BINOMINAL *each* AS AN ANAPHORIC DETERMINER: COMPOSITIONAL ANALYSIS*

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1 Introduction

For many speakers, the following sentence is ambiguous:

(1) The boys lifted three tables.

It could be true under the *collective* interpretation of the subject, in which case the sentence expresses that the boys acted as a group and together lifted three tables. It could also be true in the *cumulative* reading of the sentence. In this case the boys split lifting in such a way that in total three tables were lifted - for example, because there were three boys and each of them lifted one table. Finally, the sentence could also be true if the subject gets the *distributive* interpretation, in which case the sentence expresses that each boy lifted three tables on his own.

As is well-known, the last reading can be forced by adding the distributive quantifier *each*, as in the following sentence:

(2) Each of the boys lifted three tables.

Following Choe's terminology Choe (1987), I will call the argument that is interpreted distributively the sorting key and the argument over which the sorting key distributes the distributed share. In the example above the sorting key is *the boys* and the distributed share is *three tables*.

It is common that the distributive quantifier attaches to the sorting key, as we have seen in (2). However, this does not always need to be the case. In (3) *each* appears at the end of the sentence. Yet, the example expresses the distributive reading in which the subject functions as the sorting key. That is, the reading is "each of the boys lifted three tables".

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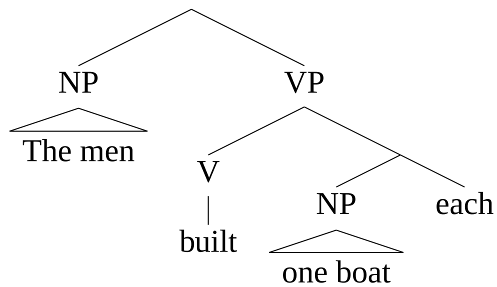
(3) The boys lifted three tables each.

From the syntactic perspective, one can think of various analyses of (3). One possibility is that *each* is a modifier to the noun phrase *three tables*. Another possibility is that *each* is a modifier to the whole verb phrase or the whole clause. Safir and Stowell (1988) argue convincingly for the first option and I will follow their conclusion. This means that (3) has the (simplified) structure shown below, in which the distributive quantifier *each* attaches to the distributed share. Following Safir and Stowell (1988) I call *each* that modifies the distributed share *binominal each* and, following Zimmermann (2002) and others, I call this instance of distributivity *distance distributivity*.

(4)



This structure raises one non-trivial question for semantics. How could *each* modify the object NP in syntax but force the distributive interpretation of the subject? While some acccounts gave up the compositional analysis of distance distributivity Choe (1987), Moltmann (1991, 1997), Balusu (2005) there are two compositional analyses thereof, Zimmermann (2002) and Blaheta (2003). In this paper I propose a novel compositional semantics for binominal *each*. In my approach, *each* is the determiner of the distributed share and is bound by the sorting key. Such an analysis is intuitively simple and more crucially, it is empirically superior to Zimmermann's and Blaheta's approach. I show that this compositional interpretation can be straightforwardly implemented in Plural Compositional DRT.

The paper is structured as follows. In Section 2, I discuss problems for the previous two analyses of binominal *each*. In Section 3 I propose a novel analysis. I introduce the framework in which the analysis can be couched (PCDRT) and then I move to the semantics of binominal *each*. In Section 4 I discuss syntactic restrictions that must supplement the semantic analysis and in Section 5 I summarize the paper and mention extensions of my account.

2 Previous compositional analyses of binominal *each*

In this overview of previous compositional analyses of *each* I follow a common assumption and treat D_{e} as the power set of the set of all entities without the empty set (Schwarzschild 1996, among others). Plural individuals are the union of atomic individuals, e.g., Alex and Sasha are $\{\textsc{Alex}\} \cup \{\textsc{Sasha}\} = \{\textsc{Alex}, \textsc{Sasha}\}$. The domain is partially ordered by inclusion, $\subseteq$. When talking about the domain e I will refer to inclusion as the part-of relation. Atomic individuals are those that have only themselves as part and nothing else, plural individuals have other entities as their part. When talking about atomic individuals, I will omit set brackets for reasons of readability, writing $\textsc{David}$ instead of $\{\textsc{David}\}$.

Blaheta (2003) proposes the semantics of binominal *each* shown in (5). Zimmermann (2002) assumes the same interpretation with two differences: first, he embeds his analysis in event semantics; second, he treats R and x as free variables in the lexical entry of *each* and assumes that

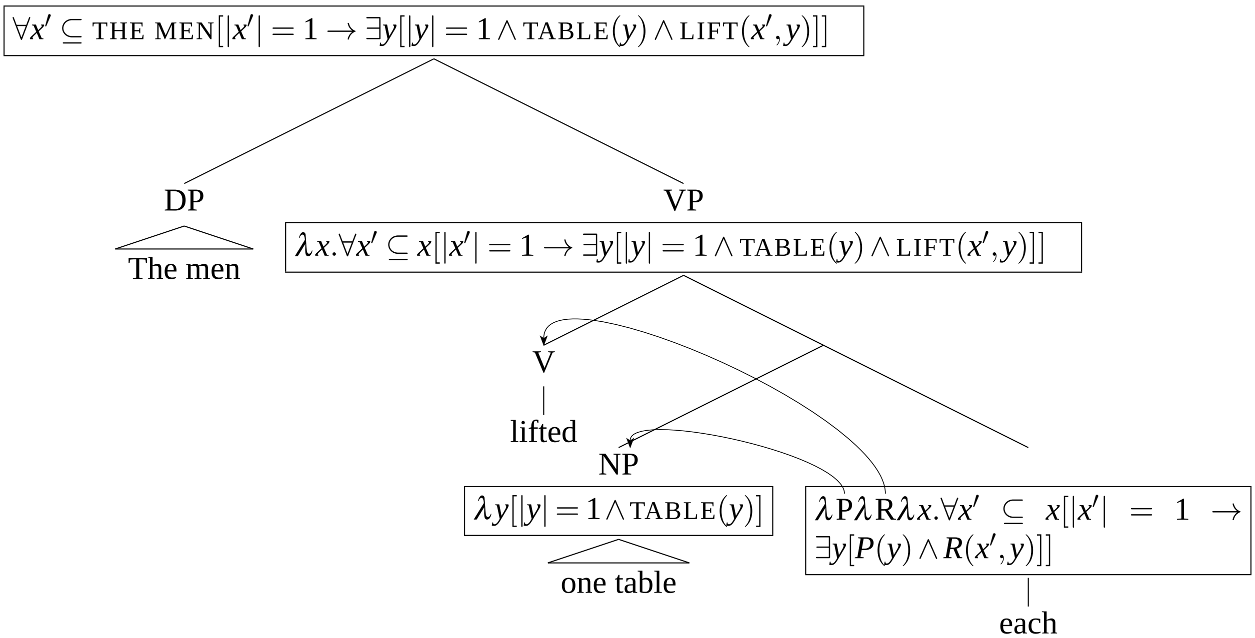


Figure 1: Annotated tree of the sentence *The men lifted one table each*

both of them are bound by the λ-prefix during semantic composition. For most cases, Blaheta's and Zimmermann's analyses make the the same prediction and Blaheta's analysis is simpler so I will use it. When the two analyses don't make identical predictions, I will differentiate between them.

(5) $[[\text{each}]] = \lambda P_{\langle e,t \rangle} \lambda R_{\langle e, \langle e,t \rangle \rangle} \lambda x_e . \forall x' \subseteq x[|x'| = 1 \rightarrow \exists y[P(y) \wedge R(x', y)]]$

In words, *each* takes three arguments: a property, a relation and an entity. It states that each atomic part of the entity is related by the relation to some entity which satisfies the property. How this works in sentences will probably become clearer in the tree of the sentence *The men lifted one table each* shown in Figure 1. *One table* is the property argument of *each*, and *lift* and *the men* are its relation and entity arguments, respectively. I annotate the most important nodes with their interpretation. The top node is true iff each of the men lifted a table, which is the correct interpretation of the sentence. Notice that we derived the correct meaning even though *each* appeared on the object NP.

2.1 Problems of Zimmermann (2002) and Blaheta (2003)

The semantics of *each* works well for the simple example discussed above. However, it has an Achilles heel: *each* always needs to find a relation which connects the distributed share to the sorting key. The problem is that binominal *each* can appear in positions where no such relation seems available. I will discuss two cases here: (i) distributed shares appearing inside an NP and (ii) *each* appearing in adjuncts.

2.1.1 Distributed share embedded in an NP

The following example is provided in Blaheta (2003).

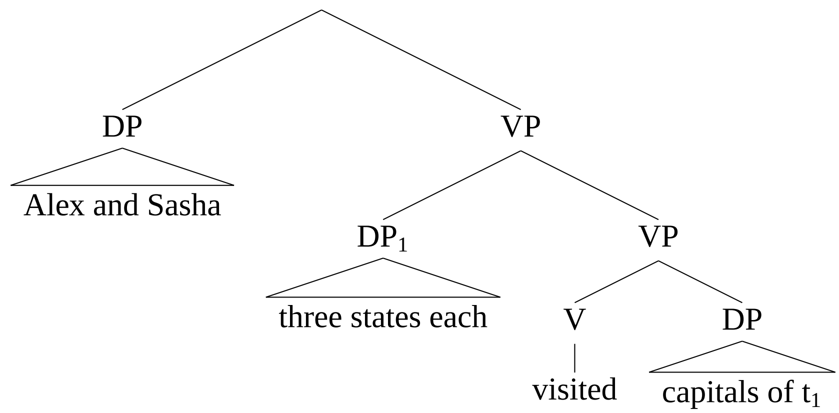


Figure 2: Attempted analysis of sentence (6)

(6) Alex and Sasha visited the capitals of three states each.

As the author notes, the example can be paraphrased by the sentence ‘Each one of Alex and Sasha visited the capitals of three states’. That is, the subject is the sorting key. What is the distributed share? In other words, to what NP does *each* adjoin? It cannot adjoin to the whole noun phrase *the capitals of three states*. We know this due to a peculiar restriction on binominal *each*: it cannot modify definites, cf. *Alex and Sasha read two/*both/*the books each* (see Safir and Stowell 1988). Thus, we know that *each* attaches to the NP *three states*. This means that *each* has to take the relation ‘$\lambda x \lambda y.x$ *visited the capitals of y*’ as its argument. The problem is that this relation is definitely not a constituent so it is not clear how it could be available to *each* in semantic composition.

One way out would be to say that *three states each* moves out of the DP and attaches to the VP *visited the capitals of*, see Figure 2. But this movement violates island constraints: the constituent with binominal *each* moves out of a definite DP and it is known that DPs are islands for covert movement May (1985), Larson (1985), Heim and Kratzer (1998). Thus, the movement shown in Figure 2 seems empirically impossible. One could also try to solve (6) by stipulating that in (6) *each* is of more complex type than in simple transitive sentences: it can percolate its meaning up, taking every word in the relation *visited the capitals of* as its argument. This might work but even if it is achieved it would complicate lexicon (we would have to have multiple entries for *each* or a lexical rule that lifts *each* from one meaning to various other ones). To conclude, examples like (6) are problematic for previous compositional accounts of binominal *each*.

2.1.2 *Each* in adjuncts

The following example is true if the subject is the sorting key. In this case the sentence can be paraphrased as ‘each of Alex and Sasha dragged three bags through four puddles’.

(7) Alex and Sasha dragged three bags through four puddles each.

The relation that *each* takes as its argument is ‘$\lambda x \lambda y.x$ *dragged three bags through y*’. However, this relation is not a constituent. One might attempt to solve this problem by saying that *four puddles each* moves and attaches to the whole VP. But again, this is a problematic assumption because normally movement out of adjuncts is impossible.

Zimmermann (2002) proposes a different solution. To see his analysis of distance distributivity in adjuncts, consider the following example, in which Alex and Sasha can function as the sorting key of the distributive reading.

(8) Alex and Sasha bought roses in two shops each.

To avoid movement out of adjuncts, Zimmermann (2002) treats *in* as a relational preposition. In (8), it relates the clausal subject and the object of the preposition *two shops each* and for this reason, it suffices to say that *each* takes the relational preposition *in* as its argument. Alternatively, if no preposition is present, as in (9) below, Zimmermann (2002) assumes that the relation can be supplied by context.

(9) The boys have knocked two times each.

Unfortunately, neither of these solutions works for (7). First, *through* does not relate the clausal subject and the prepositional object *four puddles each*. We can see this because the sentence is true even if Alex and Sasha themselves did not go through the puddles. The second solution is not viable either because the prepositional object is related to the sentence by the overt preposition *through* and therefore, it is not clear why and how context could force yet another relation to the clause on which *each* could operate. Thus, at least some examples of binominal *each* in adjuncts are problematic for Zimmermann (2002) and Blaheta (2003).

3 A new analysis of binominal *each*

3.1 Introduction

Consider the following sentence:

(10) Alex and Sasha lifted two tables.

We have seen that this sentence has (at least) three readings: the collective, cumulative and distributive one. We can represent these readings by using matrices. The first column in each matrix is the reference of the subject. The second column is the reference of the object. Finally each matrix row represents the sub-context in which the relation *lift* between the value of the first column and the value of the second column is satisfied.

(11) Collective reading:

Subject	Object
Alex and Sasha	two tables

(12) Cumulative reading:

Subject	Object
Alex	table 1
Sasha	table 2

(13) Distributive reading:

Subject	Object
Alex	two tables
Sasha	two tables

We have seen that binominal *each* forces the distributive reading, (13). My claim is that binominal *each* functions as the determiner of the distributed share, i.e., in this example it is the determiner of the NP *two tables*. It introduces a distributivity operator, δ, which scopes over the NP. Unlike standard distributivity operators (Roberts 1990, Schwarzschild 1996, Link 1998), it does not distribute directly over entities. Rather, it distributes over sub-contexts represented by rows in matrices above. It requires that each subcontext has an atomic value of the sorting key and includes the distributed share. In matrices above, *each* therefore singles out the distributive reading because the collective reading has no available sub-context with an atomic value of the sorting key and in the cumulative reading each subcontext with an atomic value of the sorting key includes only one table, not two. Thus, we correctly derive that *each* forces the distributive reading. Furthermore, since *each* distributes this way it can be treated as an anaphoric determiner. Therefore, the DP with binominal *each* is a regular quantifier and we correctly expect that it can appear in positions available to quantifiers, be these clausal adjuncts (Section 2.1.2) or DPs embedded inside other DPs (Section 2.1.1).

The idea can be straightforwardly formalized in Plural Compositional DRT (PCDRT; see Brasoveanu 2007), which is one of several frameworks that study dependencies between quantifiers by using sets of assignments (for others, see van den Berg 1996, Nouwen 2003, Väänänen 2007). PCDRT is based on Logic of Change Muskens (1996). I discuss PCDRT in the next section and afterwards, I show the analysis of binominal *each*.

3.2 PCDRT

3.2.1 Types in PCDRT

The original PCDRT consists of three basic types, but here I will work, following Muskens' Logic of Change more closely, with four types. Thus, PCDRT includes type t (truth values), type e (entities, i.e., constants like ALEX, SASHA and variables of type e, notated as x, y, z), type s (which model variable assignments of DRT, Dynamic Predicate Logic etc., whose variables are notated as i, j etc.) and type r. The last type is called registers. As Muskens mentions, we can think of registers as small chunks of space that carve out exactly one object. The intuitive idea behind registers is that whenever a new discourse referent should be "introduced", a register can be changed. Intuitively speaking, if we encounter an indefinite, say *a boy*, then a register tied to this indefinite can be changed in such a way that some boy can be stored in it. Pronouns can later retrieve the value of the register. Thus, type r plays the same role as variables in DRT and other dynamic semantics frameworks.

I discussed entities of type e in Section 2. Here, I only remind the reader that both singular and plural individuals are of type e. Elements of type s model variable assignments and entities of type r model variables. Names of registers are also called discourse referents (drefs), in other words, discourse referents are constants of type r. I notate these constants as u with subscripts. There is an infinite number of drefs and an infinite number of assignments.[1] Following Muskens (1996), I assume that PCDRT includes a non-logical constant function v of type $r\langle se\rangle$. This function gives us the occupant of a register u in an assignment i. We can think of any assignment i as the function $\lambda v_{\mathrm{r}}.\mathsf{v}(v)(i)$, which closely captures the intuition that entities of type s correspond to variable assignments, i.e., functions from variables to entities.

The crucial property of PCDRT is its use of plural information states. Each such state is a *set* of assignments, i.e., type st. Variables of this type are notated with capital letters, i.e., I, J etc. The value of a discourse referent in sets of assignments is notated as uI and defined as:

[1] I assume that assignments are total.

(14) The value of a discourse referent in the plural information state I:
$uI := \{\mathsf{v}(u)(i) : i \in I\}$

3.2.2 Interpretation of sentences in PCDRT

We can now move to the interpretation of sentences and their parts in PCDRT. (15a) is a simple intransitive sentence.[2] The interpretation of (15a) is a Discourse Representation Structure, DRS, in the box notation shown in (15b), or equivalently but with space saved as in (15c). In the latter notation, discourse referents are introduced to the left of the vertical bar '|' and conditions follow the bar.[3]

(15) a. A^{u_1} boy sleeps.

b.
$$\begin{array}{|c|}\hline u_1 \\ \hline \text{BOY}\{u_1\} \\ \text{SLEEP}\{u_1\} \\ \hline \end{array}$$

c. $[u_1|\text{BOY}\{u_1\}, \text{SLEEP}\{u_1\}]$

In PCDRT a box is an abbreviation. It is interpreted as a function of type $\langle st\rangle\langle\langle st\rangle t\rangle$, i.e., it can be thought of as a relation between plural information states. A DRS $[\mathbf{Dref}|\mathbf{C}_1 \ldots \mathbf{C}_\mathrm{n}]$ is a function which takes a plural information state I as its argument and returns a set of states such that each state J in the set differs from I at most with respect to the values assigned to the dref **Dref** and satisfies the conditions $\mathbf{C}_1 \ldots \mathbf{C}_\mathrm{n}$. The definition is specified below. In the definition, $I[u_\mathrm{m}]J$ is understood as 'J differs from I at most with respect to u_m' and $\mathbf{C}_\mathrm{n}(J)$ is understood as 'J satisfies C_n'. If no new drefs are introduced in a DRS then I and J are identical. I will elaborate on the interpretation of $I[u_\mathrm{m}]J$ and $C_\mathrm{n}(J)$ below.

(16) $[u_\mathrm{m}|\mathbf{C}_1, \mathbf{C}_2, \ldots \mathbf{C}_\mathrm{n}] := \lambda I_\mathrm{st}\lambda J_\mathrm{st}.I[u_\mathrm{m}]J \wedge \mathbf{C}_1(J) \wedge \ldots \wedge \mathbf{C}_\mathrm{n}(J)$

A DRS can be conjoined with another DRS by dynamic conjunction, notated as ';'. Sequencing of two DRSs is interpreted as a new DRS. In other words, the sequence of DRSs is again of type $\langle st\rangle\langle\langle st\rangle t\rangle$, a function from a plural information state to the set of plural information states. If we sequence two DRSs, $D_1;D_2$, the interpretation can move from the input of D_1 to the output of D_2 only if there is an intermediary state J which serves as the output of D_1 and input of D_2:

(17) Dynamic conjunction:
$D_1;D_2 := \lambda I_\mathrm{st}\lambda K_\mathrm{st}.\exists J_\mathrm{st}(D_1(I)(J) \wedge D_2(J)(K))$

Finally, I discuss the interpretation of conditions and updates by discourse referents. Conditions are tests: they check that each assignment in the input plural information state satisfies them and pass the information state on, see (18a). Cardinality conditions are tests: they check that all the values of some discourse referent have a cardinality n, see (18b).

(18) a. $R\{u_1, \ldots u_\mathrm{n}\} := \lambda I.I \neq \emptyset \wedge \forall i_\mathrm{s} \in I(R(\mathsf{v}(u_1)(i), \ldots, \mathsf{v}(u_\mathrm{n})(i)))$

[2] Superscripts indicate what discourse referent a noun phrase introduces. Subscripts indicate what discourse referent an expression is anaphoric to.

[3] The set brackets in conditions BOY$\{u_1\}$ and SLEEP$\{u_1\}$ are there to indicate that these predicates do not apply directly to u_1. See below for the interpretation of conditions.

b. $|u_1| = n := \lambda I.|\bigcup u_1 I| = n$

"Introduction" of discourse referents, notated as $I[u_\mathrm{n}]J$, is manipulation of variable assignments. We first specify $i[u_\mathrm{m}]j$, which relates two variable assignments i and j such that one differs from the other at most with respect to u_n:

(19) $i[u_\mathrm{n}]j \quad := \quad \forall v(v \neq u_\mathrm{n} \rightarrow \mathsf{v}(v)(i) = \mathsf{v}(v)(j))$
i differs from j at most with respect to u_n

$I[u_\mathrm{n}]J$ is a generalization of $i[u_\mathrm{n}]j$ to sets of assignments:

(20) $I[u_\mathrm{n}]J \quad := \quad \forall i \in I \exists j \in J(i[u_\mathrm{n}]j) \wedge \forall j \in J \exists i \in I(i[u_\mathrm{n}]j)$

Informally, (20) says that (i) each assignment i in I has some successor j in J which differs from i at most with respect to u_n and (ii) each assignment j in J comes to existence by the modification of some i in I at most with respect to u_n. This means that $I[u_\mathrm{n}]J$ cannot lead to loss of any values introduced in referents other than u_n. Second, it also means that $I[u_\mathrm{n}]J$ cannot destroy the structure (dependency) holding between discourse referents $u, u', \ldots$ different from u_n.

Finally, the truth definition of a DRS is defined as existence of an output plural information state:

(21) Truth: A DRS D is true with respect to an input info state I_{st} iff $\exists J(D(I)(J))$

All these definitions will hopefully become clearer after we discuss one example:

(22) Two boys lifted two tables.

All word meanings necessary to interpret this sentence are shown in (23). To understand these interpretations, it is important to realize that it is standard in the tradition of Montagovian semantics to take sentences and proper nouns as saturated expressions. In the extensional Montagovian framework, sentences are interpreted as truth values, type t, and proper nouns as entities, type e. In PCDRT, a sentence is interpreted as the box, that is, it is of type $\langle\langle st\rangle\langle\langle st\rangle t\rangle\rangle$. I follow Brasoveanu (2008) and abbreviate $\langle\langle st\rangle\langle\langle st\rangle t\rangle\rangle$ as $\mathbf{t}$. Type e in Montagovian semantics corresponds to type r. Types of other expressions should be derivable based on these isomorphisms: noun phrases are of type $r\mathbf{t}$, that is, $\langle r\langle\langle st\rangle\langle\langle st\rangle t\rangle\rangle\rangle$, unary quantifiers are of type $\langle\langle r\mathbf{t}\rangle\mathbf{t}\rangle$, and so on.[4]

(23) a. $[[\text{boys}]] = \lambda v_\mathrm{r}.[|\textsc{boy(s)}\{v\}]$
b. $[[\text{lift}]] = \lambda Q_{\langle \mathrm{r}\mathbf{t}\rangle\mathbf{t}} \lambda v_\mathrm{r}.Q(\lambda v'.[|\textsc{lift}\{v, v'\}])$
c. $[[\text{two}]] = \lambda P_{\mathrm{r}\mathbf{t}} \lambda v_\mathrm{r}.[||v| = 2]; P(v)$
d. $[[\text{tables}]] = \lambda v_\mathrm{r}.[|\textsc{table(s)}\{v\}]$
e. $[[\text{EC}^{\mathrm{u_n}}]] = \lambda P_{\mathrm{r}\mathbf{t}} \lambda Q_{\mathrm{r}\mathbf{t}}.[u_\mathrm{n}|]; P(u_\mathrm{n}); Q(u_\mathrm{n})$

The annotated tree of the sentence (22) is shown in Figure 3. The top node is true if there are two boys, two tables and the boys lifted the tables collectivey or cumulatively. It is common to represent

[4] I treat numerals as modifiers and assume that there is a silent counterpart of *a*, Existential closure ($\text{EC}^{\mathrm{u_n}}$), lifting predicates to quantifiers. In the interpretation of plurals, I use one more convention. Since the number interpretation is specified by numeral expressions but the English words *boy* and *boys* carry the number information, I use BOY(S) in metalangauge, which means that the predicate is satisfied by an argument that is either a boy or boys. Another way to notate the same is to use the pluralization operator, notated as $*$ Kratzer (2008). Either way, this ensures that in individual assignments, there could be one or more boys, and the number restriction is imposed only by numerical conditions.

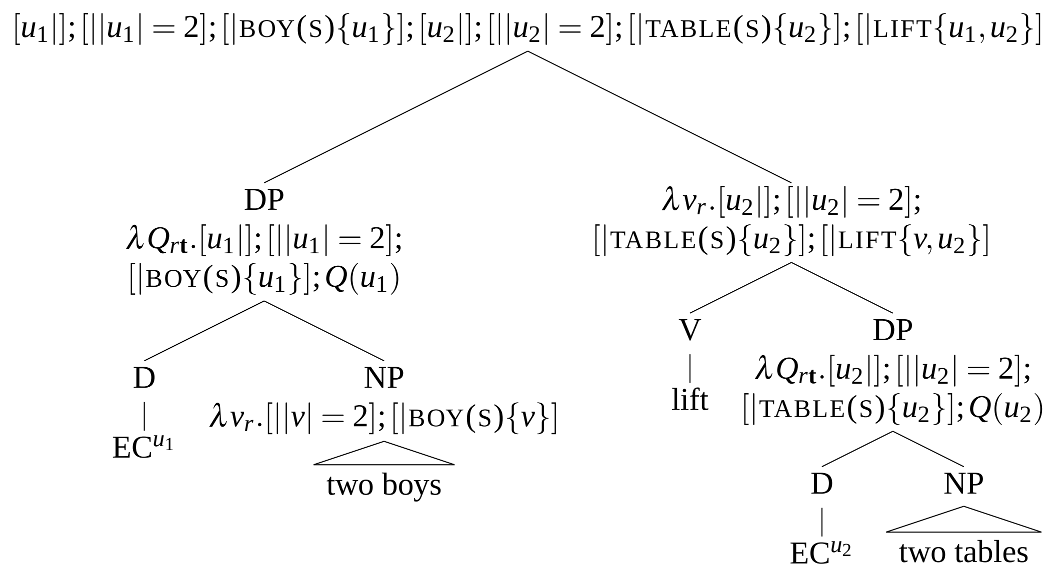


Figure 3: Syntactic tree of (22)

a plural information state in a matrix and I have already done so in Section 3.1. In this notation, each row represents values that an assignment assigns to drefs, and each column represents the values of drefs in all assignments. The interpretation of the sentence might be true given the output information state shown in (24) or the output information state shown in (25).[5] Notice that the first case represents to the collective reading: it is true if Alex and Sasha together lifted two tables. The second case represents the cumulative reading: it is true if Alex lifted table 1 and Sasha lifted table 2.

(24)

J	u_1	u_2
j_1	Alex and Sasha	two tables

(25)

J	u_1	u_2
j_1	Alex	table 1
j_2	Sasha	table 2

On the other hand, the distributive reading (paraphrasable as "two boys each lifted two tables") does not follow under our account unless the boys lift the same two tables. Consider the matrix representing the output plural information state:

(26) Distributive reading:

J	u_1	u_2
j_1	Alex	table 1&2
j_2	Sasha	table 3& 4

The problem is the discourse referent u_2. It introduces four tables while in the interpretation of the sentence we specified that u_2 is only of cardinality two, see Figure 3. This will be remedied by introducing the distributivity operator δ in the next section. The distributivity operator is the last crucial ingredience for the interpretation of binominal *each*.

[5] I ignore values of any other discourse referents in these and following matrices.

3.3 Distributivity and binominal *each*

We could not derive the distributive reading because the interpretation of the object DP *two tables* was checked in the whole plural information state. What we really want is to check its interpretation in a subset of these assignments. In particular, we want to interpret it only in those assignments in which the sorting key has an atomic value; and we want to repeat this procedure for every atomic value of the sorting key. To this end, we use the distributivity operator $\delta_{\mathrm{u_n}}$ (see van den Berg 1996 and Nouwen 2003). First, I introduce an abbreviation for sets of assignments in which u_{n} has value d.

(27) Sets of assignments in which u_{n} carries value d: $I|_{\mathrm{u_n=d}} := \{i \in I : \mathsf{v}(u_{\mathrm{n}})(i) = d\}$

The scope of $\delta_{\mathrm{u_n}}$ is restricted to each subset of assignments in which u_{n} has an atomic value.

(28) Distributivity operator:
$\delta_{\mathrm{u_n}}(D) := \lambda I_{\mathrm{st}} \lambda J_{\mathrm{st}}.u_{\mathrm{n}}I = u_{\mathrm{n}}J \wedge \forall d \in u_{\mathrm{n}}I(|\bigcup u_{\mathrm{n}}I| = 1 \wedge D(I|_{\mathrm{u_n=d}})(J|_{\mathrm{u_n=d}}))$

The work of δ will hopefully become clearer when we discuss an example of a distributive reading. Before we do so, I want to point out that we now have all ingredients ready for the interpretation of binominal *each*. Its meaning in PCDRT is provided here:

(29) Binominal *each*:
$[[\mathrm{each}^{\mathrm{u_m}}{}_{\mathrm{u_n}}]] = \lambda P_{\mathrm{r}\mathbf{t}} \lambda Q_{\mathrm{r}\mathbf{t}}.[u_{\mathrm{m}}|]; \delta_{\mathrm{u_n}}(P(u_{\mathrm{m}})); Q(u_{\mathrm{m}})$

Notice that binominal *each* introduces one dref (u_{m}) and is anaphoric to another dref (u_{n}). u_{m} is the distributed share and u_{n} is the sorting key. The formula shows that binominal *each* is a determiner (it is of the same type as the existential closure). Furthermore, it is a distributive determiner: it forces a distributive interpretation of its restrictor.

I show on the following example how the interpretation of binominal *each* and δ works:

(30) Two boys lifted two tables each.

The full derivation is shown in Figure 4. The one and only difference between the interpretation of this sentence and the tree in Figure 3 si the presence of $\delta_{\mathrm{u_1}}$ taking scope over the squence of two DRSs $[||u_2| = 2\}]; [|\textsc{table(s)}\{u_2\}]$. This difference suffices to force the distributive reading as the only possible one. To see this, consider what δ_{u1} does: it selects those set of assignments in which u_1 has one value; then, it requires that in each of these assignments the value of u_1 is atomic and u_2 is of cardinality two and has tables as its value. The collective reading, shown in (24), is excluded because there is no assignment with an atomic value of u_1 (Alex and Sasha together are not an atom). The cumulative reading, (25), is false because in the subset of assignments including one entity at the position of u_1 there is only one table at the position of u_2.

On the other hand, the distributive reading, (26), is true. This is because the object NP *two tables* is interpreted as tests which must be satisfied only in each subset of assignments that has an atomic entity at the position of u_1. This means that the object NP is interpreted at $\{j_1\}$, where it is true that the value of u_2 is two tables, and likewise for $\{j_2\}$. Thus, we correctly derive that binominal *each* forces distributive reading. Unlike Zimmermann (2002) and Blaheta (2003) this analysis treats binominal *each* as a determiner and crucially, *each* does not need to distribute over other lexical relations.[6] Since a DP with binominal *each* is just a generalized quantifier, it can

[6]This is due to the fact that lexical relations are unselectively distributive over plural information states (they universally quantify over variable assignments). Therefore, in each subset of variable assignments that δ selects lexical relations must be distributively satisfied even if δ itself does not distribute over these lexical relations.

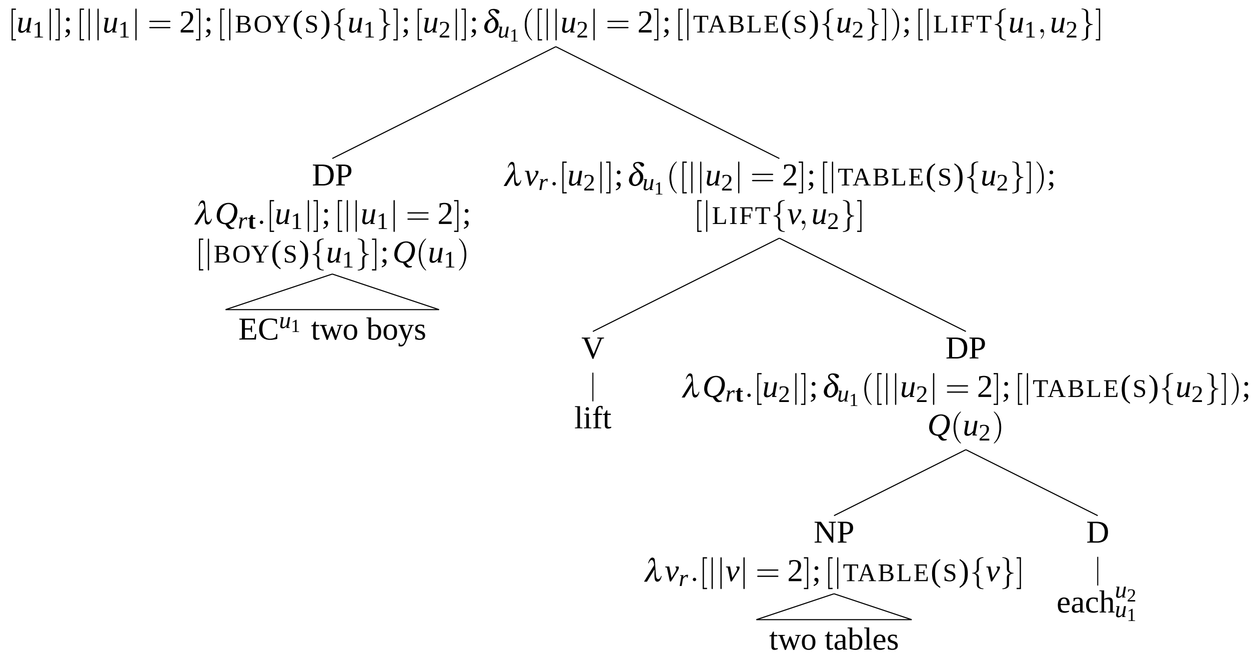


Figure 4: Syntactic tree of (30)

appear inside other noun phrases, as in (a), repeated from above, as long as quantifiers can be interpreted in this positions (see Heim and Kratzer 1998 and Büring 2005 for such analyses). The same holds for DPs with binominal *each* in adjunct positions, see (b), repeated from above.

(31) a. Alex and Sasha visited the capitals of three states each.
b. Alex and Sasha dragged three bags through four puddles each.

Similarly, it is not surprising that a DP with binominal *each* can be a conjunct in coordinations:

(32) Two women got the prize money and a silver medal each. Boeckx and Hornstein (2005)

In this case as well, we expect the sentence to be grammatical because quantifiers can normally appear in coordinations.

4 Restricting the analysis

From the discussion so far, one might get the impression that binominal *each* is completely free in its distribution. This is not correct. The following two examples from Safir and Stowell (1988) are ungrammatical.

(33) a. *The boys said that three women each had left.
b. *The boys expected Mary to kiss one child each.

The problem is that binominal *each* is separated from its antecedent by a clause boundary. We can thus add to our analysis that binominal *each* is subject to Principle A: it must be bound within a local domain. For our purposes, it suffices to assume that the local domain is the infinitival or finite clause in which *each* appears.

This analysis of the syntactic distribution of binominal *each* has been proposed in Burzio (1986). My semantic analysis is compatible with Burzio (1986) because it treats binominal *each* as an anaphoric determiner. However, there have been arguments levelled against Burzio's analysis and these affect my proposal as well. The most problematic issue is the fact that *each* cannot appear in ECM constructions and small clauses. Notice that reflexives, subject to Principle A as well, are licensed in this position.

(34) a. *The men wanted/expected/believed one field each to be reserved. Boeckx and Hornstein (2005)
b. *The boys considered one girl each intelligent. Safir and Stowell (1988)
c. The boys considered themselves to be smart.

I suspect that other issues than binding might explain why these examples are degraded. First, binominal *each* becomes possible if it follows the predicate in a small clause, as the following contrast from Boeckx and Hornstein (2005) shows. Zimmermann (2002) makes a similar point regarding cross-linguistic variation.

(35) a. The men threw out three bags each.
b. *?The men threw three bags each out.

Second, the following contrast, pointed out to me by Ash Asudeh, is important. The example (36b) is much better than (36a).

(36) a. *The boys consider one girl each intelligent.
b. The boys consider one girl each more beautiful than Sara.

Both of these points suggest that *each* can be bound in the subject position but other constraints, possibly of prosodic nature, exclude the examples in (34a) and (34b).

5 Conclusion and outlook

I have argued that binominal *each* should be analyzed as a distributive determiner anaphoric to the sorting key. This compositional analysis improves empirical coverage of Zimmermann (2002) and Blaheta (2003) and can be straightforwardly implemented in PCDRT. As a next step it would be interesting to see whether the proposed analysis could be extended to distance distributivity in other languages. A possible starting point of this extension is adnominal *jeweils* in German. However, this marker of distance distributivity does not require distribution to atoms in contrast to English *each* Zimmermann (2002), so some modifications might be necessary. Other cases of distance distributivity, like Hungarian reduplicated numerals or Czech *po*-preposition, add further complications because they can have a distributive quantifier as their sorting key. This is one reason why these expressions were often analyzed as dependent indefinites, not distributivity markers (see Farkas 1997, a.o.). Interestingly, Szabolcsi (2011) pointed out that one does not need to go outside of Germanic languages to see that markers of distance distributivity are compatible with distributive quantifiers as sorting keys. Many speakers consider the distributive quantifier *every boy* a possible antecedent of binominal *each* and for some speakers even *each boy* as the antecedent is possible:

(37) a. Every boy had one apple each.

b. %Each boy had one apple each.

This issue is somewhat controversial since in reported judgments of others Safir and Stowell (1988), Blaheta (2003) binominal *each* requires a plural *non-distributive* antecedent. What does my analysis predict? Given the discussion so far, binominal *each* distributes in (37) inside a predicate which is independently interpreted distributively due to the presence of distributive subjects. Therefore, *each* becomes vacuous, or, if we add an assumption that distribution over atoms is prohibited,[7] it leads to ungrammaticality. The same conclusion holds for Zimmermann (2002) and Blaheta (2003). Clearly, the precise status of (37), as well as extensions to other languages, are issues likely to be of utmost importance when furthering compositional analyses of distance distributivity.

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[7] We might want to add this condition to exclude sentences like *Alex had one apple each*.

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