpreted as a standard flat sum of atomic individuals, so that the distribution relation can now distribute over the individuals. Similarly for collective verbs:

(52) The boys and the girls gathered outside.

[9] The argument would also apply to Link's sums: 'Peter, Paul, and Mary have three parts.'

In an intermediate reading one only needs to distribute over members of Z, and in a collective reading one takes the sum of the atomic individuals in Z. There seems to exist no reason to interpret Z directly in the model, with a higher-order entity. We can view variables quantified by $\exists^c$ as mere temporary stores for the extensions of the conjuncts, construed via membership '$\in$' to Z. Krifka (1991) proposes a similar move in DRT, using meta-variables in the discourse level. Set-formation can also be ordered (via dynamic sets or a partial order relation), to deal with *respectively* readings without complicating the modeling structures (e.g. as in group formation in Link (1984)). Thus 'set' formation does not force us to commit to higher-order logic. However if one is inclined to do so, one may adopt generalized models and recast a second-order setting into a many-sorted first-order logic (cf. van Benthem and Doets (1983) and Lønning (1997:1020–1028)). Here, contextually restricted pluralities can be provided by the model so that one may use bounded (or guarded) fragments to avoid the problems caused by quantifying over arbitrary entities. See van Benthem (2005) for recent formal results.

4 Conclusion

This paper proposes a uniform and compositional analysis of pluralites, with particular focus on NP coordination. We consider distributive and collective readings, as well as scope ambiguities and anaphora. It is shown how the interaction between NP conjuncts can capture different plural readings in reciprocal environments. Underspecification techniques are used to cope with plural and scope ambiguities efficiently, in a DRT/HPSG interface based in Frank and Reyle (1995).

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