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## On the Syntax and Semantics of Binary Distributive Quantifiers

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There is a type of quantificational construction which has a wide cross-linguistic distribution and exhibits both semantically and syntactically interesting properties, but has received little attention in the semantic and syntactic literature. I will call such quantifiers 'binary distributive quantifiers' (henceforth 'BDQs'). They can be instantiated in a variety of ways. Subtypes of the construction in English are given in (1).

(1) binominal *each*

- a. The women own *two cars each*.
- b. The people drank *two liters of water each*.

(2) temporal BDQs

- a. John watched the films *two at a time*.
- b. Mary wrote the book *one chapter a day*.
- c. Mary gives *fifty concerts a year*.

(3) rate phrases

- a. John ran *a mile an hour*.
- b. Mary reads *two books a day*.

(4) participant- and event-related BDQs

- a. Mary wrapped the presents *individually*.
- b. Mary wrapped the presents *one by one*.

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c. John taught the children *in groups of four*.

d. The people arrived *family by family*

e. John built the house of cards *in layers*.

(5) indexical BDQs

a. Mary bought *one carpet per room*.

b. John provided *one bottle of beer per person*.

There are essentially two types of such quantifiers: purely participant-related quantifiers such as *each* in (1) and event-related quantifiers such as those in (2) - (4). The first type has been discussed to some extent in the literature by Choe (1987) (who used the term 'antiquantifier') and Safir/Stowell (1988) (see also Postal 1975, Burzio 1986). BDQs have two characteristics. First, they are necessarily related to two terms. *Each* in (1) relates both to *the women* and *two cars*. For this reason, Safir/Stowell (1988) have called *each* in the construction in (1) 'binominal *each*'. *Two at a time* in (2a) relates both to *the films* and the event described by *watched*. This event can be taken to be an event argument of *watched* in the sense of Davidson (1966). *Individually* in (4a) relates both to *the presents* and the event denoted by *wrapped*. Second, these quantifiers range over the parts of at least one of the referents of the two term they relate to. *Each* in (4a) ranges over the parts of the group of women, namely the individual women. *Two at a time* in (2a) ranges over the parts of the group of films as well as over the parts of the event denoted by *watched*. *Individually* in (4d) ranges both over the parts of the groups of presents and over the parts of the event of wrapping. These two characteristics motivate the term 'binary distributive quantifier'. Rate-phrases as in (3) syntactically and semantically classify naturally with BDQs. Finally, BDQs may take an indexical semantic antecedent as in (5).

This paper examines some patterns of common properties and variations of semantic and syntactic properties of BDQs in English and in a number of other languages such as German and Greek. Semantically, binary distributive quantifiers pattern in two distinct ways. First, BDQs sometimes behave like floated quantifiers and thus should be assigned a similar status in sentence meaning. This type of quantifier is exemplified by German *je*. Second, BDQs sometimes differ from ordinary quantifiers in crucial respects and behave rather like modifiers of a relation between complex arguments, a relation which holds if certain parts of these arguments are associated with each other. This type is exemplified by English binominal *each* and generally by all event-related BDQs. I will give semantic analyses of both types of

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binominal distributive quantifier.

I first present the common characteristics of BDQs, in particular those concerning the form of the R-term and D-term. Then I present some basic data concerning the interpretation of BDQs and provide a semantic analysis.

### 1. Common Characteristics of BDQs.

#### 1.1. BDQs in different languages

Following Safir/Stowell (1988) let me call the (plural) antecedent of binominal *each*, i.e. *the women* in (1a) the R-NP of *each*, and the NP that is immediately followed by *each* the D-NP of *each*.

BDQs can be found in many languages. However, BDQs may differ in certain respects, for instance in what may count as the antecedent of a BDQ. BDQs that behave like English binominal *each* are found, for example, in Romance languages (French *chacun*, Spanish *cada uno*, Italian *ciascuno*) and in Russian (*po*) (cf. Pesetsky 1982). Often the same BDQs may enter both nominal and event-related constructions. Sometimes they may take quantified antecedents in addition to plural antecedents, and sometimes they may take indexical antecedents in addition to plural or event antecedents.

Greek, for instance, has a construction that is parallel to binominal *each*, but takes a broader range of R-terms. In this construction, the distributive element consists of the preposition *apo*, and the D-NP is of the form *apo-numeral-N*. The construction is illustrated in (6) with a plural NP as the R-term.

(6) Ta pedhia piran apo pende mila.

'The children took prep. five apples.'

The R-NP need not be a plural NP, but may also be a universally quantified singular NP, as in (7).

(7) a. Oli piran apo pende mila.

'Everyone took prep. five apples.'

b. Kathe pedhi pire apo pende mila.

'Each child took prep. five apples.'

Furthermore, Greek *apo* may take an event as its semantic antecedent, as in (8).

(8) a. O Yanis diavase ke egrapse apo ena vivlio.

'John read and wrote prep. one book.'

b. O Yanis efage tin deftera ke tin triti apo ena mila.

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'John ate (the) Monday and (the) Tuesday prep. one apple.'

c. *Stin Vostoni ke stin Nea Yorki, O Yanis skotose apo ena kuneli.*

'In Boston and in New York, John killed one rabbit.'

That is, *apo*-phrases may quantify over the parts of a complex event, rather than over a plural referent. The event, however, must be a group with well-distinguished subevents. Such a complex event may be described by a conjoined verb, as in (8)a., or a conjoined temporal or locational adjunct, as in (8)b. or (8)c. (though not a conjoined manner adverbial). This corresponds to the way the event antecedent of *same/different* may be described as a complex event (cf. Carlson 1987).

German also has a BDQ that may take as antecedents plural NPs as well as events, namely *je*. An example with a plural antecedent is given in (9), and examples with event antecedents in (10).

(9) *Die Kinder lasen je drei Bücher.*

'The children read prt three books.'

(10) a. *Hans las und schrieb je ein Buch.*

'John read and wrote prt. one book.'

b. *Am Montag und am Dienstag ass Hans je einen Apfel.*

'On Monday and on Tuesday John ate prt. one apple.'

Furthermore, *je*-phrases need not have a syntactic antecedent: they may instead take an indexical group antecedent provided by the context (as was observed by Link 1987):

(11) *Hans las je ein Kapitel.*

'John read prt a book'

### 1.1. Conditions on the form of BDQs

BDQs of all types have a number of common syntactic and semantic characteristics.

Complex BDQs all have to be constituents. This is shown for binominal *each* (cf. Safir/Stowell 1988) and temporal BDQs in (13) - (15).

(13) a. How many pictures each did John show the women?

b. How many concerts a year does Mary give?

(14) a. Two pictures each were shown to the women.

b. Fifty concerts a year were given by Mary.

(15) a. # John showed the women two pictures now each.

b. # Mary gives fifty concerts now a year

BDQs share a number of other common characteristics: for instance, they must be clausemates with the R-NP (cf. Choe 1987, Safir/Stowell 1988).

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Furthermore, nominal BDQs may not be deep subjects (cf. Burzio 1986).<sup>1</sup> Finally, BDQs undergo reconstruction with respect to both *wh* movement and NP movement. (cf. Burzio 1986)

Binominal *each* imposes specific restrictions on the form or content of the R-NP and the D-NP. The D-NP must have a determiner which expresses a restricted quantity (cf. Safir/Stowell 1988). Numerals and numeral classifier construction function as such, *two liters of* for example. Expressions that denote vague quantities such as *many* and *a lot* are marginally acceptable. Also, the indefinite determiner *a* is to that extent still acceptable.

- (16) a. The guests brought two bottles / two liters of wine each.  
 b. ? John gave the women a lot of flowers / chocolate each.  
 c. ? John gave the women a flower each.
- (17) John wrote the book one chapter / ? a chapter / ? many chapters at a time.

### 1.2. Conditions on the antecedent of BDQs

At first sight, the R-NP appears to be obligatorily a plural NP with binominal *each* ranging over the group members of the plural referent. But this is not entirely correct: the R-NP may also be a conjoined mass NP, as in (18a). Furthermore, with a plural R-NP, binominal *each* may range over certain designated subgroups of the plural referent, rather than over individual group members, as in a possible reading of (18b).

- (18) a. The water and the wine contain two ounces of poison each.  
 b. The horses and the cows belong to one farmer each.  
 c. The two boys and the two girls had to sing two duets each.

(18b) is actually ambiguous: *each* may either range over individual horses and cows or over the maximal group of horses and the maximal group of cows, i.e. the two referents of the plural conjuncts. This can be accounted for if *each* is taken to quantify over the relevant parts of the referent of the R-NP, rather than the elements of a set, whereby the relevant parts may be either subquantities, subgroups, or group members. The relevant parts of a referent of a conjoined definite NP are by preference the maximal entities denoted by the conjuncts, as in (18a), where the maximal quantity of water and the maximal quantity of wine are the relevant parts, or in (18b), where the maximal group of horses and the maximal group of cows are the relevant parts in one reading. If the conjuncts are plural NPs, alternatively, the members of the group referents may be the relevant parts, since (18b) also allows for the reading in which *each* ranges over individual horses or cows (cf. Moltmann 1990b). In the only plausible interpretation of (18c), the

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relevant parts of the referent of *the two boys and the two girls* are the group consisting of the two boys and the group consisting of the two girls

But what is the R-term of a temporal BDQ? I assume that the semantic antecedent over whose parts the BDQ quantifies is the Davidsonian event argument of the verb, i.e. the event argument of *watched* in (2a). Hence, the verb must be the R-term of a temporal BDQ. The parts a temporal BDQ ranges over may be either temporal event parts or unspecified event parts: a BDQ such as *one at a time* or *one by one* ranges over temporal parts of an event, which may not overlap in time, whereas a BDQ such as *individually* ranges over unspecified event parts. This can be seen in the contrast between (19a) and (19b).

(19) a. John wrapped the presents one at a time / one by one.

b. John wrapped the presents individually.

Thus the general semantic structure of event-related BDQs in first approximation is as follows for the meaning of (19a) and (19b) respectively:

(20) a. Each (relevant) temporal subevent of John's wrapping the presents involves an individual present.

b. Each (relevant) subevent of John's wrapping the presents involves an individual present.

For event-related BDQs, the R-term is associated either with an implicit event part quantifier (*individually*) or with a temporal event part sortal (Q *at a time/a day/a year*). The D-term generally consists in a part sortal or an NP with numeral referring to a participant (part). Some BDQs have incorporated D-terms, for instance *individually*. In some BDQs, the D-term is a temporal adjunct, for instance in *one mile per hour*. These BDQs are rate-phrases.

We can give the following characterization of rate-phrases:

(21) A rate phrase is a BDQ whose R term is the verb and whose D-term is a temporal adjunct with a spatial sortal for event parts.

Finally, there are BDQs with 'indexical R-terms' as in (5). The meaning of (5) can be given as in (22).

(22) For each of the rooms of Mary's house, Mary bought a carpet.

### 1.3. The semantics of BDQs

#### 1.3.1. The 1-1 correlation and constraints on the antecedent

For the general semantic analysis of BDQs, let us first consider a claim put forward by Safir/Stowell (1988) (and attributed to Higginbotham). Safir and Stowell argue that *each* in this construction is a binary quantifier because it

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crucially involves an irreducible relation between the parts of the referent of the R-NP and the referents of the D-NP. This relation, unlike in the case of the floated quantifier *each*, is a 1-1 relation. (18a) implies that the horses belong to a different farmer than the cows and that the horses and the cows each do not belong to more than one farmer. This condition does not seem to be as strict as it is represented by Safir and Stowell. (24) may very well be true if some of the children saw the same movies.

(24) The children saw two movies each.

However, the condition can be maintained under the following general assumption: the distinctness condition on the referents of the D-NP should not hold between actual entities, but rather between discourse referents (Karttunen 1976, Kamp 1981, and others). Binominal *each* in (24) does not imply that the actual movies are distinct, but rather that the movies as they are represented in the universe of discourse are distinct - that is, it implies that the movies are not represented by the same discourse referents. Of course, the level of discourse referents need not represent the speaker's knowledge, but is construed entirely according to the speaker's intentions with respect to the discourse, i.e. the information the addressee should receive.

There is further evidence that a condition of distinctness should hold. As we have said, indefinite singular count NPs are marginally permitted as D-NPs. Generally, NPs of the form *the same N'* count as indefinite NPs, as seen in the environments exhibiting the indefiniteness effect in (25).

(25) a. Mary has the same car as John.

b. Everybody had the same illness.

However, NPs of the form *the same N'* are completely impossible as D-NPs of binominal *each* in contrast to NPs of the form *a different N'*.

(26) a. # The children saw the same movie each.

b. The children saw a different movie each.

In this respect, binominal *each* differs semantically from ordinary quantifiers such as *each* in (27).

(27) a. Each child saw the same movie.

b. The children each saw the same movie.

Another argument for the 1-1 correlation comes from semantic conditions on the antecedent of a BDQ. The antecedent must refer to an entity with group structure, i.e. with well-distinguished parts as described by singular count nouns or the conjuncts of a conjoined event predicate. It may not be, for instance a mass NP. The same semantic selectional requirement holds for any predicate or semantic operation that involves a binary relation between



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the parts of an argument, for instance *between* or *each other*. It does not hold for such elements as *among* or floated *all*. Therefore, they may apply to mass NPs (cf. Moltmann 1990):

- (28) a. # *between* the wood  
 b. # The wood resembles *each other*.

- (29) a. *among* the wood  
 b. The wood is *all* wet.

Further evidence for the 1-1 correlation comes from the acceptability of examples like (30).

- (30) There are no problems left because the students have solved two problems *each*.

(30) would not be acceptable if it did not imply that each student solved a different pair of two problems. This correlation is not pragmatically suggested in (30) and thus seems to be part of the content of binominal *each*.

Boalos (1981) has observed the requirement of a 1-1 correlation in another construction, namely the construction *for every A there is a B*, as in his example given in (31).

- (31) For every philosopher that has studied Spinoza thoroughly, there is one that hasn't even read the *Ethics*.

### 1.3.2. The description of single events

There is evidence that BDQs involve the description of a single event, rather than a set of disconnected events. This can be seen from a comparison of sentences containing BDQs with parallel sentences containing ordinary quantifiers, as in (32).

- (32) a. The singers sang one song *each*.  
 b. Each singer sang one song.

(32a) suggests that the singing of the songs constitutes a coherent series, whereas in (32b) each singing of a song may be unrelated to any other singing of a song.

There is another piece of evidence that BDQs involve a single event description. In Spanish, event-related binominal distributive quantifiers can be formed by attaching, for instance, *al día* or *cada día* ('every day') at the end of an NP. However, *cada día* independently acts as an ordinary temporal quantifier. Now, if the NP containing the numeral is separated from *cada día*, only the interpretation of *cada día* as an independent quantifier is available, not the interpretation in which it quantifies over the parts of the described events. Thus, the following examples form a contrast.

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(33) a. Juan leyó calladamente un capítulo al día / cada día.

'John read calmly one chapter a day / each day.

b. Juan leyó un capítulo calladamente cada día / # al día..

(33a) can be paraphrased as 'what John did was read a chapter a day'. That is, (33a) describes a single (complex) event consisting of reading a chapter daily. (33b), in contrast, can only be paraphrased as 'what John did every day was read a chapter'; it describes a number of disconnected events, each of which is a reading of a chapter on one of the days.

Another argument comes from quantification over events. Compare (34a) and (34b).

(34) a. Often John wrote one page a day.

b. ?? Often John wrote one page every day.

*Often* ranges over processes of writing. Since *write one page a day* describes single processes *often* is fine in (34a). In (34b), *often* can only quantify over larger situations which contain a sufficient number of days over which *every day* can quantify.

A final piece of evidence for the single event description comes from modification of events. Compare (35a) and (35b).

(35) a. as soon as John runs one mile per hour.

b. ??as soon as John runs a mile every hour.

## 1.3.3. The formal semantic analysis

One might suggest that binominal *each* is to be represented roughly as in (36).

(36)  $each([the\ children], [one\ movie]) (\lambda xy[saw(x, y)])$

This kind of analysis would correspond to the logical form that Safir and Stowell give for binominal *each*. However, this analysis does not account for the fact that sentences with BDQs describe single events. In order to account for this, I assume an analysis which separates the effect of binominal *each* from the content of the description of the rest of the sentence (cf. Moltmann 1990a). Such a sentence meaning consists roughly of two parts. In the first part, the described complex event is related to other arguments of the verb in question. In the second part, parts of the participant or event (referred to by the R-term) are associated with (parts of) other participants (or temporal units), namely the referents (or parts of the referent) of the D-term. Thus, a sentence with binominal *each* such as (32a) is analyzed as follows, where 'P' denotes the relation 'is a relevant part of'.

(37)  $\exists x[sing(e, [the\ singers], x) \ \& \ songs(x) \ \& \ \exists f(f \ 1-1 \ \& \ ran \ f =$

$$\{z | zP[\textit{the singers}] \& \text{dom } f \subseteq [\textit{one song}] \& f \subseteq \{ \langle z, y \rangle | \exists e' (e'Pe \& \text{sing}(e', z, y)) \} \}$$

According to (26), (32a) is true if there is an event of singing by the singers of a group of songs such that there is a function  $f$  which is one-to-one and relates the relevant parts of the singers to single songs in the relation of singing.

Sentences with binominal event quantifiers receive a parallel analysis, as in (38) for *John wrote the book in chapters*

$$(38) \exists e (\text{write}(e, [\textit{John}], [\textit{the book}]) \& \exists f (f \text{ 1-1} \& \text{ran } f = \{e | e'Pe\} \& \text{dom } f \subseteq [\textit{one chapter}] \cap \{y | yP[\textit{the book}]\} \& f \subseteq \{ \langle e', y \rangle | e'Pe \& \text{write}(e', [\textit{John}], y) \} \})$$

(38) states that there is an event  $e$  of writing the book by John such that the parts of  $e$  can be associated in a 1-1 relation with individual chapters of the book in the relation of writing.

Further evidence for this bipartite interpretation of sentences with BDQs comes from the ability (or rather inability) of BDQs to interact in scope with certain quantifiers, as will be discussed in the next section.

## 2. Further semantic peculiarities of BDQs

### 2.1. Scope interaction with other quantifiers

BDQs exhibit some interesting properties with respect to how they interact with other quantifiers in scope or with the distributive interpretation of plurals that do not act as antecedents. The scope data in English appear to be less clear than in other languages, for instance Romance or Greek. The following generalization seems to hold for those languages or the relevant varieties of English: BDQs can interact in scope with quantified adjuncts, but not with quantified arguments.

For all speakers, it seems, binominal *each* can interact in scope with quantified adjuncts, provided the adjunct is in an appropriate syntactic position. Consider the examples with the event quantifiers *twice* and *on two consecutive days* in (39).

- (39)a. Once / On two consecutive days, John and Mary wrote to two relatives each.  
 b. John and Mary once / on two consecutive days wrote to two relatives each.  
 c. John and Mary wrote once / on two consecutive days to two

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relatives *each*.

- d. John and Mary wrote to two relatives *each* once / on two consecutive days.

*Once* and *on two consecutive days* in (39a) and (39b) can only be understood as having wide scope with respect to *each*. That is, (39a) and (39b) can only mean that on one occasion or on each of two consecutive days *t*, John and Mary wrote to two relatives *each* on *t*. (39c) and (39d), in contrast, can mean that for each *x* among John and Mary there is one occasion or two consecutive days such that *x* wrote on that occasion or those two days to the two relatives. Thus, the occasion or the days for Mary may be distinct from the occasion or the days for John.

Moreover, (40) shows that without binominal *each*, quantifier scope interaction with event quantifiers or indefinite NPs cannot take place:

- (40) a. The men gave the flowers to two women.

- b. The girls wrote on two consecutive days to two relatives.

The much preferred reading of (40a) is the one in which only two women were involved in the flower givings by the men. The preferred reading of (40b) is that there are two days on which the girls both wrote to the same two relatives.

Binominal *each* does not - at least not for all speakers - allow indefinite NPs in its *c*-command domain to take narrow scope with respect to the universal quantifier representing binominal *each*. Many speakers can interpret (41a) only in such a way that the same woman was given a flower by every man. That is, *a woman* can refer to only one woman. The situation often becomes clearer with NPs that are not simple indefinite NPs, but rather contain a cardinality attribute like *two*. Thus, (41b) is often understood as being true only if the same two women were involved in all the flower givings.

- (41) a. The men gave one flower *each* to a woman.

- b. The men gave one flower *each* to two women.

However, there are also speakers that allow scope interactions between *a woman* or *two women* and binominal *each*. For these speakers, the analysis in (36) is actually the right one.

The ability of binominal *each* to interact in scope with quantified adjuncts, but not with quantified arguments, can be accounted for in the following way on the basis of the bipartite semantic analysis given in the last section. Quantified adjuncts may be represented in the second part of the sentence

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meaning. Here, they may have the status of having 'narrow scope with respect to the universal quantifier ranging over the parts of the referent of the R-term'. In contrast, quantified arguments must be represented in the first part of a sentence meaning. Thus the representation of (42a) with narrow scope of *twice* over *each* would be as in (42b), where *twice* holds of an event *e* iff *e* consists of two separated temporal subevents.

(42) a. The men gave one flower each twice to a woman.

b.  $\exists x(\text{woman}(x) \ \& \ \text{give}(e, [\textit{the men}], [\textit{flowers}], x) \ \& \ \exists f(f \text{ 1-1} \ \& \ \text{ran } f = \{y \mid yP[\textit{the men}]\} \ \& \ \text{dom } f \subseteq \{x \mid \textit{one flower}(x)\} \ \& \ f \subseteq \{ \langle e', y', x' \rangle \mid \textit{twice}(e') \ \& \ \forall e''(e''Pe'' \rightarrow \textit{give}(e'', y', x')) \})$

(42b) allows for a situation in which each man is involved in flower-givings on a two different occasions.

Another characteristic of binominal *each*, which again holds only for a certain number of speakers, is that it does not allow for a distributive interpretation of a plural NP in its scope. Compare (43a) and (43b).

(43) a. The men gave one flower each to the women.

b. The men gave the flowers to the women.

For the relevant group of speakers, (43a) implies that the women were always collectively given one flower by each man. (43b), in contrast, allows for an interpretation in which each woman individually was given a flower by some man. Thus, the rule that is responsible for distributive interpretation, a rule that, among other things, associates parts of arguments with parts of other arguments in the relation specified by the verb, cannot interact with the distributivity effect that is carried by *each*. This is accounted for in the analysis above because it does not involve any part quantifier ranging over the parts of any argument other than the R-term or D-term referent. Thus, (43a) accordingly is analyzed as in (44).

(44)  $\exists x(\textit{give}(e, [\textit{the men}], x, [\textit{the women}]) \ \& \ \textit{flowers}(x) \ \& \ \exists f(f \text{ 1-1} \ \& \ \text{ran } f = \{z \mid zP[\textit{the men}]\} \ \& \ \text{dom } f \subseteq [\textit{one flower}] \ \& \ f \subseteq \{ \langle z, y \rangle \mid \exists e'(e'Pe' \ \& \ \textit{give}(e', z, y)) \})$

## 2.2. Scope interactions with German *je*

German *je* differs with respect to quantifier scope interaction when compared to BDQs in English, Romance, or Greek. *Je*-phrases may not only interact in scope with quantified adjuncts, but also with quantified arguments. (45a) does not imply that only one woman was involved in the flower givings; it may be true if each flower was given to a different woman. Similarly, *zwei Bekannte* in (45b) may take narrow scope with respect to *je zwei Briefe*. (I. e. each child may have written to a different two relatives.)

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(45) a. Die Männer gaben je eine Blume einer Frau.

'The men gave each a flower to a woman.'

b. Die Kinder schrieben je zwei Briefe an zwei Bekannte.

'The children wrote prt two letters to two relatives.'

This suggests that sentences with *je* should be analyzed semantically as in (46) (representing (45a))

(46)  $\forall x x'(xP[\textit{the men}] \& x'P[\textit{the men}] \& x \neq x' \rightarrow \exists e'yy'zz(\textit{flower}(y) \& \textit{flower}(y') \& y \neq y' \& \textit{woman}(z) \& \textit{woman}(z') \& \textit{give}(e, x, y, z) \& \textit{give}(e, x', y', z'))$

In an analysis such as (46) the universal quantifier ranging over the parts of the R-term referent may have wide scope over any other quantifier, whether it represents an argument or an adjunct.

## Notes

<sup>1</sup> This does not hold for German *je*. NFs with *je* may appear in subject position as deep subjects, as seen in (1).

(1) a. Je zwei Polizisten beobachteten diese Männer.

'Prt. two policemen observed these men.'

b. Je zwei Kinder sahen Hans und Maria.

'Prt. two children saw John and Mary.'

This is presumably so because *je* may take an 'indexical R-term', which may 'coincide' with a deep object. Thus, in (1a) *diese Männer* seems to be the R-term for *je*. The R-term may in fact be indexical, however.

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