On the Interpretation of Three-Dimensional Syntactic Trees

Friederike Moltmann
Massachusetts Institute of Technology

Introduction

Within generative syntax it has been proposed that coordinate sentences should be analysed by three-dimensional phrase markers (cf. Goodall 1985, Muadz 1991). We will show that three-dimensional syntactic trees allow for a syntactically and semantically adequate treatment of a certain type of coordinate construction which has often puzzled syntacticians working on coordination as well as semanticists working on plurals. The construction is illustrated in (1).

(1) John bought and Mary sold a total of ten cars.

In the reading that is relevant here, (1) can describe a situation in which John bought four cars and Mary sold six other cars. In this construction, roughly speaking, an element that may take a collective 'antecedent' takes an 'antecedent' that consists of parts of conjuncts. Thus, in (1) the 'antecedents' of *a total of* consists of the parts of the clausal conjuncts *John* and *Mary* and *bought* and *sold*.

On the basis of a slight extension of Muadz' theory of coordination and general rules of how to interpret three-dimensional syntactic trees, we will show that the construction in (1) can receive an analysis that explains a number of syntactic and semantic peculiarities of the construction.

1. The phenomenon

Let us first introduce some terminology that will facilitate the discussion. In the description of (1) we have said that *a total of* takes a collective 'antecedent'. Clearly *a total of* does not take an antecedent in the traditional sense in which an antecedent refers to an entity the anaphor refers to. But still expressions like *a total of* require a syntactic relation to some other elements in the sentence in order to be semantically evaluated; for instance *a total of* in (1) is related to both the NPs *John* and *Mary* and the verbs *bought* and *sold*. In this more general sense, I will refer to those other elements as 'antecedents'. As a 'collective antecedent' I will refer to an antecedent that denotes a group entity. For instance, plural NPs or conjoined verbs can be collective antecedents.

The construction exemplified by (1) appears in a variety of ways with a variety of elements taking a collective antecedent. This is illustrated in (2) - (4) with four different constructions, some of which occur both with IP and NP conjunction.

Right Node Raising
(2) *John* solved and *Mary* will solve the *same* problem / *related* problems / two problems *each*.
Relative Clause Extraposition

(3) a. Mary met a *man* and John met a *woman who knew each other well*..
b. every *man* and every *woman who danced together*

ATB wh movement

(4) a. How many books *each* did *John* write and *Mary* read?
b. Which pictures of *themselves* did *John* like and *Mary* hate?

IP/NP adjunction

(5) a. On the *same* day / *Together* / *Independently* / *Simultaneously* Mary *sang* and John *played*.
b. a *man* and a *woman* from the *same* city / with *similar* interests / with *a total of* ten relatives

In (2), we have the internal reading of *same* and *related* which take the parts of the conjuncts *John* and *Mary* as antecedents or *solves* and *will solve* given the view of Carlson (1987) and Moltmann (to appear), in which relational adjectives in the internal reading take events as antecedents. So-called binominal *each* in (2), a construction discussed most extensively by Safir/Stowell (1988), takes *John* and *Mary* together as a plural antecedent. In (5) the 'collective adverbials' *together, independently* and *simultaneously*, which take group events as semantic antecedents, take *sang* and *played* together as syntactic antecedents (see Lasersohn 1990 for an event-based analysis of *together*) .

Constructions such as (1-5) have been noted in various places in the literature. For relational adjectives and *a total of* in NPs in Right Node Raising constructions, the construction has first been noted by Abbott (1976). (See also Gazdar et al. 1982.) For relative clause extraposition, the construction has been discovered by Perlmutter/Ross (1970). For adverbs containing relational adjectives and collective adverbials such as *together*, the construction has extensively been discussed by Jackendoff (1977). All these authors have essentially only mentioned the constructions as a problem for traditional syntactic and semantic accounts of coordination and plurals, without making a general attempt of a syntactic or semantic solution. The semantic analysis of Link (1984) is restricted to relative clauses with NP coordination.

The elements that may enter the construction in English include *a total of*, relational adjectives, binominal *each*, plural reflexives in picture NPs and collective adverbials. This might suggest that in fact all elements that take collective antecedents may enter the construction. However, this is not the case. In English, for instance the reciprocal *each other* and simple plural reflexives may not enter the construction:

(6) * *John* hates and *Mary* likes *each other* / *themselves*.

Furthermore, languages differ with respect to which elements may take a collective antecedent consisting of parts of conjuncts (see Moltmann, forthcoming).

An important constraint, which we will note at this point in order to characterize the construction appropriately, is the restriction to coordinate structures. That is, the parts constituting the collective antecedents have to belong to different conjuncts. This is seen in (7).

(7) a. * A *man* saw a *woman who had danced together*.
b. * John met a *man* with a *dog who were quite similar*.

Let us now clarify why exactly the constructions in (1-5) present a problem for the traditional views on coordination and plurals.

2. The problem

The problem that the construction in (1-5) poses is that there is no syntactic structure compatible with standard assumptions that could provide the basis for a semantic interpretation compatible with standard assumptions. Consider (1). There are two possible syntactic structures on which the interpretation of (1) could be based. However, it can easily be seen that both of them yield the wrong semantic result. First, (1) cannot be interpreted as if *a total of ten cars* were in a position in each conjunct. That is, (1) cannot be interpreted as (8), which clearly means something different.

(8) John bought a total of ten cars and Mary sold a total of ten cars.

Second, (1) in the relevant reading cannot be interpreted appropriately if *a total of ten cars* was related to two traces in the two conjuncts, as in (9).

(9) [John bought t and Mary sold t] a total of ten cars.

The only way to evaluate (9) in a way different from (7) would be the following. *A total of ten* counts the cars that John bought and that Mary sold. But this implies that John bought the same cars that Mary sold. But crucially (1) can describe a situation in which John bought five cars which are different from another five cars which Mary sold.

The interpretation of *a total of ten cars* is unproblematic when *John* and *Mary* and *bought* and *sold* are coordinated by phrasal conjunction as in (10).

(10) John and Mary bought and sold a total of ten cars.

Here *and* is not Boolean *and*, but rather the *and* of group formation, which yields for *John and Mary* a group term referring to John and Mary as a group and for *bought and sold* a predicate describing group events of selling and buying. (See Link 1983 and others for the interpretation of *and* by group formation.)

Clearly, one would expect that the same semantic operation evaluating *a total of* in (10) applies to (1). Furthermore, as is most commonly assumed, one might want to maintain the principle that group formation as a semantic operation of sentence semantics is restricted to plurals and categories conjoined by *and*.[1] Thus group formation should not apply to the relevant terms in (1). Let me call these two assumptions 'the assumption of semantic invariance' and 'the assumption of the syntactic basis of group formation'.

(11) The Assumption of Semantic Invariance
The same semantic rules apply for the interpretation of *a total of, same, each* etc. in (1-5) as apply in 'simple plural sentences' such as (10).
(12) The Assumption about the Syntactic Basis of Group Formation
Group formation (as part of sentence grammar) can apply to constituents only on the basis of the category plural or *and*.

Thus, the construction under discussion constitutes a problem precisely because of the assumptions (11) and (12) on the one hand and standard assumptions about the syntactic structure of (1-5) on the other hand. In the next section, we will discuss possible approaches to handle the construction and then present our own.

3. The approach

The only way to deal with the construction is either to give up (11) or (12) or the standard assumptions about the syntactic structure. To give up (11) seems highly implausible. A more plausible approach to the construction could be based on abandoning (12).

Such an approach was taken by Hoeksema (1986) within the framework of Discourse Representation Theory (Kamp 1981). Hoeksema did not assume that group formation requires the category plural or *and*, but proposed that in the case of (1-5) it applies to discourse referents that have been introduced independently by the conjuncts. In this account, first *a man* and *a woman* introduce two discourse referents x and y in a discourse representation structure. Then the operation of group formation applies to x and y and yields a group discourse referent z. The relative clause now is evaluated with respect to the resulting discourse representation structure, modifying z.

The problem with this account is that it is far too unrestrictive. For instance, it cannot predict (and incidentally Hoeksema denies the facts) that the construction is possible only in coordinate structures. There are many other purely syntactic constraints on the construction that this approach, which relies on semantic flexibility, could not account for. We will come to some of those in section 5.

We will take a different approach. Instead of giving up standard assumptions about the semantics of group formation, we will give up traditional assumptions about the syntactic structures of the constructions in (1-5). That is, we will assume nonstandard syntactic structures. These syntactic structures are based on three-dimensional phrase markers.

Three-dimensional phrase markers have been proposed for coordinate structures within Generative Grammar most notably by Goodall (1987). For a number of reasons, though, we will not assume Goodall's conception of three-dimensional phrase markers, but rather the one developed more recently by Muadz (1991) (see Moltmann, forthcoming, for a comparison of the two theories).

The basic idea in employing three-dimensional phrase markers for the constructions in (1-5) is that the parts of the conjuncts that form the collective antecedents are 'implicitly coordinated'. Thus in (1) *John* and *Mary* and *sold* and

bought are implicitly coordinated. Furthermore, we will propose that structures with implicit coordination receive two partial interpretations, one which evaluates the implicit phrasal coordinations, and one which evaluates the explicit clausal (or NP) coordination. These two partial interpretations have to be appropriately combined to yield the full interpretation of the sentence. Crucially, the evaluation of the sentence with respect to the implicit coordinations also evaluates the element taking a split collective antecedent. In this partial interpretation (1) comes out as roughly equivalent to (9) repeated here as (13).

(13) John and Mary bought and sold a total of ten cars.

(13), however, does not represent all the information represented by (1). In particular, unlike (1), (13) does not specify whether John did the buying and Mary the selling or John did the selling and Mary the buying or John and Mary together did the selling and buying, or perhaps John and Mary did the buying and Mary did the selling. However, this information will be represented in the second partial interpretation of (1).

In the partial interpretation of the clausal conjunction of (1), the semantic effect of *a total of ten cars* is disregarded and the NP is instead evaluated as a free variable, which will later be bound by an operator relating to *a total of ten cars* in the first partial interpretation. In fact the value of this variable will be a subgroup of the cars that *a total of ten cars* refers to. In this interpretation (13) comes out as roughly equivalent to (14).

(14) John bought some of the cars and Mary sold some of the cars.

(14) clearly specifies that John did the buying and Mary the selling.

In the next section , we will present the for the relevant features of the conception of three-dimensional phrase markers by Muadz (1991). Then we will extend Muadz' theory somewhat and introduce the notion of implicit coordination. After that, we will be able to show how a semantic interpretation of three-dimensional phrase markers can be conceived in general and how it applies to the syntactic structures proposed for the constructions in (1-5).

4. The syntactic background: Muadz (1991)

4.1. The basic idea

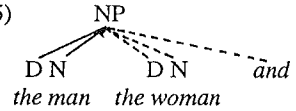
There are two basic ideas in Muadz' theory of coordination. The first one is that coordination consists in the base-generation of a node dominating several expansions which are not linearly ordered. This is captured by an extension of the usual phrase structure rules as in (14):

(14) A --> $\langle B_1, ..., B_n \rangle$J, where B_i is a legal expansion of A and J a coordinator.

Let me call a node that dominates several expansions a **'splitting node'**.

Given (14), *the man and the woman* will have the structure in (15), where the NP node is a splitting node dominating two expansions and a coordinator

(15)



Crucial in Muadz' theory is the notion of a **plane**. As defined by Muadz, a plane of a three-dimensional tree is a subtree which is obtained by selecting one of the expansions of each splitting node. Thus, in (15) we have two planes, one which consists in the subtree with the terminal nodes *the man* and another one which consists in the subtree with the terminal nodes *the woman*.

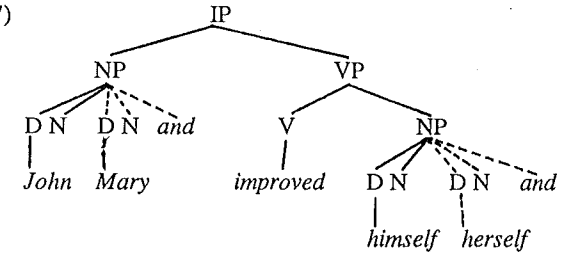
The second basic idea in Muadz' theory is that grammatical principles such as those of Theta Theory, Case Theory and Binding Theory apply to coordinate structures in the standard way, namely by applying to the individual planes.

Let us illustrate the assumptions of Muadz' theory with a more complex example, namely (16) in the 'respectively' reading.

(16) John and Mary improved himself and herself (respectively).

The syntactic representation of (16) is in a simplified fashion given in (17).

(17)



In the 'respectively' reading, (16) involves two planes, which are represented in (18):

(18) plane 1: John$_i$ improved himself$_i$.
plane 2: Mary$_j$ improved herself$_j$.

The verb *improved* and the V node dominating it are contained in both planes. Therefore, they are called **'shared nodes'**.

We see in (18) how Binding Theory applies in individual planes: *himself* is is in the ordinary way bound by *John* in the first plane and *herself* by *Mary* in second plane.

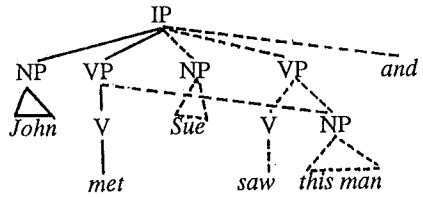
Muadz makes an important assumption about the semantic interpretation of three-dimensional trees. Three-dimensional trees are interpreted by evaluating the

separate planes and combining the results by the semantic operation associated with the relevant coordinator. Thus (16) is interpreted by evaluating *John improved himself* and *Mary improved herself* and conjoining the results by Boolean conjunction. We will see later that if this assumption is to be maintained, the notion of a plane has to be modified. Otherwise it will lead, for instance, to an unlimited scope of a coordinator.

4.2. A further application: Right Node Raising

Muadz' applies his theory to another coordinate construction that is relevant for the present discussion, namely Right Node Raising (RNR). In Muadz' account, Right Node Raising structures do not come about by movement, but rather are base-generated. Nodes that 'have undergone' RNR are repesented by nodes that are dominated by several projection. Consider (19a). (19a) is represented as in (19b), where the NP node dominating *this man* is dominated both by the VP node dominating *met* and the VP node dominating *saw*.

(19) a. John met and Sue saw this man.
b.



We will call a multiply dominated node a **'joining node'**. Joining nodes are base-generated, but subject to certain well-formedness conditions, in particular they have to be rightmost in a phrase marker in English.

Given these basics of the conception of three-dimensional phrase markers, we will now show how it can be extended to allow for implicit coordination in the constructions (1-5).

5. Implicit coordination

Let us consider again (1), repeated here as (20):

(20) John bought and Mary sold a total of ten cars.

What we what to achieve is that *John* and *Mary* and *bought* and *sold* are implicitly coordinated. This notion of implicit coordination can be straightforwardly represented within the three-dimensional phrase marker approach. As with explicit coordination, the idea that *John* and *Mary* in (20) are implicitly coordinated would simply mean that they are dominated by one and the same splitting NP node. The only difference between explicit and implicit coordination would be that in the first case, but not in the second one, the splitting node also dominates an overt

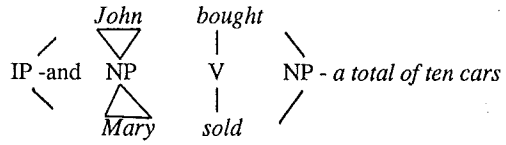
coordinator. Thus we can give the following definitions of explicit and implicit coordination:

(21) a. Constituents C_1,... ,C_n are explicitly coordinated iff C_1,... ,Cn are dominated by the same node X which also dominates a coordinator
b. Constituents C_1, ...,C_n are implicitly coordinated iff C_1, ... , C_n are dominated by the same node X which does not dominate a coordinator.

A further assumption we have to make is that implicit coordination is semantically evaluated by group formation like explicit phrasal conjunction; thus, for instance, the implicit coordination of *John* and *Mary* in (20) is evaluated as the group consisting of John and Mary.

The syntactic structure of (20) now looks in a simplified notation as follows:

(22)



The V node dominating *bought* and *sold* in (22)is not only a splitting node, but also a joining node: it is dominated both by the VP node that is a sister of the NP node dominating *Mary* and the VP node that is a sister of the NP node dominating *John*. Thus, the V node can appropriately be called a **'splitting/joining node'**.

The possibility of splitting/joining nodes requires an extension of Muadz' theory: joining nodes should not only be allowed in Right Node Raising contexts (where the node has to be rightmost in the phrase marker), but also in those cases in which the node is a splitting node not dominating a coordinator. For reasons of space, we will not go into how this extension should be formally implemented. But in any case we will assume that splitting/joining nodes are base-generated. Furthermore, they are subject to certain well-formedness conditions. For instance, splitting/joining nodes not dominating a coordinator should be able to occur in a phrase marker only if they are dominated by a node dominating a coordinator. This is stated in (23).

(23) A joining/splitting node that does not dominate a coordinator must be dominated by a node dominating an overt coordinator.

(23) might actually have a derived status and follow from conditions on the interprettion of a three-dimensional phrase markers.

We have now given a syntactic representation of constructions such as (1-5) in which the elements taking collective antecedents can take antecedents of the syntactically appropriate sort, namely implicitly coordinated categories. Thus, in this respect, the structure of the examples in (1-5) is parallel to simple plural sentences. However, it is not yet clear how the semantic evaluation of these three-

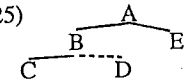
dimensional syntactic structures should proceed. We will come to the interpretation of the structures in the next section, where we will first propose a way to interpret three-dimensional trees compositionally in general.

6. The formal semantic account: Interpreting three-dimensional syntactic trees

6.1. The problem of the interpretation of three-dimensional syntactic trees

Three-dimensional syntactic trees raise a general conceptual and empirical issue about how they should be interpreted compositionally. Consider the simple tree in (25), where B is a splitting node.

(25)



There are in principle two ways, or two 'directions', in which (25) could be interpreted. First, C and D, that is all expansions of the splitting node B, are first evaluated as a unit and then the resulting semantic value is combined with the interpretation of E. Second, first C and E are interpreted as a unit and simultaneously D and E, and then the semantic values of CE and of DE are combined. In the first case, the interpretation of (25) proceeds in a 'local crossplanar' way; in the second interpretation, first the individual planes are evaluated and then the results are semantically combined.

Recall from section 4.1. that Muadz had intended only the second strategy of interpretation as the way in which three-dimensional trees are evaluated. The case he had in mind was primarily 'respectively' sentences, which were interpreted as the conjunction of several propositions corresponding to the individual planes, rather than as a single proposition about group objects. Let us again consider the example (16) repeated here as (26).

(26) John and Mary improved himself and herself (respectively).

In order to get the intended interpretation, the syntactic basis for the interpretation of a (simple) three-dimensional tree can be conceived in the following way. Every tree T is assigned a set of planes such that each expansion of a splitting node in T is contained in such a plane. Furthermore, a plane assignment is associated with a set of one or more occurrences of a coordinator. The notion of a plane assignment is given in (27):

(27) The Notion of a Plane Assignment (first version)
Let T be a three-dimensional phrase marker , A a set of expressions, B a set of phrase markers, then <A, B> is a **plane assignment** of T (<A, B> ∈ PA(T)) iff (i) - (iii) hold:
(i) all elements in A are occurrences of the same coordinator J,

(ii) all elements T' of B are two-dimensional subtrees of T,
(iii) for each expansion X of a splitting node Y of T, X is part of some T'∈ B.

Thus for (26) we have the following plane assignment:

(28) <{*and*$_1$, *and*$_2$}, {*John improved himself, Mary improved herself*}> ∈ PA(T)

The semantic interpretation of a three-dimensional phrase marker is based to such a plane assignment. We can give the following rule for the interpretation of a plane assignment - assuming for the sake of simplicity that coordinators denote functions applying to the set of the meanings of the conjuncts.

(29) The Evaluation of a Plane Assignment
If <A, B> ∈ PA(T), then [T] = [a]({[T']| T' ∈ B}) for some a ∈ A.

There are two kinds of cases where the second interpretation of a tree such as (25) as formalized here is not adequate - at least not with the notion of a plane as defined by Muadz. First, in this interpretation coordinators would always get maximal scope, that is, a scope which extends over the entire sentence. This is certainly not correct. Consider (30).

(30) a. John invented the rumor that Sue and Bill won the race.
b. John and Mary believe that Sue and Bill (respectively) won the race.

Maximal scope of *and* is impossible for (30a); that is, (30a) excludes a reading in which John invented two distinct noncontradictory rumors, one with the content that Sue won the race and another one with the content that Bill won the race. Similarly, the 'respectively' reading is hardly available for (30b).

A natural way to account for the limited scope of coordinators is to modify the notion of plane assignment. A plane need not be a two-dimensional subtree extending over the entire tree, but may be only a subtree of such a maximal two-dimensional subtree. I will call the three-dimensional subtree that corresponds to the scope of the coordinator, the **'domain'** of the coordinator. Thus the domain of the second occurrence of *and* in (30b) presumably is the three-dimensional subtree whose root is the embedded IP node. This requires the following modfication of the notion of plane:

(31) The Notion of a Plane Assignment (revised version)
A plane of a three-dimensional tree with respect to a coordinator J is a two-dimensional subtree that is obtained by selecting one of the expansions of each splitting node in the domain of D.

Another case for which the second strategy of interpretation does not work are phrasal conjunctions that are interpreted by group formation. For instance, (32)

cannot be interpreted as a conjunction of the interpretation of *John met* and *Mary met*.

(32) John and Mary met.

Again, a way to solve this problem is by modifying the notion of plane. In order to get the right interpretation of (32), one should not construe maximal planes, that is, planes rooted in the IP node, but rather planes much smaller than that, namely planes that are rooted in the NP node. One of these planes will be the tree whose only terminal node is *John*, another one will be the tree whose only terminal node is *Mary*. We get the following plane assignment for (33).

(33) <{*and*}, {*John, Mary*}>

In order to interpret (32) with respect to this plane assignment, *and* will be evaluated by group formation rather than by Boolean conjunction. For (32), we can say that the domain of *and* is the three-dimensional subtree rooted in the NP node.

In order to account for multiple phrasal conjunctions in a sentence that are interpreted by group formation (*John and Mary embraced and laughed simultaneously*), the interpretation of a three-dimensional phrase marker must now be based on a set of plane assignments, rather than a single plane assignment.

The new possibilities for plane assignments raise several questions. First, when does one have to build 'small planes' and when 'big planes'? Second, is it possible that a sentence is interpreted simultaneously with respect to small planes and with respect to big planes? In the next section, we will answer the first question partially and give a positive answer to the second question. We will argue that sentences with implicit coordination require two simultaneous partial interpretations with respect to a set of assignments of small planes and a set of assignments of big planes.

Let us conclude this section by specifying formal semantic rules for the interpretation of phrasal conjunction in general.

Consider (34).

(34) John and Mary sang and played.

(34) allows for a variety of readings. These readings include the following four situations.

1. John sang and Mary played.
2. John played and Mary sang.
3. John sang and played and Mary sang and played.
4. John sang and Mary sang and played.

We will give rules for the interpretation of (34) based on a set of 'small plane assignments' which account for all four situations. The relevant set of plane assignments to (34) consists of (35a) and (35b).

(35) a. <{*and*}, {*John, Mary*}>
b. <{and}, {*sang, played*}>

For referential NPs, the required semantic rule is given in (36), where 'sum' is an operator mapping a set of entities into its sum (cf. Link 1983 and others).

(36) Let X_1 and X_2 be referential NPs, then
[{*and*}, {X_1, X_2}] = sum([[X_1], [X_2]])

Thus the plane assignment of (34) given in (35a) will be evaluated as the group consisting of John and Mary.

We will adopt the Davidsonian view on verb meanings according to which verbs taking n arguments denote (n+1)-place relations between events and n arguments. Thus *sing* and *play* denote two-place relations between events and agents. For the evaluation of two-place predicates in general, we assume the following semantic rule:

(37) Let Y_1 and Y_2 be two-place predicates, then
[{*and*}, {Y_1, Y_2}] = {<e, x>|∃e'x'e"x"(Y_1(e', x')& Y_2(e", x") & e = sum({e', e"}) & x = sum({x', x"})}

Thus, we have for an event e and an entity x, [*sing and play*](e, x) iff e consist of two parts e' and e" and x consists of two parts x' and x" such that e' is a playing by x' or x" (or both) and e" a singing by x' or x" (or both) and both x' and x" are the agents of either e' or e". The reader can easily check that all four situations given above are captured by these rules when applied to the two plane assignments given in (35).

Let us now come back to the sentences with implicit coordination and show how they can be semantically interpreted on the basis of the notions and rules given in this section.

6.2. The interpretation of syntactic structures with implicit coordination

The basic idea for the interpretation of sentences with implicit coordination is that they involve two partial interpretations, one where our initial example (20) is equivalent to (38a) and one where it is equivalent to (38b).

(38) a. John and Mary sold and bought a total of ten cars.
b. John sold and Mary bought some of the cars.

These two partial interpretations come about by interpreting (20) on the basis of two distinct plane assignments, one where (20) is assigned small planes and a second

one where it is assigned big planes. The assignment of small planes is, of course, based on the implicit coordination of *John* and *Mary* and of *sold* and *bought*. Since there are no overt coordinators, this plane assignment will contain the empty set rather than a set of coordinator occurrences. The assignment of small planes to (20) is given in (39).

(39) The set of assignments of small planes to (20)
{<{}, {*John, Mary*}>, <{}, {*sold, bought*}>}

We will assume that when the first element of a plane assignment is the empty set, the same rules (36) and (37) apply that apply when the first element contains an occurrence of the coordinator *and*.

There are various ways to conceive of a partial interpretation of a sentence. The way we will do it in this paper (which is motivated primarily by simplicity and perspicuity) is to conceive it as a relation between events and participants that is formulated within first order logic. Thus the partial interpretation of (20) on the basis of the assignment of small planes will be the relation between events and objects given in (40).

(40) λey[sold and bought(e, [<{}, {*John, Mary*}>], y) & cars(y) & Ae'y'(sold and bought(e', [<{}, {*John, Mary*}>], y') & cars(y') --> card(y') ≤ 10))]

(40) is the relation that holds between an event e and an object y iff e is a selling-and-buying of y by John and Mary and y a group of cars and any selling-and buying event of cars y' by John and Mary is such that y' has at most ten members. The second conjunct in (40) should represent the semantic effect of *a total of*. (The adequacy of this is not so much at stake here.) (40) clearly can be construed in a compositional way; but in the present context it is not necessary to elaborate this.

(40) leaves open whether John did the selling and Mary the buying or conversely. Recall that the rule of predicate conjunction given in (37) is entirely vague in this respect. However, this information is obtained by the second partial interpretation of (20), namely the interpretation of (20) on the basis of 'big planes'.

The set of assignments of big planes to (20) is given in (41).

(41) The set of assignments of big planes to (20)
{<{*and*}, {*John bought a total of ten cars, Mary sold a total of ten cars*}>}

At first sight, the interpretation of the plane assignment in (41) seems to give the wrong results. According to (41), (20) seems to imply that John bought a total of ten cars and Mary sold a total of ten cars.

However, we will propose that by a general principle of the interpretation of planes, *a total of ten* can be disregarded in the evaluation of the plane assignment in (41). This principle says that (at least certain) elements in a plane need not be semantically evaluated if they are already semantically evaluated with respect to another plane assignment. More generally, the principle says that an element when

possible has to be evaluated only once (with respect to one of its meaningful syntactic functions). The principle is stated in (42).

(42) The Principle of the Single Evaluation of Syntactic Elements.
An element has to be semantically evaluated only once (with respect to one of its meaningful syntactic functions).

Thus, since *a total of* in (20) has already been evaluated in the interpretation of the assignment of small planes, it can be disregarded in the evaluation of the assignment of big planes. We will assume that instead the entire NP *a total of ten cars* is interpreted as a free variable in the evaluation of the big plane assignment. This variable will be bound by the lambda-operator which defines the meaning of the plane as a relation between events and objects.

The meanings of the big planes of (20) can also be conceived as relations between events and participants. Thus, one of the planes expresses the relation in (43)a., the other one the relation in (43)b.

(43) a. λey[bought(e, [*John*], y)]
b. λey[sold(e, [*Mary*], y)]

The assignment of big planes then is evaluated by applying the operation for predicate conjunction given earlier, namely (37), to the two relations expressed by the two planes. This yields the relation in (44).

(44) λye[e = sum({e', e"}) & y = sum({y', y"}) & bought(e', [*John*], y') & sold(e", [*Mary*], y")]

(44) is the relation that holds between events e and objects y iff e is the sum of two events e' and e" and y is the sum of two objects y' and y" such that e' is a buying of y' by John and e" a selling of y" by Mary.

The full meaning of (20) can now be obtained by conjoining the two partial interpretations (40) and (44) and applying existential closure to the event and the object variable. The result is given in (45):

(45) ∃ey(e = sum({e', e"}) & y = sum({y', y"}) & bought(e', [*John*], y') & sold(e", [*Mary*], y"))

There are a number of questions that still have to be answered. First of all, for the interpretation of (20) apparently both sets of plane assignments are required, rather than optional. The assignments of small planes certainly are required in order to provide an appropriate basis for the interpretation of *a total of*. Otherwise, *a total of* would not receive an interpretation at all and - one way of putting it - the sentence would constitute a violation of the Principle of Full Interpretation. But how should the assignment of big planes be necessitated? This plane assignment can be considered a consequence of the same principle: it provides the (only) basis for an

interpretation of the overt coordinator *and*. Without this plane assignment *and* would be semantically vacuous in (20).

7. Deriving syntactic peculiarities of implicit coordination constructions

Constructions with implicit coordination have a number of syntactic particuliarities that follow straightforwardly from the present account - given certain very general principles about how to establish meaningful syntactic relations in three-dimensional syntactic trees. I will first describe the characteristic syntactic properties of the construction, before giving an explanation within the three-dimensional phrase marker approach.

7.1. The observations

1. the restriction to coordinate structures
One of the properties of the construction was already mentioned at the very beginning of this paper, namely the restriction to coordination. Old and new examples are given in (46).

(46) a. * A *man* saw a *woman who had danced together*.
b. * John met a *man* with a *dog who were quite similar*.
c. * Mary *sang* because John *played simultaneously / together / independently*.

2. the anaphoric element must belong to all conjuncts
Another very general constraint is that the element that takes the split antecedent must belong to all conjuncts. Thus (47) with the meaning 'John and Mary talked and wrote independently about this book' is bad because *independently* only belongs to the first conjunct, not to the second one.

(47) *John* talked *independently* and *Mary* wrote about this book.

3. the Coordinate Structure Constraint/ATB principle
Another peculiarity of the construction is that it obeys parallel conditions to the Coordinate Structure Constraint (CSC) and the Across-the-Board (ATB) Principle. The CSC disallows the extraction of a phrase from a conjunct of a coordinate structure, as in (48a), whereas the ATB principle suspends the CSC just in case the phrase has been extracted from each of the conjuncts of the coordinate structure, as in (48b).

(48) a. * Who did John see t and Mary come?
b. Who did John see t and Mary meet t?

The constructions in which an element takes a collective antecedent composed of parts of conjuncts pattern in exactly parallel fashion. That, is, if one of the

conjuncts of a coordinate structure provides a part of the antecedent, then all of the conjuncts must do so. This is seen in (49), where a requirement parallel to the CSC is violated.

(49) a. * John met a woman, Mary met a man and Bill remained alone who have had an affair.
b. * John was upset, Mary was angry and it was raining on two days each.

4. The satisfaction of syntactic conditions on antecedent-anaphor relationships in each conjunct
A final characteristic property of the constructions in (1-5) is that any syntactic conditions on the relevant antecedent-anaphor relationship have to be satisfied in each conjunct, namely with respect to the phrase in the conjunct that forms a part of the antecedent. We will illustrate this requirement with binominal *each* and *themselves* in picture NPs. Both of these anaphors when occurring in an object NP must take an antecedent in the same minimal finite clause:

(50) a. **The women* said that Bill painted ten pictures *each*.
b. **The women* said Bill sold pictures of *themselves*.

This constraint must be satisfied in each conjunct if the antecedent is composed of parts of conjuncts. Thus, (51a) and (51b) are bad because the constraint is satisfied only in the first, not in the second conjunct.

(51) a. **John* saw and *Mary* said Bill painted ten pictures *each*.
b. * *John* sold and *Mary* said Bill sold pictures of *themselves*.

None of these four syntactic peculiarities falls out naturally in a purely semantic approach to the phenomenon such as the one Hoeksema (1986) takes. However, they are all straightforward consequences of the three-dimensional phrase marker approach advocated here given certain general and independently motivated conditions on syntactic relations in three-dimensional phrase markers.

7.2. Explaining the syntactic peculiarities

1: In the present account, the restriction of the construction to coordination follows simply from the definition of implicit coordination as multidominance. Implicit coordination requires that the phrases that are coordinated belong to distinct planes, which is possible only in a coordinate structure.

2: This constraint follows from a very general and plausible condition on how meaningful syntactic relations are established in three-dimensional syntactic trees. The condition requires that the items standing in such a relation belong to the same planes and hence one of the items (such as *independently* in (47) which belongs to only the first plane) may not belong to fewer planes than the other one (in (47) the set of phrases {*John, Mary*}, which belongs to both planes). If we call nodes and

sets of co-dominated nodes **'syntactic units'**, the principle can be stated as in (52).

(52) Condition on Syntactic Units Standing in a Syntactic Relation in a Three-Dimensional Syntactic Tree
Two syntactic units X and Y can stand in a meaningful syntactic relation in a tree T only if X and Y belong to the same planes assigned to T.

3: The correlate of the CSC and ATB principle can be derived from the Principle of Full Interpretation (FI) when it is to apply to individual planes. Applied to the present case, FI implies that an element X requiring an antecedent has to take an antecedent in each plane that X belongs to. Note that FI has been adduced in the same way by both Goodall (1987) and Muadz (1991) to derive the CSC and the ATB principle as conditions on extraction.

4: This constraint can be made to follow from another general and plausible condition on how meaningful syntactic relations are established in three-dimensional trees. This principle says that a meaningful syntactic relation is holds between two syntactic units in a three-dimensional tree only if the relation is established in the ordinary way among the units or parts of the units in individual planes.

(53) Condition on Establishing Syntactic Relations among Syntactic Units in a Three-Dimensional Syntactic Tree
A meaningful syntactic relation R holds between syntactic units X and Y in a three-dimensional syntactic tree only if for any plane that X and Y belong to, R holds between an X' and a Y', where X' is a part of X or X itself and Y' is a part of Y or Y itself.

Clearly, in (53) X' must be X itself just in case X is a shared node (and similarly for Y').

In order to facilitate readability, the conditions (52) and (53) are stated in a rather informal way. Clearly this does not exclude the possibility of a precise formulation.

Constructions with implicit coordination also exhibit a number of semantic peculiarities. In the next section, we will discuss some of them and show how they follow or can easily be made to follow from the account of the interpretation of implicit coordination constructions given earlier.

8. Deriving semantic peculiarities of implicit coordination constructions

There are two characteristic semantic properties of implicit coordination constructions we will discuss, first the semantic behavior of what we will call simple plural arguments and second a distinction between arguments and adjuncts with respect to simple plurals.

8.1. The semantic behavior of simple plural arguments

The discussion of implicit coordination constructions has centered on the example (20) which contained the expression *a total of*. The main problem was to explain how (20) could have the reading in which John sold, let's say, five cars and Mary bought another five cars. Let us call such a reading of a plural NP the **'split reading'**. The availability of a split reading for *a total of ten cars* in (20) has been explained on the basis of the fact that *a total of ten* can take implicitly coordinated antecedents and hence can be disregarded in the evaluation of (20) with respect to the clausal coordination.

An important question is whether plural NPs not modified by *a total of* allow or disallow a split reading. Let us call such NPs, that is, NPs like *ten cars, the ten cars, the cars* or *which cars*, **'simple plural NPs'**. The answer to the question is that simple plural NPs generally disallow the split reading in constructions allowing for implicit coordination:

(54) a.These two women John married and Bill proposed to.
b. Which two women did John marry and Bill propose to.

(54)a. and b. do not have a reading in which John married one of the women and Bill proposed to the other woman. But both sentences allow for the implicit coordination of *John* and *Bill* and of *married* and *proposed to*.

The following explanation of the absence of the split reading of simple plural arguments can be given within the present approach. *A total of ten* in (20) enters a relation to an antecedent, the implicitly coordinated phrases *John* and *Mary* and *bought* and *sold*. However, these antecedents themselves do not require the relation; without *a total of* the sentence is perfectly interpretable. Simple plural NPs such as *these two women* in (54a) do not enter a relation to an antecedent. They only enter the relation of argumenthood to a verb. Crucially, the relation of argumenthood is required by the verb itself. Moreover, the relation of argumenthood is required both by the verbs in the big planes (that is, by *married* in the first plane and by *proposed to* in the second plane in 54a) and by the implicitly coordinated verbs (that is, by the implicit coordination of *married* and *proposed to* in 54a). Therefore, a simple plural NP has to be an argument both in the two big planes and with respect to the implicitly coordinated verbs. Thus, the partial interpretations of (54a) on the basis of the two plane assignments have to literally represent the following two propositions. (55a) corresponds to the assignments of small planes and (55b) to the assignment of big planes.

(55) a. John and Bill married and proposed to these two women.
b. John married these two women and Bill proposed to these two women.

Clearly (55b) is incompatible with a split reading.

For the explanation of the absence of the split reading, we have relied on the fact that other elements in the sentence (namely the verbs) require a syntactic relation to the plural argument NP. This predicts that adjuncts with plural NPs should behave

differently. They should allow for the split reading. In the next subsection, we will see that this prediction is in fact borne out.

8.2. A difference between arguments and adjuncts with respect to the split reading

Plural NPs in adjuncts such as *in these two rooms* in (56) behave differently from plural NPs as verbal arguments in that they allow for the split reading:

(56) a. In these two rooms, John was born and Mary died.
b. I can't remember in which two rooms John was born and Mary died.

(56a) has two readings. First, it has the absurd reading in which John was born in the two rooms and Mary died in the two rooms. But then it also has the reading in which John was born in one of the rooms and Mary died in the other one, that is, the split reading.

The difference between arguments and adjuncts with respect to the split reading also shows up in NP coordinations that involve implicit coordination. This is seen in the contrast between (57a) and (57b).

(57) a. the husband and the fiancee of these two women
b. the man and the woman with the two black dogs

(57a), which contains a plural argument, does not allow for the split reading in which the two women have monogamous relationships. But the split reading is available for (57b), which contains a PP adjunct. (57b) can refer to the man who has one of the two dogs and the woman who has the other dog.

The difference between simple plurals in adjuncts and in arguments, as observed so far, follows immediately from the line of explanation used in the previous section: adjuncts are not required by any other element in the sentence. For this reason and by principle (42), they can be disregarded in the evaluation of a sentence with respect to a given set of plane assignments, provided they are evaluated with respect to some other set of plane assignments.

Thus, *in these two rooms* in (56a) can be disregarded in the interpretation with respect to the assignment of big planes, given that *in these two rooms* is evaluated in the interpretation of (56a) with respect to the assignment of small planes. In this case, we get the split reading of *these two rooms*. The other, absurd reading of (56a) is obtained when *in these two rooms* is evaluated with respect to big planes .

In this section, we have observed two semantic peculiarities of constructions that allow for implicit coordination, namely the unavailability of the split reading of simple plurals in arguments and the availability of the split readings of simple plural NPs in adjuncts. The difference between adjuncts and arguments has been explained on the basis of two general principles. First, elements may be semantically evaluated with respect to one of their syntactic functions just once in multiple simultaneous interpretations of a sentence. Second, an element that has a syntactic function that is required by other elements in the sentence has to always be

evaluated with respect to this function. When the second principle applies, clearly the first principle cannot apply. This is the case when simple plurals are arguments.

10. Summary

There are three aspects that distinguish the treatment of the constructions with implicit coordination given in this paper. First, the treatment was based on a rather novel type of syntactic structure. The syntactic structures that were employed consist of three-dimensional phrase markers and involve a new construction type of implicit coordination. Second, given these syntactic structures, the interpretation of elements taking collective antecedents such as *a total of*, binominal *each*, relational adjectives etc. require only independenly established semantic rules which apply in the usual way. Third, the meanings of the sentences involving implicit coordination require a new type of interpretation, a simultaneous partial interpretation of the sentence with respect to at least two different plane assignments. These partial interpretations have to be combined to yield the full meaning of the sentence.

Acknowledgments

Some versions of this paper were presented at the University of Illinois, Urbana, the University of Pennsylvania, Philadelphia, and the University of Amsterdam. I would like to thank the audiences for helpful criticism. For discussions I would like to thank in particular Noam Chomsky, Howard Lasnik and David Pesetsky.

Notes

[1] Carlson (1987) argues that the antecedent of relational adjectives such as *same* and *different* is always an event. Thus given Davidsonian event semantics, the syntactic antecedent would always be a verb. This view is in a more formal way pursued in Moltmann (to appear). However, there are also cases where relational adjectives clearly take objects as antecedents, for instance in (5b), where NPs are coordinated. In this paper, we will not commit ourselves to the view that relational adjectives always take events as antecedents, not even when there is a potential event antecedent as in (2).

[2] The view that the semantic operation of group formation is restricted to the category plural and *and* is not universally maintained. In particular , in applications of Discourse Representation Theory to plural anaphora, group formation is assumed to also apply at the level of discourse referents (see van Eijck 1983, Kamp/Reyle, forthcoming). However, then group formation arguably is not a semantic operation in the strict sense, but rather an operation of disourse semantics.

References

Abbott, B. (1976): 'Right Node Raising as a Tests of Constituenthood'. Linguistic Inquiry 7.

Carlson, G. (1987): 'Same and Different: Some Consequences for Syntax and Semantics'. Linguistics and Philosophy 10.

van Eijck, J. (1983): 'Discourse Representation Theory and Plurality'. In A.G.B. ter Meulen (ed.): Studies in Model-theoretic Semantics. Foris, Dordrecht.

Gazdar, G. / G. K. Pullum / I. A. Sag / T. Wasow (1982): 'Coordination and Transformational Grammar'. Linguistic Inquiry 13.

Goodall, G. (1985): Parallel Structures in Syntax. Cambridge University Press, Cambridge.

Hoeksema, J. (1986): 'An Account of Relative Clauses with Split Antecedents'. In M. Dalrymple et al. (eds.): Proceedings of WCCFL 5. Stanford Linguistic Student Association, Stanford University, Stanford.

Jackendoff, R. (1977): Semantic Interpretation in Generative Grammar. MIT Press, Cambridge (Mass.).

Kamp, H. (1981): 'A Theory of Truth and Semantic Representation'. In J. Groenendijk et al. (eds.): Formal Methods in the Study of Language. Mathematical Centre, Amsterdam.

Kamp, H. / U. Reyle (forthcoming): From Discourse to Logic. Ms. University of Stuttgart.

Lasersohn, P. (1990): 'Group Action and Spatio-Temporal Proximity'. Linguistics and Philosophy 13.

Link (1983): 'The Logical Analysis of Plurals and Mass Terms: A Lattice-Theoretical Approach'. In R. Baeuerle et al. (eds.): Meaning, Use and the Interpretations of Language. de Gruyter, Berlin.

------ (1984): 'Hydras. On the Logic of Relative Clause Constuctions with Multiple Heads'. In F. Landman et al. (eds.): Varieties of Fromal Semantics. Foris, Dordrecht.

Moltmann, F. (to appear): '*Same / Different* and *Each Other*. Towards a Semantic Analysis.' Linguistics and Philosophy.

---------- (forthcoming): Coordination and Comparatives. PhD dissertation, MIT Cambridge (Mass).

Muadz, H. (1991): A Planar Theory of Coordination. PhD dissertation, University of Arizona, Tucson (Arizona).

Perlmutter, D. / J. Ross (1970): 'Relative Clauses with Split Antecedents'. Linguistic Inquiry 1.

Safir, K. /T. Stowell (1988): 'Binominal *Each*'. J. Blevins et al. (eds.): Proceedings of NELS 18, Graduate Linguistic Student Association, University of Massachusetts, Amherst.

Massachusetts Institute of Technology
Department of Linguistics
20E-D213
Cambridge, MA 02139
USA
moltmann@athena.mit.edu