5 The Semantics of "Respective," Symmetrical, and Summative Predicates

The analyses of Gapping and NCC in the previous two chapters have demonstrated that the flexible but systematic interaction between the vertical slash and the directional slashes in Hybrid TLCG can be profitably exploited in making sense of the complex empirical patterns exhibited by the Gapping construction in English. In this chapter, we present an analysis of yet another complex interaction between syntactic and semantic phenomena, namely the so-called "respective" predication and related phenomena (such as symmetrical predicates), and argue that Hybrid TLCG again enables a successful analysis of the seemingly quite complex set of empirical phenomena exhibited by these expressions. The analysis we propose not only accounts for the basic properties of "respective" predicates and related phenomena but also extends straightforwardly to interactions between these phenomena and noncanonical coordination (RNR and DCC), as well as interactions among these phenomena themselves.

The so-called "respective" readings of plural and conjoined expressions and the internal readings of symmetrical predicates such as *same* and *different* in (153a,b) have posed difficult challenges to theories of the syntax-semantics interface. Summative predicates such as *a total of X* in (153c) present a similar problem.

(153) a. John and Bill sang and danced, respectively.
(= 'John sang and Bill danced')
b. {The same performer/Different performers} sang and danced.
(≈ 'The performer who sang and the performer who danced are the same/different')
c. John and Bill spent a total of $10,000 last year.
(= 'The amount that John spent last year and the amount that Bill spent last year add up to $10,000')

These phenomena interact with coordination, including nonconstituent coordination (NCC; both Right-Node Raising and Dependent Cluster Coordination):

(154) a. John read, and Bill reviewed, *Barriers* and *LGB* (respectively).

b. John introduced the same girl to Chris on Thursday and (to) Peter on Friday.
c. John spent, and Bill lost, a total of $10,000 last year.
(= 'The amount that John spent last year and the amount that Bill lost last year add up to $10,000')

Moreover, these expressions can themselves be iterated and interact with one another to induce multiple dependencies:

(155) a. John and Bill introduced Mary and Sue to Chris and Pat (respectively).
b. John and Bill gave the same book to the same man.
c. John and Mary showed the same book to his brother and her sister (respectively).
d. John and Mary collected a total of $10,000 for charity from his family and her clients, respectively.
e. John and Mary gave a total of $10,000 to the same man.

Any adequate analysis of these phenomena needs to account for these empirical facts. In particular, the parallel between the phenomena in the multiple dependency cases in (155), especially the interdependency between "respective," symmetrical, and summative predicates in (155c–e), raises the possibility that the same (or a similar) mechanism is at the core of the semantics of these three phenomena.

Our goal in this chapter is precisely such a unified analysis of the three phenomena. While the "respective" readings and symmetrical predicates have been extensively studied in the previous literature, there does not currently exist an analysis, at any level of formal explicitness, which offers a systematic explanation for their parallel behaviors observed above. By building on several analyses of these phenomena from the previous literature, we develop an analysis that posits a common mechanism of pairwise predication involving multiple list-like data structures and show that this analysis straightforwardly captures their parallel behaviors.

5.1 The Meanings of "Respective," Symmetrical, and Summative Predicates

"Respective" readings of plural and conjoined expressions (cf., e.g., Kay 1989; McCawley 1998; Gawron and Kehler 2004; Winter 1995; Bekki 2006; Chaves 2012) and the semantics of symmetrical predicates such as *same* and *different* (cf., e.g., Carlson 1987; Moltmann 1992; Beck 2000; Barker 2007; Brasoveanu 2011) have been known to pose significant challenges to theories of compositional semantics. Each of these two constructions alone presents a set of quite complex problems, and previous authors have thus mostly focused on studying the properties of one or the other. However, as we discuss below, the problems that the two phenomena exhibit are remarkably similar. A less frequently discussed type of sentence but one which raises essentially the same problem for compositionality comes from the interpretation of expressions such as *a total of X* and *X in total*. We call these expressions "summative" predicates. Summative predicates have been discussed in the literature mostly in the context of Right-Node Raising (RNR) (Abbott 1976; Jackendoff 1977). Some representative examples of each construction were given in (153)–(155).

The difficulty that these phenomena pose can be illustrated by the following examples involving "respective" readings:[1]

(156) a. John and Bill bought the book and the CD, respectively. (NP coordination)
b. John and Bill ran and danced, respectively. (VP coordination)
c. John read, and Bill listened to, the book and the CD, respectively. (RNR)
d. John gave the book and the CD to Sue on Wednesday and to Mary on Thursday, respectively. (Dependent-Cluster Coordination [DCC])

These examples exhibit readings that can be paraphrased by the sentences in (157).[2]

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1. It has been noted by Postal (1998), Kehler (2002), and Chaves (2012) that "respective" readings interact with extraction, as exemplified by the following data (called "interwoven dependency" by Postal (1998)):

(i) a. Which pilot$_i$ and which sailor$_j$ will Joan invite __$_i$ and Greta entertain __$_j$ respectively?
b. What book$_i$ and what magazine$_j$ did John buy __$_i$ and Bill read __$_j$ respectively?

It is possible to construct parallel examples involving summative readings (symmetrical predicates seem to be uncomfortable in fronted *wh* or topicalized positions, and we weren't able to construct relevant examples):

(ii) How many frogs in total did Greg capture __ and Lucille train __?

The semantic analysis of "respective" predication we propose in section 5.3.1 is in principle compatible with these data. However, since there is a technical problem in the syntactic analysis of ATB extraction (which constitutes an exception to the linearity of the calculus underlying TLCG), we will not attempt to formulate an explicit analysis.

2. One might be inclined to think that the adjective *respective* in examples like the following should be given a parallel treatment:

(i) John and Bill talked to their respective supervisors.

However, as convincingly argued by Okada (1999) and Gawron and Kehler (2002), the properties of the adjective *respective* are significantly different from those of the *respectively* sentences in (156). In particular, contrasts such as the following suggest that the adjective *respective* takes scope strictly within the NP in which it occurs:

(ii) a. Intel and Microsoft combined their respective assets.
b. #Intel and Microsoft combined their assets respectively.

We thus set aside the adjective *respective* in the rest of this chapter. See Gawron and Kehler (2002) for an analysis of *respective* that captures its strictly local scope correctly.

Other expressions whose interpretations are similarly sensitive to the order of mention include *successively*, *progressively*, and *increasingly*:

(iii) Robin, Terry, and Leslie got successively higher grades on the SAT.

(157) a. John bought the book and Bill bought the CD.
b. John ran and Bill danced.
c. John read the book and Bill listened to the CD.
d. John gave the book to Sue on Wednesday and gave the CD to Mary on Thursday.

The difficulty that these examples pose essentially lies in the fact that they seem to require having access to the denotations of parts of a phrase (for example, the meaning **ran** is not retrievable from the boolean conjunction $\lambda x.\mathbf{ran}(x) \wedge \mathbf{danced}(x)$ that is standardly taken to be the meaning of *ran and danced*). This violates the principle of compositionality at least in its strictest formulation, which dictates that, once the meaning of a phrase is constructed, the grammar should no longer have direct access to the meanings of its parts. Things are especially tricky in examples like (156c) and (156d), where neither the whole nor the part of the coordinate structure is even a constituent in the standard sense. So far as we are aware, there is no explicit analysis of these *respectively*/NCC interactions in the literature. In particular, it is worth noting that the proposals by Gawron and Kehler (2004) and Chaves (2012) that we review below both fail to extend to these NCC cases since they assume phrase structure–based syntax for formulating their analyses (but to be fair, it should be noted that, at least in the case of Gawron and Kehler [2004], the semantic analysis they propose does not depend in any crucial way on the syntactic assumptions they make).

One might object to the characterization we have just given (see, e.g., Chaves [2012] and Schwarzschild [1996]—but see also Gawron and Kehler [2002] for a critique of Schwarzschild [1996]; we address Chaves's [2012] approach in detail in section 5.4.1.3): at least cases like (156a) can be dealt with by an independently needed mechanism for yielding the so-called cumulative readings of plurals (Scha 1981):

(158) Seven hundred Dutch companies have used ten thousand American computers.

In the cumulative reading of (158), a set of seven hundred Dutch companies is related to a set of ten thousand American computers in the "*x*-used-*y*" relation. The sentence does not specify which particular company used which particular computer, but it only says that the total number of companies involved is seven hundred and the total number of computers involved is ten thousand.

The "respective" reading in (156a) could then be thought of as a special case of this cumulative reading. Unlike the more general cumulative reading, the "respective" reading is sensitive to an established order among elements in each of the conjoined or plural terms (that is, (156a) is false in a situation in which John bought the CD and Bill bought the book), but one could maintain that the core compositional mechanism is the same.

However, an attempt to reduce the "respective" reading to the cumulative reading fails, at least if we adhere to the conventional assumption about the latter that it is induced by a lexical operator that directly applies to the meanings of verbs. As should be clear from the examples in (156b–d), it is not just co-arguments of a single verb that can enter into the "respective" relation. Thus, a lexical operator–based approach is not general enough.[3]

But we think there is a grain of truth in this attempt to relate cumulative and "respective" readings. The "violation" of compositionality under discussion exhibited by "respective," symmetrical, and summative readings arises only in connection with coordinated or plural expressions. (Examples involving symmetrical and summative predicates are introduced below.) Thus, instead of claiming that these constructions pose serious challenges to the tenet of compositionality (as some authors indeed have; cf. Kay 1989), it seems more plausible to find ways to relax compositionality just in the context of coordination and plural expressions, in such a way that these apparent violations of compositionality (but nothing more) are allowed.

Building on related ideas explored by previous authors, in particular, Gawron and Kehler (2004) and Barker (2007), we argue precisely for such an approach in this chapter. In fact, in the case of conjoined NPs, which are standardly taken to denote sums (or, more correctly, joins in a semilattice, but for convenience of presentation we will continue to use the informal locution of plurals "denoting" sums), the issue of compositionality is already moot since the denotation itself ($\mathbf{j} \oplus \mathbf{b}$) retains the internal structure of the conjunction that can be accessed by other operators such as the distributivity operator commonly assumed in the semantics literature (compare this situation to the generalized conjunction of the lifted versions of the individual terms $\lambda P.P(\mathbf{j}) \wedge P(\mathbf{b})$, for which the individual parts are no longer directly accessible). As shown in detail for "respective" readings by Gawron and Kehler (2004), by generalizing this approach to non-NP-type meanings, the complex semantics that "respective" readings and related phenomena exhibit can be uniformly handled by modeling the meanings of expressions involving plurals or conjunction by a structured object—either (generalized) sums (Gawron and Kehler 2004) or tuples (Winter 1995; Bekki 2006).

The idea, in a nutshell, is to keep track of the meanings of components (e.g., the meanings of each verb **ran** and **danced** for the conjoined VP *ran and danced*) as distinct tuple (or sum) elements so that they can be separately retrievable from the meaning of the whole conjoined expression. The grammar conforms to the standard notion of compositionality in all other respects, and in this sense, this approach involves only a limited degree of noncompositionality, as it were. The present chapter extends this approach to the other two empirical phenomena (symmetrical and summative predicates),

3. An event-based analysis (along the lines, e.g., of Lasersohn [1992]) is conceivable for examples like (156b) (and possibly for (156c) and (156d) as well, though working out the details would be nontrivial). See the discussion about (225) in section 5.4.1 for why we do not pursue this approach.

as well as embedding the analysis in Hybrid TLCG, which offers a flexible and explicit syntax-semantics interface. As will become clear below, our choice of tuples over sums for the underlying data structure—departing, in this respect, from Gawron and Kehler's (2004) original proposal—is primarily motivated by the need to generalize the analysis to the other two phenomena (see section 5.4 for discussion). Our analysis of the class of predicates under consideration has the advantage that the interactions with NCC exhibited by data such as (156c) and (156d) (and their counterparts involving symmetrical and summative predicates introduced below) become straightforward. This is especially important since interactions between NCC and each of these phenomena have been known to pose significant problems for analyses of coordination in the literature (see, e.g., Abbott 1976, Jackendoff 1977, and Beavers and Sag 2004 for some discussion), and a fully general solution is still missing in previous proposals.

We now turn to the specifics of each of the three phenomena. For the "respective" reading, note first that if we remove the adverb *respectively*, the sentences still have the "respective" interpretation as one of their possible senses.

(159) John and Bill bought the book and the CD.

But in this case, the sentence is multiply ambiguous. For example, in (159), both the subject and object NPs could be construed collectively: the two people bought the two things together. The sentence also allows for readings in which only the subject or the object NP exhibits a distributive reading (e.g., 'John bought the book and the CD and Bill also bought the book and the CD'). The presence of the adverb *respectively* disambiguates the interpretation to the "respective" reading.

In the "respective" readings with overt conjunction (as in the examples in (156)), the *n*-th conjunct in one term is matched up with the *n*-th conjunct in the other term. As noted by many (cf. McCawley 1998, Kay 1989, among others), if the order of elements is clear from the (nonlinguistic) context, then not just conjoined NPs but plural NPs can also enter into "respective" predication, as in the following examples:

(160) a. [Caption under a picture showing five men standing next to each other:] These five men are Polish, Irish, Armenian, Italian, and Chinese, respectively.
b. The three best students received the three best scores, respectively.

McCawley (1998) also notes that, when there are more than two plural or conjoined terms in the sentence, multiple "respective" relations can be established among them. Disambiguation with *respectively* works in the same way as in the simpler examples, with the consequence that (161b) with a single *respectively* is ambiguous whereas (161a) with two occurrences of *respectively* is unambiguous:

(161) a. George and Martha sent a bomb and a nasty letter respectively to the president and the governor respectively.
b. George and Martha sent a bomb and a nasty letter to the president and the governor respectively.

As we discuss below, the availability of this multiple "respective" reading turns out to be particularly important in formulating a compositional semantic analysis of "respective" interpretations. Moreover, a parallel multiple dependency is observed with symmetrical predicates, and this poses a severe problem for the compositional analysis of *same* and *different* by Barker (2007, 2012) (see section 5.4.1.2). So far as we are aware, Gawron and Kehler (2004) was the first to propose a formally explicit solution for this problem in the analysis of "respective" readings, and our own analysis generalizes the solution to all of the three phenomena we consider in this chapter.

Turning now to symmetrical predicates, note first that symmetrical predicates such as *same*, *different*, *similar*, and *identical* exhibit an ambiguity between the so-called internal and external readings (Carlson 1987).

(162) a. The same waiter served Robin and poured the wine for Leslie.
b. Different waiters served Robin and poured the wine for Leslie.

When uttered in a context in which some waiter is already salient (for example, when (162a) is preceded by *I had a very entertaining waiter when I went to that restaurant last week, and yesterday evening* . . .), *the same waiter* in (162a) anaphorically refers to that individual already introduced in the discourse. This is called the *external reading*, corresponding to an anaphoric expression such as *that very waiter*. But this sentence can be uttered in an "out of the blue" context too, and in this case, it simply asserts that the individual who acted as Robin's server and the one who poured Leslie's wine were identical and that that individual, whoever s/he was, was indeed a waiter—the so-called *internal reading*. The external reading is just an anaphoric use of these expressions and does not pose a particularly challenging problem for compositional semantics. For this reason, we set it aside and focus on the internal reading in the rest of this chapter (but see section 5.3.2, where we briefly discuss a possibility in which the internal and external readings may be related in our setup).

The distribution of the internal reading of symmetrical predicates is remarkably similar to that of "respective" readings. First, like "respective" readings, the internal reading is available in all types of coordination:

(163) a. John and Bill read {the same book/different books}. (NP coordination)
b. {The same waiter/Different waiters} served Robin and poured the wine for Leslie. (VP coordination)
c. John read, and Bill reviewed {the same book/different books}. (RNR)

d. I gave {the same book/different books} to John on Wednesday and to Bill on Thursday. (DCC)

Examples like (163c) and (163d) are especially problematic since they show that deletion-based analyses of NCC (which derive, for example, the RNR example (163c) from an underlying source *John read the same book and Bill reviewed the same book*) do not work (Abbott 1976; Jackendoff 1977; Carlson 1987).

Second, both plural and conjoined expressions induce the internal reading. Thus, by replacing *John and Bill* in (163a) by *the men*, both the external and internal readings are available:

(164) The men read {the same book/different books}.

Third, just like multiple "respective" readings, multiple internal readings are possible:

(165) a. John and Bill bought the same book at the same store.
b. John and Bill bought the same book at different stores.
c. John and Bill bought the same book at the same store on the same day for the same price.

Note moreover that the "respective" reading and the internal reading interact with one another:

(166) a. John and Mary showed the same book to his brother and her sister respectively.
b. The White House proposed, and the Justice Department formally recommended, different codes of conduct to the Boy Scouts and the CIA Operations Section respectively on the same day.

These similarities, especially the fact that the two phenomena interact with one another systematically as in (166), strongly suggest that one and the same mechanism is at the core of the compositional semantics of these constructions.

The parallel distributional pattern in fact extends to the interpretations of summative predicates such as *a total of N* and *N in total* as well. The problem that summative predicates pose for the syntax-semantics interface is best known in the context of RNR, in examples such as the following (Abbott 1976):

(167) John spent, and Bill lost, a total of $10,000 last year.

Just like the internal reading for symmetrical predicates (cf. (163c)), (167) has a reading that is not equivalent to its "paraphrase" with clausal coordination:

(168) John spent a total of $10,000 last year and Bill lost a total of $10,000 last year.

But the summative reading exhibited by (167) (where $10,000 corresponds to the sum of amounts that respectively satisfy the two predications) is not limited to RNR. The same reading is found in the full range of coordination constructions:

(169) a. The two men spent a total of $10,000. (NP coordination)
b. A total of $10,000 was spent and lost. (VP coordination)
c. John donated a total of $10,000 to the Red Cross on Thursday and to the Salvation Army on Friday. (DCC)

Note that here too, both plural NPs (as in (169a)) and conjoined expressions (as in (169b,c)) can enter into summative predication.

Moreover, just as with "respective" readings and internal readings, iterated summative readings are also possible, and these phenomena interact with one another:

(170) a. A total of three boys bought a total of ten books.
b. John collected, and Mary got pledges for, a total of $10,000 for charity from his family and her clients, respectively.
c. John gave, and Bill lent, a total of $10,000 to {the same student / different students}.

We are not aware of any explicit previous analysis that accounts for the interactions of these phenomena with each other as exemplified by (170b,c) and (166) above. We take it that these examples provide a particularly strong argument for a unified analysis of these phenomena.

In the next section, we propose just such an analysis of "respective," symmetrical, and summative predicates, accounting for the parallels and interactions among these phenomena straightforwardly. The key idea that we exploit is that all these expressions denote tuples—that is, ordered lists of items—and the same "respective" predication operator mediates the complex (yet systematic) interactions they exhibit that pose apparent challenges to compositionality. While the semantics of each of these phenomena have been studied extensively in the previous literature by several authors, to our knowledge, a unitary and fully detailed compositional analysis—especially one that extends straightforwardly to cases involving interactions with NCC—has not yet been achieved. (But see Chaves [2012] for a recent attempt, some of whose key ideas we inherit in our own analysis; see section 5.4.1.3 for a comparison.) We believe that the unified analysis we offer below clarifies the compositional mechanism underlying these phenomena—in particular, illuminating the way it interacts with the general syntax and semantics of coordination, including both standard constituent coordination and NCC.

5.2 Some Residual Issues Regarding the Empirical Properties of "Respective," Symmetrical, and Summative Predicates

Before moving on to the analysis, we would like to address residual issues, some of which might initially appear to threaten the unified treatment of "respective," symmetrical and summative predicates presented in the next section.

5.2.1 Apparent Nonparallels between "Respective," Symmetrical, and Summative Predicates

As we have discussed above, the analysis presented below builds on the idea that a single common mechanism is at the core of the semantics of the three phenomena reviewed above. One might object to this assumption by noting cases where these phenomena apparently do not behave in a completely parallel fashion. We believe that in each such case, the superficial difference can be attributed to independent factors orthogonal to the core semantic mechanism common to these phenomena.

5.2.1.1 Interactions with universal quantifiers The first alleged discrepancy among the three phenomena comes from examples involving the universal quantifiers *every* and *each*. Note first that *every* and *each* license internal readings of symmetrical predicates quite readily:

(171) a. Every student read {the same book/a different book}.
b. Each student read {the same book/a different book}.

Given the parallel between symmetrical predicates on the one hand and "respective" and summative predicates on the other, as noted above, one might then expect the latter two to induce the relevant readings with universal quantifiers similarly. This expectation seems initially falsified by data such as the following:

(172) a. {Each/Every} student read a total of twenty books.
b. #{Each/Every} student read *War and Peace*, *Anna Karenina*, and *The Idiot*, respectively.

These sentences lack the relevant "respective"/summative readings. (172a) can be interpreted only on the strictly distributive reading of *each*/*every* (where each of the students read a total of twenty books separately) and (172b) is simply infelicitous since the adverb *respectively* is incompatible with the distributive reading of *each* and *every*.

However, it has been noted in the literature that the relevant readings are available at least in certain examples:

(173) a. Three copy-editors (between them) caught every mistake in the manuscript. (Kratzer 2007)

b. (. . .) it is essential that an agreement be reached as to the costs that each party will respectively bear. (Chaves 2012)

There seem to be several factors involved in the contrast between the examples in (173) and those in (172). One relevant factor is arguably pragmatic. Both the "respective" reading and the summative reading seem to require that the totality of the set identified by the quantified NP containing *every* or *each* be identifiable, so that a proper correspondence between each member of that set and the corresponding subparts of the other plurality can be established. For the "respective" reading, there also needs to be at least an implicit linking between specific members of one set to the members of the other. Typically, this is established by a linguistically or contextually invoked ordering (as already discussed), but an implicit dependency between the members of the two sets (as facilitated by the expression *costs*, which readily invokes such dependency) seems to play the role of establishing the relevant linking in examples like (173b).

Another relevant factor seems to be real-time sentence processing. Note that, in both of the examples in (173), where the "respective"/summative readings are licensed with *each/every*, the NP containing *each/every* linearly follows the plural that it relates to.[4] While a complete account of why linear order would matter in inducing "respective" predication is beyond the scope of our proposal, we believe that something along the following lines is at work. The "respective" and summative readings are, in a sense, more complex than distributive readings and internal readings of symmetrical predicates in that they involve codependency of interpretation between the sets identified by *every/each N* and the other plural. Distributive and internal readings, by contrast, involve only quantification over the set of objects identified by *each/every* (the internal reading is somewhat more complex than the distributive reading, but the extra complexity boils down to the (non-)distinctness of the property predicated of each object that the quantifier ranges over). When the plural precedes the quantifier, the codependency relation can be established more easily since by the time the processor encounters the quantifier, the plural NP that it associates with is already identified. By contrast, in examples like (172), the NP containing *each/every* appears sentence-initially, and this sets a strong bias for a distributive quantification interpretation (in the broader sense encompassing the internal readings of symmetrical predicates) in which the quantifier meaning is processed without taking into account its codependency to another expression.

4. Kratzer (2007) attributes the contrast between (173a) and *Every copy editor caught five hundred mistakes in the manuscript* (which does not induce the relevant summative reading) to differences in grammatical relations. However, see Champollion (2010) for a discussion that grammatical relation is not the relevant factor.

Thus, while there apparently is an asymmetry between "respective" and summative predicates on the one hand and symmetrical predicates on the other as to how readily the relevant reading is available, we believe that the contrast observed in (171)–(173) receives independent explanation and that it is not problematic for the unified analysis we propose below.

5.2.1.2 The incompatibility of overt *respectively* with symmetrical and summative predicates Unlike "respective" readings, symmetrical and summative predicates are incompatible with the adverb *respectively*:

(174) a. #John and Bill read {the same book/different books}, respectively.
b. #John and Bill spent a total of $10,000, respectively.

This does not pose any problem for our unified analysis of "respective," symmetrical, and summative predicates. As noted by Chaves (2012), the function of the adverb *respectively* is to ensure that the bijection established is in accordance with the contextually provided ordering (where the relevant ordering is either given by the linguistic context [i.e., order of mention] or the pragmatic context). Although the technical analysis we propose below makes use of the same mechanism for establishing a bijective mapping in the three phenomena, the nature of the ordering is crucially different in the case of *respectively* sentences on the one hand and symmetrical and summative predicates on the other. In the latter two cases, the relevant ordering is introduced purely for the sake of ensuring that a proper bijective mapping is established. Thus, since there is no contextually salient ordering involved, these expressions are incompatible with the meaning of the adverb *respectively*.

5.2.1.3 "Respective" readings with disjunction As noted by Eggert (2000) and Yatabe and Tam (2019), there are examples in which the "respective" reading is induced by disjunction rather than conjunction, such as the following:

(175) a. If the cup is too small or too large, then you should go up or down, respectively, in cup size.
b. The n and N commands repeat the previous search command in the same or opposite direction, respectively.

One might think that this type of example would pose a challenge to the analysis of the "respective" reading that we propose in the next section, since our analysis takes a generalized version of the distributivity operator to be responsible for inducing the "respective" reading.

We suspect that all such examples involve the alternative-invoking meaning of *or* in English (cf., e.g., Alonso-Ovalle 2006), rather than boolean disjunction. Once this possibility is recognized, it seems to us to be premature to draw the conclusion that these data pose a problem for our approach, since alternative semantic values in alternative semantics (Rooth 1985) are model-theoretic objects that can enter into more complex compositional operations, just like elements of a sum in sum-based semantics for plurality. This being said, we leave a detailed examination of these disjunctive "respective" reading examples to another occasion.

5.2.2 Non-coordinate RNR and Dependent Clusters

It is well-known that RNR is not restricted to coordination (Hudson 1976; Phillips 1996):

(176) a. Stone also suggests that Nixon knew of, though he did not attempt to participate in, US attempts to assassinate Fidel Castro. (*Boston Globe* Sunday movie section)

b. The people who liked, easily outnumbered the people who disliked, the movie we saw yesterday.

Interestingly, some instances of "non-coordinate" RNR can induce the "respective" reading and the internal reading of symmetrical predicates:[5]

(177) a. John defeated, {whereas/although} Mary lost to, the exact same opponent.

b. John defeated, whereas Mary lost to, Sam and Kim, respectively.

Note further that, as pointed out by Beavers and Sag (2004), the disjunction *or* is seriously degraded in the internal reading, and other types of non-coordinate RNR whose (truth-conditional) meanings do not correspond to conjunction similarly fail to induce the relevant readings:

(178) a. #John hummed, or Mary sang, the same tune. (Beavers and Sag 2004)

b. #The people who liked, easily outnumbered the people who disliked, the same movie.

We think that the relevant generalization is whether the construction in question has the meaning of conjunction. *Whereas* and *although* are truth-conditionally equivalent to conjunction, with an extra pragmatic function of indicating a particular discourse relation (some kind of contrast) between the two clauses. Since the analysis we present below is predicated of the conjunctive meaning of *and* rather than its syntactic coordinatehood, the examples in (177), rather than undermining our analysis, in fact provide further corroboration for it.

5. The following example, however, does not induce the summative reading:

(i) John spent, whereas Mary lost, a total of $10,000.

This seems to be due to the fact that the "contrast" discourse relation lexically invoked by *whereas* is inherently incompatible with the pragmatics of summative interpretation (in which the two clauses need to be construed to pertain to some common point rather than being in contrast with one another).

More challenging to our approach are cases like the following, in which dependent cluster formation interacts with comparatives. As noted by Moltmann (1992) and Hendriks (1995a), comparatives license the internal reading of *same* (but this does not seem to be possible with other symmetrical predicates such as *different* and *similar*), and this works in examples involving nonconstituents in the comparative clause also:

(179) a. I gave the same girl more books on Saturday than CDs on Sunday.
b. ??I gave {different/similar} girls more books on Saturday than CDs on Sunday.

We do not know of any compositional analysis of internal readings of symmetrical predicates that can account for the interaction of *same* and comparatives in examples like (179a). It is tempting to speculate that the internal reading here is supported by some core meaning (something like "parallel predications" involving multiple clauses) common to conjunction and comparatives and that, once this core meaning is identified, the existing analyses of internal readings would straightforwardly carry over to cases like (179a). However, given the lack of a concrete proposal, we simply leave this as an open issue for future study.

5.3 The Compositional Semantics of "Respective" Predication

In this section, we present a unified analysis of "respective," symmetrical, and summative predicates in Hybrid TLCG. Key to our proposal is the idea that the same underlying mechanism of pairwise predication between terms that denote tuples is involved in the semantics of these phenomena. This analytic idea itself is theory-neutral, but we show that formulating the analysis in Hybrid TLCG enables us to capture the complex yet systematic properties of this class of phenomena particularly transparently. More specifically, the order-insensitive mode of implication involving the "vertical slash" ($\upharpoonright$), the key novel feature of Hybrid TLCG, enables a unified analysis of the two essential properties of these phenomena identified in section 5.1: (i) interactions with NCC; and (ii) multiple dependency that these predicates exhibit, including the interactions of the three phenomena with one another.

5.3.1 Hypothetical Reasoning and "Respective" Predication

We start with the analysis of "respective" readings since our analysis of the other two phenomena builds on the core semantic operator that we introduce for this construction. The underlying intuition of most formal analyses of "respective" readings (cf. Gawron and Kehler 2004; Winter 1995; Bekki 2006) (which we also adopt) is that sentences like (180) involve pairwise predication between two (or more) sets of entities where the "corresponding" elements of the two sets are related by some predicate in the sentence.

(180) Mary and Sue married John and Bill (respectively).

In the case of (180), this "predicate" is simply the lexical meaning of the verb, but in certain cases that we discuss below, the predicate that relates the elements of the two sets (as well as the elements in the two sets themselves) can be of a more complex type.

Among the previous approaches, Gawron and Kehler (2004) (G&K) work out the relevant compositional mechanism in most detail (see section 5.4.1.1 for more on their approach). G&K model the meanings of expressions to be related in a "respective" manner in terms of the notion of sums. While this works well with cases of "respective" readings, G&K's approach faces a technical difficulty if one attempts to extend it directly to the case of symmetrical predicates (see section 5.4.1.1). Since our goal is to provide a unified analysis of the three phenomena, we adopt a different approach. Specifically, following Winter (1995) and Bekki (2006), we first recast the relevant aspects of G&K's analysis in terms of the notion of tuple, which is essentially a list that comes with an ordering of elements. Our reasons for taking the ordering of elements to be part of the denotation of plural and conjoined expressions are given in section 5.4.2. As we discuss there, this choice is purely for expository convenience; a multiset-based reformulation of the analysis (which relocates the ordering information to pragmatics) is conceivable, but then the relevant compositional mechanism becomes much more complex.

Tuples can be formally defined in several different ways.[6] Here, we adopt a functional definition, where an n-tuple $\langle a_1, a_2, \ldots, a_n \rangle$ is a function whose domain is a set of integers $\{1, \ldots, n\}$ such that

$$\langle a_1, a_2, \ldots, a_n \rangle =_{def} \begin{bmatrix} 1 \longmapsto a_1 \\ 2 \longmapsto a_2 \\ \vdots \\ n \longmapsto a_n \end{bmatrix}$$

6. A standard definition in mathematics is in terms of ordered pairs:

(i) a. For any a and b, the ordered pair $\langle a, b \rangle$ is a two-tuple and is written as (a, b).
b. If A (= $(a_1, a_2, \ldots, a_n)$) is an n-tuple, then for any b, the ordered pair $\langle A, b \rangle$ is an $(n+1)$-tuple and is written as $(a_1, a_2, \ldots, a_n, b)$.

However, this formulation has the problem that an n-tuple and an $(n-1)$-tuple whose first component is itself a tuple are formally indistinguishable (e.g., the triple $\langle a, b, c \rangle$ and the double $\langle \langle a, b \rangle, c \rangle$ are identical under this definition). This is problematic for our purposes since an n-tuple does not behave like an $(n-1)$-tuple in the "respective" readings:

(ii) #Alice, Betty, and Cathy met Dan and Eric, respectively.
intended: 'Alice and Betty met Dan and Cathy met Eric.'

Importantly, unlike sums (or sets), tuples are inherently ordered. Thus, $a \oplus b \oplus c = a \oplus c \oplus b$, but $\langle a,b,c \rangle \neq \langle a,c,b \rangle$.

We assume that the conjunction word *and* denotes the following tuple-forming operator (this needs to be generalized to cases involving more than two conjuncts, but we omit this detail since it is not directly relevant for the ensuing discussion):[7]

(181) and; $\lambda \mathcal{W} \lambda \mathcal{V}.\langle \mathcal{V}, \mathcal{W} \rangle$; $(X \backslash X)/X$

This enables us to assign tuples of individuals like $\langle \mathbf{mary}, \mathbf{sue} \rangle$ and $\langle \mathbf{mary}, \mathbf{sue}, \mathbf{ann} \rangle$ as the meanings of expressions like *Mary and Sue* and *Mary, Sue, and Ann*.[8] Then, to assign the right meaning to (180), the two tuples $\langle \mathbf{mary}, \mathbf{sue} \rangle$ and $\langle \mathbf{john}, \mathbf{bill} \rangle$, each denoted by the subject and object NPs, need to be related to each other in a "respective" manner via the relation **married**: Mary married John and Sue married Bill. Establishing this "respective" relation is mediated by the **resp** operator in (182), which is a prosodically empty operator that takes a relation and two tuple-denoting terms as arguments and returns a tuple consisting of propositions obtained by relating each member of the two tuples in a pairwise manner with respect to the relation in question (see below for the denotation for the adverb *respectively*; the role of *respectively* is essentially to ensure that the bijective mapping obtained by this covert **resp** operator conforms to the contextually established ordering):

(182) $\mathbf{resp} = \lambda \mathcal{R} \lambda \mathcal{T}_{\times_n} \lambda \mathcal{U}_{\times_n}.\prod_i^n \mathcal{R}(\pi_i(\mathcal{T}_{\times_n}))(\pi_i(\mathcal{U}_{\times_n}))$

$\mathcal{T}_{\times_n}$ and $\mathcal{U}_{\times_n}$ range over n-tuples. We omit the subscript n if its value is contextually obvious. Thus, in (182), the cardinality of the input tuples needs to match. π_i is the projection function which returns the i-th member of the tuple. $\prod_i^n$ is a tuple constructor defined as follows:

(183) $\prod_i^n a_i = \langle a_1, a_2, \ldots, a_n \rangle$

From this, it should be clear that the cardinality of the input and output tuples matches.

---

7. At this point, one might wonder whether the tuple meaning in (181) is the only meaning of conjunction that we need, or if we need to assume the boolean conjunction meaning in addition. As discussed in Kubota and Levine (2014b), the two rules in (252) in section 5.5 become derivable in our setup. Sentences like (ia) and the distributive readings of sentences like (ib) can then be obtained with these rules.

(i) a. John walked and talked.
    b. John and Bill walked.

Alternatively, boolean conjunction meanings (for any given type) can be derived as a theorem from the tuple-type meaning for *and* in (181) via hypothetical reasoning with the **resp** operator in (182) and the tuple constructor in (183). Thus, boolean conjunction does not need to be separately posited. See Krifka (1990) for some discussion about the relationship between boolean and non-boolean *and*.

8. We assume, as per our discussion in the preceding chapter, that plural NPs denote sums lexically and that they are converted to tuples via an empty operator when some contextually salient ordering is available.

By giving the relation denoted by the verb and the two tuples denoted by the object and subject NPs as arguments to the **resp** operator, we obtain the following result:

(184) $\mathbf{resp}(\mathbf{married})(\langle \mathbf{j},\mathbf{b}\rangle)(\langle \mathbf{m},\mathbf{s}\rangle) = \prod_i \mathbf{married}(\pi_i(\langle \mathbf{j},\mathbf{b}\rangle))(\pi_i(\langle \mathbf{m},\mathbf{s}\rangle))$
$= \langle \mathbf{married}(\mathbf{j})(\mathbf{m}), \mathbf{married}(\mathbf{b})(\mathbf{s})\rangle$

This tuple of two propositions is then mapped to a boolean conjunction via a phonologically empty operator with the following meaning:

(185) $\lambda p_\times . \bigwedge_i \pi_i(p_\times)$

By applying (185) to (184), we obtain the proposition $\mathbf{married}(\mathbf{j})(\mathbf{m}) \wedge \mathbf{married}(\mathbf{b})(\mathbf{s})$. As will become clear below, keeping the two components separate in the form of a tuple after the application of the **resp** operator is crucial for dealing with multiple "respective" (or symmetrical/summative) readings in examples like those in (161), (165), and (170).

The next question is how to get this semantic analysis to mesh with a compositional analysis of the sentence. Things may seem simple and straightforward in examples like (180), where the two terms to be related to each other in a pairwise manner are co-arguments of the same predicate. However, as noted already, this is not always the case. For treating more complex cases, G&K propose to treat "respective" predication in terms of a combination of recursive applications of both the "respective" operator and the distributive operator, but their approach quickly becomes unwieldy. Since we need to deal with complex examples involving interactions with nonconstituent coordination, we simply note here that the compositional mechanism assumed by G&K is not fully general and turn to an alternative approach (see section 5.4.1.1 for a more complete critique of their approach; see also section 5.5 for some more general remarks about the relationship between the present proposal and G&K's approach).

It turns out that a more general (and simpler) approach which serves our purpose here is straightforwardly available in Hybrid TLCG by (two instances of) hypothetical reasoning with the vertical slash, as we show momentarily. Crucially, the interdependence between the two product-type terms is mediated by double abstraction via $\upharpoonright$ in the syntax, whose output (together with the two product-type terms themselves) is immediately given to the **resp** operator, which then relates them in a pairwise manner with respect to some relation $\mathcal{R}$. This is essentially an implementation of Barker's (2007) "parasitic scope" strategy. (For a comparison between the present proposal and Barker's analysis of *same*, see section 5.4.1.2.)

In Hybrid TLCG, we can abstract over any arbitrary positions in a sentence to create a relation that obtains between objects belonging to the semantic types of the variables that are abstracted over. This is illustrated in the following partial derivation for (180). By abstracting over the subject and object positions of the sentence, we obtain an expression of type $S\upharpoonright NP\upharpoonright NP$, where the "gaps" in the subject and object positions are kept track of via explicit λ-binding in the phonology, just in the same way as in the analysis of quantifier scope in chapter 2.

(186)
$$\dfrac{\dfrac{\dfrac{[\varphi_2; y; \mathrm{NP}]^2 \quad \dfrac{\text{married}; \textbf{married}; \mathrm{VP/NP} \quad [\varphi_1; x; \mathrm{NP}]^1}{\text{married} \circ \varphi_1; \textbf{married}(x); \mathrm{VP}}/\mathrm{E}}{\varphi_2 \circ \text{married} \circ \varphi_1; \textbf{married}(x)(y); \mathrm{S}}/\mathrm{E}}{\lambda\varphi_2.\varphi_2 \circ \text{married} \circ \varphi_1; \lambda y.\textbf{married}(x)(y); \mathrm{S}{\upharpoonright}\mathrm{NP}}{\upharpoonright}\mathrm{I}^2}{\lambda\varphi_1\lambda\varphi_2.\varphi_2 \circ \text{married} \circ \varphi_1; \lambda x\lambda y.\textbf{married}(x)(y); \mathrm{S}{\upharpoonright}\mathrm{NP}{\upharpoonright}\mathrm{NP}}{\upharpoonright}\mathrm{I}^1$$

The “respective” operator, defined as in (187), then takes such a doubly abstracted proposition as an argument to produce another type $\mathrm{S}{\upharpoonright}\mathrm{NP}{\upharpoonright}\mathrm{NP}$ expression. Phonologically, it is just an identity function, and its semantic contribution is precisely the **resp** operator defined above.

(187) $\lambda\sigma\lambda\varphi_1\lambda\varphi_2.\sigma(\varphi_1)(\varphi_2); \textbf{resp}; (Z{\upharpoonright}X{\upharpoonright}Y){\upharpoonright}(Z{\upharpoonright}X{\upharpoonright}Y)$

The derivation completes by giving the two product-type arguments denoted by *John and Bill* and *Mary and Sue* to this “respectivized” type $\mathrm{S}{\upharpoonright}\mathrm{NP}{\upharpoonright}\mathrm{NP}$ predicate and converting the pair of propositions to a boolean conjunction by the boolean reduction operator in (185). (As per our standard practice, dotted lines in derivations correspond to reductions of semantic translations to enhance readability and should not be confused with the application of logical rules designated by solid lines. Unlike the latter, purely from a formal perspective, these reduction steps are redundant.)

(188)
$$\dfrac{\begin{array}{l}\lambda\varphi.\varphi;\\ \lambda p_\times.\\ \quad \bigwedge_i \pi_i(p_\times);\\ \mathrm{S}{\upharpoonright}\mathrm{S}\end{array} \quad \begin{array}{c}\dfrac{\begin{array}{c}\vdots\\ \text{mary} \circ \\ \text{and} \circ \\ \text{sue};\\ \langle\mathbf{m},\mathbf{s}\rangle; \mathrm{NP}\end{array} \quad \dfrac{\begin{array}{c}\vdots\\ \text{john} \circ \\ \text{and} \circ \\ \text{bill};\\ \langle\mathbf{j},\mathbf{b}\rangle; \mathrm{NP}\end{array} \quad \dfrac{\begin{array}{l}\lambda\sigma\lambda\varphi_1\lambda\varphi_2.\\ \quad \sigma(\varphi_1)(\varphi_2);\\ \textbf{resp};\\ (Z{\upharpoonright}X{\upharpoonright}Y){\upharpoonright}(Z{\upharpoonright}X{\upharpoonright}Y)\end{array} \quad \begin{array}{l}\quad\quad\vdots\\ \lambda\varphi_3\lambda\varphi_4.\\ \quad \varphi_4 \circ \text{married} \circ \varphi_3;\\ \textbf{married}; \mathrm{S}{\upharpoonright}\mathrm{NP}{\upharpoonright}\mathrm{NP}\end{array}}{\begin{array}{c}\lambda\varphi_1\lambda\varphi_2.\varphi_2 \circ \text{married} \circ \varphi_1;\\ \textbf{resp}(\textbf{married}); \mathrm{S}{\upharpoonright}\mathrm{NP}{\upharpoonright}\mathrm{NP}\end{array}}{\upharpoonright}\mathrm{E}}{\begin{array}{c}\lambda\varphi_2.\varphi_2 \circ \text{married} \circ \text{john} \circ \text{and} \circ \text{bill};\\ \textbf{resp}(\textbf{married})(\langle\mathbf{j},\mathbf{b}\rangle); \mathrm{S}{\upharpoonright}\mathrm{NP}\end{array}}{\upharpoonright}\mathrm{E}}{\begin{array}{l}\text{mary} \circ \text{and} \circ \text{sue} \circ \text{married} \circ \text{john} \circ \text{and} \circ \text{bill};\\ \textbf{resp}(\textbf{married})(\langle\mathbf{j},\mathbf{b}\rangle)(\langle\mathbf{m},\mathbf{s}\rangle); \mathrm{S}\end{array}}{\upharpoonright}\mathrm{E}\\ \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\\ \begin{array}{l}\text{mary} \circ \text{and} \circ \text{sue} \circ \text{married} \circ \text{john} \circ \text{and} \circ \text{bill};\\ \langle\textbf{married}(\mathbf{j})(\mathbf{m}), \textbf{married}(\mathbf{b})(\mathbf{s})\rangle; \mathrm{S}\end{array}\end{array}}{\begin{array}{l}\text{mary} \circ \text{and} \circ \text{sue} \circ \text{married} \circ \text{john} \circ \text{and} \circ \text{bill};\\ \textbf{married}(\mathbf{j})(\mathbf{m}) \wedge \textbf{married}(\mathbf{b})(\mathbf{s}); \mathrm{S}\end{array}}{\upharpoonright}\mathrm{E}$$

Note in particular that prosodic λ-binding with $\upharpoonright$ enables “lowering” the phonologies of the two product-type terms in their respective positions in the sentence, thus mediating the syntax-semantics mismatch between their surface positions and semantic scope (of the **resp** operator that they are arguments of) in essentially the same way as with quantifiers.

We now turn to the treatment of the adverb *respectively*. We assume that the function of *respectively* is to ensure that the order of elements in the tuples that the covert **resp** operator takes as arguments conforms to some contextually established ordering. This can be encoded as a condition on the arguments via the predicate $\mathbf{order}_C$ (with contextual parameter C), where $\mathbf{order}_C(X_\times)$ is true of a tuple $X_\times$ if and only if the ordering of elements encoded in $X_\times$ conforms to the contextual ordering of its elements in C. The lexical entry for *respectively* can then be written as follows:

(189) $\lambda\sigma\lambda\varphi_1\lambda\varphi_2.\sigma(\varphi_1)(\varphi_2) \circ \mathsf{respectively};$
$\lambda\mathcal{R}\lambda\mathcal{T}_{\times:\mathbf{order}_C(\mathcal{T}_\times)}\ \lambda\mathcal{U}_{\times:\mathbf{order}_C(\mathcal{U}_\times)}.\mathcal{R}(\mathcal{T}_\times)(\mathcal{U}_\times); (Z{\upharpoonright}X{\upharpoonright}Y){\upharpoonright}(Z{\upharpoonright}X{\upharpoonright}Y)$

By applying this operator to the "respectivized" relation **resp**(**marry**), we obtain

(190) $\lambda\mathcal{T}_{\times:\mathbf{order}_C(\mathcal{T}_\times)}\ \lambda\mathcal{U}_{\times:\mathbf{order}_C(\mathcal{U}_\times)}.\mathbf{resp}(\mathbf{marry})(\mathcal{T}_\times)(\mathcal{U}_\times)$

It might appear that the function of *respectively* is completely redundant in examples like (180), since the tuples already record the correct ordering reflecting the order of mention. However, this is an artificial consequence of adopting a tuple-based formulation of the analysis. In a multiset-based reformulation (which we discuss briefly in section 5.4.2), *respectively* does make a substantial contribution to the meaning of the sentence by filtering out ordering possibilities that do not conform to the contextual ordering (e.g., #*The front and the back of the ship are called the bow and the stern, respectively, but which is which?*).

Another point which needs to be noted about *respectively* is that it is an adverb, and just like other adverbs, its surface word order is relatively flexible.

(191) a. John and Mary will meet Peter and Sue, respectively.
b. John and Mary respectively will meet Peter and Sue.
c. John and Mary will respectively meet Peter and Sue.

With the lexical entry in (189), our analysis attaches *respectively* at the end of the whole string. We assume that surface reordering principles (of the sort that can be implemented in our system by enriching the prosodic component along the lines discussed in chapter 11) are responsible for generating the other orders such as (191b,c).

It should be clear that the analysis extends straightforwardly to cases where one of the product-type terms appears in a sentence-internal position, such as the following:

(192) John and Bill sent the bomb and the letter to the president yesterday, respectively.

For this sentence, we first obtain the following doubly abstracted proposition in the same way as in the simpler example above:

(193) $\lambda\varphi_1\lambda\varphi_2.\varphi_1 \circ \mathsf{sent} \circ \varphi_2 \circ \mathsf{to} \circ \mathsf{the} \circ \mathsf{president} \circ \mathsf{yesterday};$
$\lambda x \lambda y.\mathbf{yest}(\mathbf{sent}(y)(\mathbf{the\text{-}pres}))(x); \mathrm{S}{\upharpoonright}\mathrm{NP}{\upharpoonright}\mathrm{NP}$

The **resp** operator then takes this and the two product-type terms as arguments to produce a sign with the surface string in (192) paired with the following semantic interpretation (after the application of boolean reduction):

(194) $\mathbf{yest}(\mathbf{sent}(\mathbf{the\text{-}bomb})(\mathbf{the\text{-}pres}))(\mathbf{j}) \wedge \mathbf{yest}(\mathbf{sent}(\mathbf{the\text{-}letter})(\mathbf{the\text{-}pres}))(\mathbf{b})$

We now turn to an interaction with NCC, taking the following example as an illustration:

(195) John and Bill met Robin on Thursday and Chris on Friday, respectively.

The analysis is in fact straightforward. As discussed in chapter 2, Dependent Cluster Coordination is analyzed by treating the apparent nonconstituents that are coordinated in examples like (195) to be (higher-order) derived constituents via hypothetical reasoning (with the directional slashes / and \).

Specifically, via hypothetical reasoning, the string *Robin on Thursday* can be analyzed as a constituent of type $(\mathrm{VP}/\mathrm{NP})\backslash\mathrm{VP}$, an expression that combines with a transitive verb and an NP (in that order) to its left to become an S (see (253) in section 5.6 for a complete proof):

(196) $\mathsf{robin} \circ \mathsf{on} \circ \mathsf{thursday}; \lambda R.\mathbf{onTh}(R(\mathbf{r})); (\mathrm{VP}/\mathrm{NP})\backslash\mathrm{VP}$

We then derive a sentence containing gap positions corresponding to this derived constituent and the subject NP (see (254) in section 5.6):

(197) $\lambda\varphi_1\lambda\varphi_2.\varphi_1 \circ \mathsf{met} \circ \varphi_2; \lambda x \lambda \mathscr{P}.\mathscr{P}(\mathbf{met})(x); \mathrm{S}{\upharpoonright}((\mathrm{VP}/\mathrm{NP})\backslash\mathrm{VP}){\upharpoonright}\mathrm{NP}$

The rest of the derivation involves giving this relation and the two product-type arguments of types NP and $(\mathrm{VP}/\mathrm{NP})\backslash\mathrm{VP}$ as arguments to the **resp** operator, which yields the following translation for the whole sentence:

(198) $\mathbf{onTh}(\mathbf{met}(\mathbf{r}))(\mathbf{j}) \wedge \mathbf{onFr}(\mathbf{met}(\mathbf{c}))(\mathbf{b})$

Finally, multiple "respective" readings, exemplified by (199), are straightforward.

(199) Tolstoy and Dostoevsky sent *Anna Karenina* and *The Idiot* to Dickens and Thackeray (respectively).

As in G&K's analysis, the right meaning can be compositionally assigned to the sentence via recursive application of the **resp** operator, without any additional mechanism. The key point of the derivation is that we first derive a three-place predicate of type $\mathrm{S}{\upharpoonright}\mathrm{NP}{\upharpoonright}\mathrm{NP}{\upharpoonright}\mathrm{NP}$, instead of a two-place predicate of type $\mathrm{S}{\upharpoonright}\mathrm{NP}{\upharpoonright}\mathrm{NP}$ (as in the simpler case in (188)), to be given as an argument to the first **resp** operator:

(200) $\lambda\varphi_1\lambda\varphi_2\lambda\varphi_3.\varphi_3 \circ \mathsf{sent} \circ \varphi_1 \circ \mathsf{to} \circ \varphi_2; \mathbf{sent}; \mathrm{S}{\upharpoonright}\mathrm{NP}{\upharpoonright}\mathrm{NP}{\upharpoonright}\mathrm{NP}$

After two of the tuple-denoting terms are related to each other with respect to the predicate denoted by the verb, the resultant S↾NP expression denotes a tuple of two properties (see (255) in section 5.6 for a complete proof):

(201) $\lambda\varphi_3.\varphi_3 \circ \textsf{sent} \circ \textsf{AK} \circ \textsf{and} \circ \textsf{Id} \circ \textsf{to} \circ \textsf{Di} \circ \textsf{and} \circ \textsf{Th};\ \langle \mathbf{sent}(\mathbf{ak})(\mathbf{di}), \mathbf{sent}(\mathbf{id})(\mathbf{th})\rangle;$ $\mathrm{S}{\restriction}\mathrm{NP}$

And the remaining conjoined term $\langle \mathbf{to}, \mathbf{do}\rangle$ is related to this product-type property by a derived two-place "respective" operator in the following way:

(202)

$$\dfrac{\begin{array}{c}\textsf{To} \circ \textsf{and} \circ \textsf{Do};\\ \langle \mathbf{to}, \mathbf{do}\rangle; \mathrm{NP}\end{array} \quad \dfrac{\begin{array}{l}\vdots\\ \lambda\sigma\lambda\varphi.\sigma(\varphi);\\ \lambda P_\times \lambda X_\times.\prod_i \pi_i(P_\times)(\pi_i(X_\times));\\ (\mathrm{S}{\restriction}\mathrm{NP}){\restriction}(\mathrm{S}{\restriction}\mathrm{NP})\end{array} \quad \begin{array}{l}\vdots\\ \lambda\varphi_3.\varphi_3 \circ \textsf{sent} \circ \textsf{AK} \circ \textsf{and} \circ \textsf{Id} \circ\\ \quad \textsf{to} \circ \textsf{Di} \circ \textsf{and} \circ \textsf{Th};\\ \langle \mathbf{sent}(\mathbf{ak})(\mathbf{di}), \mathbf{sent}(\mathbf{id})(\mathbf{th})\rangle; \mathrm{S}{\restriction}\mathrm{NP}\end{array}}{\begin{array}{l}\lambda\varphi.\varphi \circ \textsf{sent} \circ \textsf{AK} \circ \textsf{and} \circ \textsf{Id} \circ \textsf{to} \circ \textsf{Di} \circ \textsf{and} \circ \textsf{Th};\\ \lambda X_\times.\prod_i \pi_i(\langle \mathbf{sent}(\mathbf{ak})(\mathbf{di}), \mathbf{sent}(\mathbf{id})(\mathbf{th})\rangle)(\pi_i(X_\times)); \mathrm{S}{\restriction}\mathrm{NP}\end{array}}{\restriction}\mathrm{E}}{\begin{array}{l}\textsf{To} \circ \textsf{and} \circ \textsf{Do} \circ \textsf{sent} \circ \textsf{AK} \circ \textsf{and} \circ \textsf{Id} \circ \textsf{to} \circ \textsf{Di} \circ \textsf{and} \circ \textsf{Th};\\ \prod_i \pi_i(\langle \mathbf{sent}(\mathbf{ak})(\mathbf{di}), \mathbf{sent}(\mathbf{i})(\mathbf{th})\rangle)(\pi_i(\langle \mathbf{to}, \mathbf{do}\rangle)); \mathrm{S}\\ \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\\ \textsf{To} \circ \textsf{and} \circ \textsf{Do} \circ \textsf{sent} \circ \textsf{AK} \circ \textsf{and} \circ \textsf{Id} \circ \textsf{to} \circ \textsf{Di} \circ \textsf{and} \circ \textsf{Th};\\ \langle \mathbf{sent}(\mathbf{ak})(\mathbf{di})(\mathbf{to}), \mathbf{sent}(\mathbf{id})(\mathbf{th})(\mathbf{do})\rangle; \mathrm{S}\end{array}}{\restriction}\mathrm{E}$$

The two-place **resp** operator, which directly relates the product-type property (of type S↾NP) with the product-type NP occupying the subject position via pairwise function application of the corresponding elements, can be derived from the lexically specified three-place **resp** operator via hypothetical reasoning. The proof is given in (256) in section 5.6.

5.3.2 Extending the Analysis to Symmetrical and Summative Predicates

We exploit the **resp** operator introduced above in the analysis of symmetrical and summative predicates as well. The intuition behind this approach is that NPs containing *same*, *different*, and the like (we call such NPs symmetrical terms below) in examples like (203) denote tuples (linked to the other tuple denoted by the plural *John and Bill* in the same way as in the "respective" readings above) but impose special conditions on each member of the tuple.

(203) John and Bill read the same book.

In (203), John and Bill need to be each paired with an identical book, and in the case of *different*, they need to be paired with distinct books. To capture this additional constraint on the tuples denoted by symmetrical terms, we assign to them GQ-type meanings of type S↾(S↾NP), where the abstracted NP in their arguments are product-type expressions semantically. More specifically, we posit the following lexical entries for *the same* and *different*:[9]

(204) a. $\lambda\varphi\lambda\sigma.\sigma(\mathsf{the} \circ \mathsf{same} \circ \varphi)$;
$\lambda P \lambda Q.\exists X_{\times} \forall i P(\pi_i(X_{\times})) \wedge \forall i \forall j[\pi_i(X_{\times}) = \pi_j(X_{\times})] \wedge Q(X_{\times})$;
$S{\upharpoonright}(S{\upharpoonright}NP){\upharpoonright}N$

b. $\lambda\varphi\lambda\sigma.\sigma(\mathsf{different} \circ \varphi)$;
$\lambda P \lambda Q.\exists X_{\times} \forall i P(\pi_i(X_{\times})) \wedge \forall i \forall j[i \neq j \rightarrow \pi_i(X_{\times}) \neq \pi_j(X_{\times})] \wedge Q(X_{\times})$;
$S{\upharpoonright}(S{\upharpoonright}NP){\upharpoonright}N$

In both cases, the relevant tuple (which enters into the "respective" relation with another tuple via the **resp** operator) consists of objects that satisfy the description provided by the noun. The difference is that in the case of *same*, the elements of the tuple are all constrained to be identical, whereas in the case of *different*, they are constrained to differ from one another.

We now outline the analysis for (203) (the full derivation is given in (257) in section 5.6). The key point is that we first posit a variable that semantically denotes a tuple and relate it to the other tuple-denoting expression (*John and Bill* in this case) via the **resp** operator. This part of the analysis follows proof steps completely parallel to the analysis of "respective" readings shown in the previous section. Specifically, by hypothetically assuming an NP with phonology φ and semantics $X_{\times}$, we can derive the expression in (205).

(205) $\mathsf{john} \circ \mathsf{and} \circ \mathsf{bill} \circ \mathsf{read} \circ \varphi$; $\bigwedge_i \pi_i(\mathbf{resp}(\mathbf{read})(X_{\times})(\langle \mathbf{j}, \mathbf{b} \rangle))$; S

At this point (where boolean reduction has already taken place), we withdraw the hypothesis to obtain an expression of type $S{\upharpoonright}NP$. This is then given as an argument to the symmetrical term *the same book*, which, as noted above, has the GQ-type category $S{\upharpoonright}(S{\upharpoonright}NP)$. The symmetrical term lowers its phonology to the gap and semantically imposes the identity condition on the members of the relevant tuple. These last steps are illustrated in (206).

9. There is a close connection between the lexical entries for the internal readings posited in (204) and those for the external readings. The lexical entries in (204) essentially establish (non-)identity among each element of a tuple, and in this sense, they can be thought of as involving a reflexive anaphoric reference. By replacing this reflexive anaphoric reference with an anaphoric reference to some external object and stating the (non-)identity conditions to pertain to the object identified by the symmetrical term and the anaphorically invoked external object, we obtain a suitable lexical meaning for the external readings for *same* and *different*. Thus, while it may not be possible to unify the lexical entries for the two readings completely, we believe that our approach provides a basis for understanding the close relationship between the two readings. In fact, whether a unified analysis of internal and external readings is desirable seems still controversial. See Brasoveanu (2011) and Bumford and Barker (2013) for discussion.

(206)

$$\dfrac{\begin{array}{c}\vdots\\ \lambda\sigma_0.\sigma_0(\mathsf{the}\circ\mathsf{same}\circ\mathsf{book});\\ \mathbf{same}(\mathbf{book});\mathrm{S}\upharpoonright(\mathrm{S}\upharpoonright\mathrm{NP})\end{array} \qquad \dfrac{\dfrac{\begin{array}{ccc}\vdots & \underline{[\varphi;X_\times;\mathrm{NP}]^1} & \vdots\\ \vdots & \vdots & \vdots\end{array}}{\begin{array}{c}\mathsf{john}\circ\mathsf{and}\circ\mathsf{bill}\circ\mathsf{read}\circ\varphi;\\ \bigwedge_i\pi_i(\mathbf{resp}(\mathbf{read})(X_\times)(\langle\mathbf{j},\mathbf{b}\rangle));\mathrm{S}\end{array}}}{\begin{array}{c}\lambda\varphi.\mathsf{john}\circ\mathsf{and}\circ\mathsf{bill}\circ\mathsf{read}\circ\varphi;\\ \lambda X_\times.\bigwedge_i\pi_i(\mathbf{resp}(\mathbf{read})(X_\times)(\langle\mathbf{j},\mathbf{b}\rangle));\mathrm{S}\upharpoonright\mathrm{NP}\end{array}}\upharpoonright\mathrm{I}^1}{\begin{array}{c}\mathsf{john}\circ\mathsf{and}\circ\mathsf{bill}\circ\mathsf{read}\circ\mathsf{the}\circ\mathsf{same}\circ\mathsf{book};\\ \mathbf{same}(\mathbf{book})(\lambda X_\times.\bigwedge_i\pi_i(\mathbf{resp}(\mathbf{read})(X_\times)(\langle\mathbf{j},\mathbf{b}\rangle)));\mathrm{S}\end{array}}\upharpoonright\mathrm{E}$$

The reason that boolean reduction precedes the abstraction over the product-type NP in (206)/(257) is that the meaning of the symmetrical term is a GQ over product-type NPs. That is, the type $\mathrm{S}\upharpoonright\mathrm{NP}$ property given to it as an argument is a property of product-type NPs that returns a truth value, rather than a tuple, by taking its product-type NP argument. One way to see what's going on in this derivation is that the hypothetical reasoning with the tuple-denoting variable $X_\times$ and "respective" predication involving it is needed since a symmetrical term denotes a quantifier over tuple-denoting expressions and hence cannot directly fill in an argument slot of a lexical verb (which is looking for non-tuple-denoting expressions as its arguments).

The final translation is unpacked in (207):

(207)
$$\begin{aligned}&\mathbf{same}(\mathbf{book})(\lambda X_\times.\textstyle\bigwedge_i\pi_i(\mathbf{resp}(\mathbf{read})(X_\times)(\langle\mathbf{j},\mathbf{b}\rangle)))\\ &=\exists X_\times\forall i\,\mathbf{book}(\pi_i(X_\times))\wedge\forall i\forall j[\pi_i(X_\times)=\pi_j(X_\times)]\wedge\textstyle\bigwedge_i\pi_i(\mathbf{resp}(\mathbf{read})(X_\times)(\langle\mathbf{j},\mathbf{b}\rangle))\\ &=\exists X_\times\forall i\,\mathbf{book}(\pi_i(X_\times))\wedge\forall i\forall j[\pi_i(X_\times)=\pi_j(X_\times)]\wedge\\ &\qquad\mathbf{read}(\pi_1(X_\times))(\mathbf{j})\wedge\mathbf{read}(\pi_2(X_\times))(\mathbf{b})\end{aligned}$$

Since $\pi_1(X_\times)=\pi_2(X_\times)$, this correctly ensures that the book that John read and the one that Bill read are identical.

Before moving on to more complex cases, a comment is in order on the semantic analysis of *same* and *different* in (204). So far as we can tell, the lexical meanings given in (204) capture the truth conditions for the internal readings of *same* and *different* correctly. One might think that (204a) is too weak as the meaning of *same* since according to this definition, (203) can be true in a situation in which the sets of books that John and Bill read are different, as long as one can identify some common book read by both individuals. Thus, one might think that some kind of maximality condition should be imposed on the set of books identified by *same*. We do not agree with this judgment. We believe that (203) is true and felicitous as long as one can identify (at least) one book commonly read by John and Bill. They may have read other books in addition, but that doesn't make (203) false or infelicitous. Such an implication, if felt to be present, is presumably a conversational implicature since it is clearly cancelable:

(208) John and Bill read the same book, although they both read several different books in addition.

Similarly, (204b), as it stands, does not exclude a possibility in which there is some set of books commonly read by John and Bill. We again take this to be the correct result. The following example shows that the implication excluding the existence of common books read by the two (which indeed seems to be present) is not part of the entailment of the sentence:[10]

(209) John and Bill read different books, although they read the same books too.

We now move on to multiple dependency cases. In fact, the present analysis already assigns the right meanings to these sentences. Specifically, since the same **resp** operator is at the core of the analysis as in the case of "respective" readings, we immediately predict that symmetrical predicates can enter into multiple dependencies both among themselves and with respect to "respective" predication, as exemplified by examples like the following:

(210) a. John and Bill gave the same book to Mary and Sue (respectively).
b. John and Bill gave the same book to the same man.

Since the relevant derivations can be reconstructed by taking the derivation for multiple "respective" readings presented in the previous section as a model, we omit the details and reproduce here only the derived meanings for (210a) and (210b) in (211) and (212), respectively (see (258) in section 5.6 for a complete derivation for (210b)).

(211) $\mathbf{same}(\mathbf{book})(\lambda X_\times.\mathbf{gave}(\mathbf{m})(\pi_1(X_\times))(\mathbf{j}) \wedge \mathbf{gave}(\mathbf{s})(\pi_2(X_\times))(\mathbf{b}))$
$= \exists X_\times \forall i\, \mathbf{book}(\pi_i(X_\times)) \wedge \forall i \forall j[\pi_i(X_\times) = \pi_j(X_\times)] \wedge$
$\mathbf{gave}(\mathbf{m})(\pi_1(X_\times))(\mathbf{j}) \wedge \mathbf{gave}(\mathbf{s})(\pi_2(X_\times))(\mathbf{b})$

(212) $\mathbf{same}(\mathbf{book})(\lambda X_\times.\mathbf{same}(\mathbf{man})(\lambda Y_\times.\mathbf{gave}(\pi_1(Y_\times))(\pi_1(X_\times))(\mathbf{j}) \wedge$
$\mathbf{gave}(\pi_2(Y_\times))(\pi_2(X_\times))(\mathbf{b})))$
$= \exists X_\times \forall i\, \mathbf{book}(\pi_i(X_\times)) \wedge \forall i \forall j[\pi_i(X_\times) = \pi_j(X_\times)] \wedge \exists Y_\times \forall i\, \mathbf{man}(\pi_i(Y_\times)) \wedge$
$\forall i \forall j[\pi_i(Y_\times) = \pi_j(Y_\times)] \wedge \mathbf{gave}(\pi_1(Y_\times))(\pi_1(X_\times))(\mathbf{j}) \wedge$
$\mathbf{gave}(\pi_2(Y_\times))(\pi_2(X_\times))(\mathbf{b})$

The derivation for the multiple *same* sentence (210b) involves first positing two product-type variables $X_\times$ and $Y_\times$, which are linked to the plural term *John and Bill* via the recursive application of the **resp** operator and then bound by the two GQs over product-type terms *the same man* and *the same book*.

10. There is a certain awkwardness to (209). But again, we believe that this arises from a Gricean implicature. Had the speaker known that (209) were the case, s/he could have less confusingly and more cooperatively said *John and Bill read some of the same books, but some different ones too*, or something equivalent. Thus, we take (209) to be only awkward, but crucially, not contradictory.

In the present analysis, the interaction between multiple "respective" predication with NCC, exemplified by sentences like the following, is similarly straightforward:

(213) Terry gave the same gift to Bill and Sue as a Christmas present on Thursday and as a New Year's gift on Saturday (respectively).

The full derivation, which combines the proof steps for the NCC/"respective" interaction and multiple "respective" readings already outlined, is given in (259) in section 5.6. We reproduce here the final translation and unpack it:

(214) $$\begin{aligned}&\mathbf{same}(\mathbf{gift})(\lambda X_\times.\mathbf{onTh}(\mathbf{asChP}(\mathbf{gave}(\pi_1(X_\times)(\mathbf{b}))))(\mathbf{t}) \\ &\quad\wedge \mathbf{onS}(\mathbf{asNYG}(\mathbf{gave}(\pi_2(X_\times)(\mathbf{s}))))(\mathbf{t})) \\ &= \exists X_\times.\forall i\,\mathbf{gift}(\pi_i(X_\times)) \wedge \forall i \forall j[\pi_i(X_\times) = \pi_j(X_\times)] \wedge \\ &\quad \mathbf{onTh}(\mathbf{asChP}(\mathbf{gave}(\pi_1(X_\times))(\mathbf{b})))(\mathbf{t}) \wedge \mathbf{onS}(\mathbf{asNYG}(\mathbf{gave}(\pi_2(X_\times))(\mathbf{s})))(\mathbf{t})\end{aligned}$$

The present analysis also assigns intuitively correct truth conditions for sentences such as the following, where two symmetrical terms exhibit interdependency with each other without being mediated by a separate plural term (unlike (210b)):

(215) a. Different students bought different books.
b. The same student bought different books.

The derivation proceeds by abstracting over the subject and object positions, "respectivizing" the relation thus obtained, and then "quantifying-in" the symmetrical terms in the subject and object positions one by one. This yields the following translation for (215a):

(216) $$\begin{aligned}&\exists X_\times.\forall i\,\mathbf{student}(\pi_i(X_\times)) \wedge \forall ij[i \neq j \rightarrow \pi_i(X_\times) \neq \pi_j(X_\times)] \wedge \\ &\exists Y_\times.\forall i\,\mathbf{book}(\pi_i(Y_\times)) \wedge \forall ij[i \neq j \rightarrow \pi_i(Y_\times) \neq \pi_j(Y_\times)] \wedge \mathbf{resp}(\mathbf{bought})(X_\times)(Y_\times)\end{aligned}$$

This asserts the existence of a set of students and a set of books such that the buying relation is a bijection between these two sets. Thus, no two students bought the same book and no two books were bought by the same students. This corresponds to one of the intuitively available readings of the sentence. In section 5.4.2, we discuss a more complex type of reading for the same sentence according to which the sets of books that each student bought are different from one another, where, for any given pair of students s_1 and s_2, there could be a partial (but not total) overlap between the sets of books that s_1 and s_2 respectively bought.

Examples like (217), in which the universal quantifiers *every* and *each* interact with symmetrical predicates, can be analyzed by treating NPs containing universal quantifiers like *every/each N* as maximal pluralities satisfying the description *N* that are obligatorily associated with a distributive or "respective" operator (see also Barker [2007] for a similar idea, but one that is technically implemented in a somewhat different way).[11]

(217) {Every/Each} student read {the same book/a different book}.

The assumption that universal quantifiers in English (effectively) denote "sums" (or pluralities) is advocated by several authors, including Szabolcsi (1997), Landman (2000), Matthewson (2001) and Champollion (2010).[12] This assumption also accounts for the interactions between universal quantifiers and "respective" and summative predicates as exemplified by (173) from section 5.2.1.1. In the present setup, the obligatory "distributive" nature of *every* and *each* can be captured by specifying in their lexical entries that they take as arguments sentences missing product-type NPs. This can be done by syntactically encoding the semantic distinction between product-type and non-product-type NPs via some feature.[13]

The present analysis straightforwardly extends to scope interactions between symmetrical predicates and negation and quantifiers in examples like the following:

(218) a. John and Bill didn't read the same book.
b. John and Bill didn't read different books.
c. Every boy gave every girl a different poem.

(218a) has a reading (perhaps the most prominent one) which seems to intuitively mean the same thing as 'John and Bill read different books.' Similarly, (218b), again on its perhaps most prominent reading, seems to mean the same thing as 'John and Bill read the same book.' By having the negation scope over the symmetrical predicate (which is straightforward by adopting the analysis of auxiliaries that we proposed in chapter 3), we obtain the following translations for (218a) and (218b):

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11. We take distributive readings to be derived by the **resp** operator we posit in our system (see footnote 7), following a proposal by Bekki (2006). Our assumption here is in the same spirit as G&K's suggestion of unifying the distributive and "respective" operators in their system.

12. Dotlacil (2010) objects to this idea by noting the infelicity of the following (the judgments are his):

(i) a. *Each boy each read a book.
b. *Each boy read a book each.
c. *Each boy talked to each other.

But the awkwardness of these examples seems to be due to the redundant marking of distributivity by the same word (albeit perhaps in distinct uses of it; compare, for example, the sentences in (i) with ??*All boys all went swimming*, which is degraded for precisely the same reason of redundancy). Thus, we do not take these data to provide a convincing counterevidence to the family of "universal as sum" type approaches.

13. One issue that remains is why the NP containing *different* is singular if the licensor is a distributive quantifier rather than a plural NP. In order to get our compositional mechanism to yield the right result, we need to assume that *a different book* in (217) denotes a tuple just like *different books*. We suspect that the singular marking here is a matter of morphological agreement with the licensor, but leave a detailed investigation of this matter for a future study.

(219) a. $\neg[\exists X_\times \forall i\, \mathbf{book}(\pi_i(X_\times)) \wedge \forall i \forall j[\pi_i(X_\times) = \pi_j(X_\times)] \wedge$
$\mathbf{read}(\pi_1(X_\times))(\mathbf{j}) \wedge \mathbf{read}(\pi_2(X_\times))(\mathbf{b})]$

b. $\neg[\exists X_\times \forall i\, \mathbf{book}(\pi_i(X_\times)) \wedge \forall i \forall j[i \neq j \rightarrow \pi_i(X_\times) = \pi_j(X_\times)] \wedge$
$\mathbf{read}(\pi_1(X_\times))(\mathbf{j}) \wedge \mathbf{read}(\pi_2(X_\times))(\mathbf{b})]$

It may appear that these truth conditions do not quite match the intuitive meanings of the sentences. But note that both (218a) and (218b) seem to implicate that both John and Bill read at least one book (we do not attempt here to characterize the nature of this implication, but given that it is available in the nonnegative counterparts of (218a) and (218b), and moreover seems to survive other presupposition holes [such as conditionals], this implication is most likely a presupposition of *same*/*different*). By taking these implications into account, the intuitively observed meanings of (218a) and (218b) do in fact follow from (219a) and (219b).

As noted by Bumford and Barker (2013), (218c) is ambiguous between two readings: if the subject quantifier scopes over the object quantifier, it means that no boy gave the same poem to multiple girls, whereas if the object quantifier scopes over the subject quantifier, the sentence means that no girl received the same poem from multiple boys. Since our approach has a fully general mechanism for scope-taking for quantifiers and symmetrical predicates (via hypothetical reasoning involving $\upharpoonright$), this scope ambiguity is straightforwardly predicted.

We now turn to an analysis of summative predicates such as *a total of $10,000*. The approach to symmetrical predicates above uses the **resp** operator to create pairings between corresponding elements of two tuples and then imposes a further condition on one of the two tuples involved. The (in)equality relation incorporated in this analysis is only one possible condition that could be so imposed, however; theoretically there are an unlimited number of other possible conditions, and we could expect a certain variety in the way natural language grammars exploit such possibilities. It turns out that we indeed see evidence of exactly this type of variety (for example, *an average of X* is yet another such expression, as discussed by Kennedy and Stanley [2008]). In particular, in examples like (220) involving summative predicates, the tuple elements are required to (together) satisfy a quantity condition: taking $n^\$$ and $m^\$$ to be the tuple elements denoting amounts of money, then, roughly speaking, (220) asserts that $\mathbf{spent}(\mathbf{r}, n^\$)$ and $\mathbf{lose}(\mathbf{l}, m^\$)$ and that $n^\$ + m^\$ = \$10{,}000$.

(220) Robin spent and Leslie lost a total of $10,000.

In other words, the condition "adds up to $10,000" is imposed on the members of the tuple, instead of the (in)equality or similarity relations.

To capture this idea, we once again treat the relevant expressions as GQs over product-type terms of type $S\upharpoonright(S\upharpoonright NP)$, assigning to *a total of* the following meaning:

(221) $\lambda\varphi\lambda\sigma.\sigma(a \circ \mathsf{total} \circ \mathsf{of} \circ \varphi)$; $\lambda S \lambda P.\exists X_{\times_n} \sum_{1 \leq i \leq n} \pi_i(X_{\times_n}) = S \wedge P(X_{\times_n})$; $\mathrm{S}{\upharpoonright}(\mathrm{S}{\upharpoonright}\mathrm{NP})$

This operator takes a sum S and a predicate P (over product-type terms) as arguments and asserts the existence of some tuple $X_{\times_n}$ where the sum of all of the elements of $X_{\times_n}$ equals S and $X_{\times_n}$ itself satisfies the predicate P. Since P is a predicate of product-type terms, this effectively means that $X_{\times_n}$ enters into a "respective" relation with some other product-type term in the sentence. The tuple $X_{\times_n}$ can be thought of as a possible partitioning of the sum S into subportions that can respectively be related to the other tuple(s), which, in the case of (220), is contributed by the plural NP.

(220) is then analyzed in a way parallel to the symmetrical predicate example above. We first derive a sentence in which a hypothetically assumed tuple-denoting expression (φ_1; $X_\times$; NP) enters into a "respective" predication with an overt conjoined term (which, in this case, is a "nonconstituent" *John spent and Bill lost*; for details, see the full derivation in (260)):

(222) $\mathsf{john} \circ \mathsf{spent} \circ \mathsf{and} \circ \mathsf{bill} \circ \mathsf{lost} \circ \varphi_1$; $\mathbf{spent}(\mathbf{j}, \pi_1(X_\times)) \wedge \mathbf{lost}(\mathbf{b}, \pi_2(X_\times))$; S

By abstracting over $X_\times$, we obtain an expression of type $\mathrm{S}{\upharpoonright}\mathrm{NP}$. This is then given as an argument to the GQ-type $\mathrm{S}{\upharpoonright}(\mathrm{S}{\upharpoonright}\mathrm{NP})$ expression denoted by *a total of $10,000*, and we obtain the final translation in (223), which captures the intuitively correct meaning of the sentence:

(223) $\mathbf{total}(\mathbf{\$10k})(\lambda X_\times.\mathbf{spent}(\mathbf{j}, \pi_1(X_\times)) \wedge \mathbf{lost}(\mathbf{b}, \pi_2(X_\times)))$
$= \exists X_{\times_2}.\pi_1(X_{\times_2}) \oplus \pi_2(X_{\times_2}) = \mathbf{\$10k} \wedge \mathbf{spent}(\mathbf{j}, \pi_1(X_{\times_2})) \wedge \mathbf{lost}(\mathbf{b}, \pi_2(X_{\times_2}))$

5.4 Comparisons and Larger Issues

5.4.1 Comparisons with Related Approaches

In the previous section, we have proposed a unified analysis of "respective," symmetrical, and summative predicates. The key components of our analysis are the treatment of expressions involving conjunction as denoting tuples and the flexible syntax-semantics interface of Hybrid TLCG. As demonstrated above, in our analysis, hypothetical reasoning for relating the relevant tuples in the "respective" manner that underlies the semantics of these expressions interacts fully systematically with hypothetical reasoning for forming syntactic constituents that enter into that "respective" predication. While our proposal builds on several key insights from previous proposals on these phenomena, we are unaware of any other proposal, at any level of formal explicitness, which accounts for the same range of data for which we have provided an explicit account. In this section, we present three previous approaches, namely, Gawron and Kehler (2004), Barker (2007, 2012) and Chaves (2012), that are closely related to our own and discuss their key insights as well as limitations.

We focus on these three approaches here since, as we discuss below, we build on and combine key ideas that are most explicitly embodied in these proposals. But before moving on, we would like to briefly comment on other previous proposals. As for symmetrical predicates in particular, there are various accounts that contain important insights but which are not explicitly formalized, such as Dowty (1985), Carlson (1987) and Oehrle (1996). See Barker (2007) for a useful summary of these previous proposals. Barker's proposal and our own refinement of it can be thought of as an attempt to explicitly formalize the analytic intuitions embodied in these earlier works.

A more formally developed analysis of symmetrical predicates has been offered by Brasoveanu (2011). Though technically implemented in a different way, Brasoveanu's (2011) analysis of *different* embodies essentially the same analytic intuition as ours (see also Dotlacil 2010; Bumford and Barker 2013). Brasoveanu accounts for the pairwise matching between the sets of objects designated by the NP containing *different* and the correlate NP (i.e., a quantifier or a plural) via a device in an extended DRT called "plural information states," which are formally sets of assignment functions and which can be thought of as stack-like objects. There is an obvious relation between tuples and stacks in that they are both formal constructs that keep track of the internal structures of complex objects with some ordering imposed on their elements.[14]

Moltmann (1992) perhaps deserves a special comment as well. In this work, Moltmann develops an approach to coordination which is essentially a version of multidominance analysis. This allows her to analyze interactions between RNR and symmetrical predicates such as the following via the notion of "implicit coordination," where *John* and *Mary*, "parallel" elements within conjuncts in RNR, are effectively treated as if they were coordinated for the purpose of interpretation of the shared element *the same book*.

(224) John read, and Mary reviewed, the same book.

This approach raises many questions about compositionality and the architecture of the syntax-semantics interface (in particular, it is unclear what exactly is the status of the "implicitly coordinated" *John and Mary* within the overall interpretation of the sentence). Moreover, since Moltmann's (1992) approach and ours start from totally different sets of assumptions, comparing the two directly does not seem to be very useful. However, there are two points which seem to be worth noting. First, although the key underlying intuitions are similar, Moltmann takes the *syntactic* coordinate structure to provide the basis for "respective" readings (and related phenomena). Following authors

14. Since Brasoveanu's approach and our own primarily focus on different sets of issues pertaining to the semantics of symmetrical predicates, a direct comparison does not seem to be very meaningful, but we would nevertheless like to note that it is unclear whether Brasoveanu's DRT-based system extends in any straightforward way to the interactions of symmetrical predicates (and related phenomena) and NCC.

such as G&K, we take this assumption to be implausible, since this account does not extend in any straightforward way to "respective" readings of non-conjoined plural NPs. The other point which seems worth noting is that, unlike RNR, DCC seems less straightforward to analyze in a multidominance-type approach. The difficulty essentially lies in the fact that, unlike RNR, the shared string in DCC involves two separate constituents. It is unclear how the semantics of the sentence can be properly assigned in such a complex multidominance structure (especially in cases involving interactions with "respective," symmetrical, and summative predicates). Moltmann does not discuss how her approach may be extended to DCC, and, so far as we are aware, this issue has not been addressed in any of the more recent variants of multidominance analyses of coordination such as Bachrach and Katzir (2007, 2008).

Finally, we would like to briefly comment on event-based approaches, along the lines, for example, of Lasersohn (1992). One might think that, in an event-based approach, by introducing the notion of "event sums," many of the examples discussed above can be treated without tweaking the notion of compositionality and representing the meanings of conjoined predicates directly as a tuple (or sum) of atomic predicates. We do not think that this type of approach is general enough for the problem at hand. Note in particular that "respective" readings (and related phenomena) are possible with non-eventive predicates such as the following:[15]

(225) The numbers nine and six are odd and even, respectively.

In order to extend an event sum–based account to examples like this, one would need to assume an abstract conceptualization of the notion of event devoid of any independent empirical justification.[16] Moreover, in examples like (225), the issue of event individuation, an inherent problem of event-based semantics in general, seems to become particularly unwieldy. Given the murkiness of these issues, we find an event-based approach less than ideal for the class of phenomena considered in this chapter.

5.4.1.1 Gawron and Kehler (2004) As noted in the previous section, our own analysis builds directly on Gawron and Kehler's (2004) (G&K's) proposal in the core semantic analysis of "respective" readings. The key difference between our proposal and G&K's is that G&K take the ordering of elements in the denotations of plural or conjoined expressions to be given by an external contextual parameter of sequencing

15. Note also that the adverb *alternately*, on which Lasersohn (1992) focuses in his event sum–based approach, similarly allows the relevant reading with non-eventive predicates:

(i) The coefficients in this expansion of the function are alternately positive and negative integers.

16. See also Barker (2007, 418) for essentially the same point in connection to a similar example with *same*.

functions, whereas in our analysis, this information is directly encoded in the denotation of the expressions themselves in the form of tuples. With the ordering information removed from the denotations of the expressions themselves, G&K can model the meanings of plural and conjoined expressions in terms of sums, in line with one established tradition in the literature on plurality (cf., e.g., Link 1983, Lasersohn 1988, and Schwarzschild 1996, but see also Landman 1989). As we discuss below, this tuple/sum difference in the two approaches has some important implications when extending the analysis to symmetrical predicates. Another, perhaps less essential (but nonetheless important) difference between the two approaches is that G&K's proposal is formulated in a strictly phrase structure–based syntax-semantics interface. For this reason, their analysis, at least in its original form, does not extend straightforwardly to interactions with NCC.[17]

G&K's approach presupposes that the argument of the sequencing function is a sum and not an atom. This assumption is necessary in their analysis for ensuring that the right matching of elements is established between the two sums in the case of "respective" readings, but it causes a problem for at least a subset of symmetrical predicates. Recall from the previous section that the symmetrical predicate *the same* imposes an equality relation among each member of the tuple. If we recast this analysis in a sum-based analysis à la G&K, then the n-tuple denoted by *the same N* that is to be related to another n-tuple in a pairwise manner collapses to a single object, since a sum of multiple "tokens" of the same object collapses to that object itself (i.e., $a \oplus a = a$ by definition). But then, it would be predicted that *John and Bill read the same book* is infelicitous since in G&K's analysis, the sequencing function is defined only for sums that have proper subparts (lifting this condition would incorrectly admit into their analysis examples like #*Sue and Bob like Fred, respectively*).[18]

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17. There is an additional technical problem in G&K's proposal. Their analysis, in which "respective" readings are analyzed via a series of successive applications of the distributive and "respective" operators, turns out to be rather unwieldy in cases such as the following ((ib) is the same example as (192)):

(i) a. John and Bill read and reviewed the book, respectively.
    b. John and Bill sent the bomb and the letter to the president yesterday, respectively.

The problem essentially is that the distributive operator that G&K posit (which is identical in all relevant respects to the distributive operator standardly assumed in the formal semantics literature) can only distribute a functor over the components of a sum of argument objects, not vice versa. But the analysis of (ia) requires distributing the object argument to the conjoined functor *read and reviewed*. See Kubota and Levine (2014b) for a more detailed discussion of this problem and possible solutions for it (the most straightforward of which is to extend the phrase structure–based setup of G&K to an architecture like our own, which recognizes hypothetical reasoning fully generally).

18. Gawron and Kehler (2004, 174) claim that this assumption explains the ill-formedness of the following:

(i) ??Sue and Bob like Fred and Fred, respectively.

But note that (i) is just a clumsy way of saying the same thing as the following:

An essentially analogous problem arises with *similar*. The similarity condition that *similar* imposes on its tuple elements does not exclude a possibility that the elements are completely identical. Suppose, for example, Alice suggests to her collaborator Betty:

(226) Ok, Betty, let's work on these problems separately first, and then if we run into similar problems, let's get together and discuss.

They later confer by email and discover that they are stuck on exactly the same problem. Alice refuses to get together and discuss and insists that they keep working separately, since they've run into exactly the same problem, not similar problems. We think that Alice would be a perverse person in such a situation. Thus, the implication of 'similar but not the same' is arguably a Gricean implicature. But then, this means that if the tuple elements happen to be identical, a G&K-based analysis predicts sentences containing *similar* to be infelicitous. In other words, (the *if* clause of) (226) is predicted to be infelicitous just in case Alice and Betty run into exactly the same problem. This does not seem to be a correct prediction.

It then seems fair to conclude that G&K's sum-based approach does not extend straightforwardly to the analysis of symmetrical predicates. As we have discussed in section 5.1, we take the parallel between "respective" readings on the one hand and symmetrical and summative predicates on the other to be robust. Thus, in the absence of an explicit and fully general analysis of symmetrical predicates in a sum-based approach (in this connection, see also the discussion of the empirical problems of Barker's [2007, 2012] approach in the next section), we take our tuple-based analysis to be an improvement over G&K's original sum-based analysis of "respective" readings.

5.4.1.2 Barker (2007, 2012) Barker (2007) proposes an analysis of symmetrical predicates via the notion of "parasitic scope," which captures the syntax-semantics interface underlying the compositional semantics of these predicates quite elegantly. In his analysis, *same* receives the following translation:

(227) $\lambda \mathscr{F} \lambda X \exists \mathfrak{f} \forall x <_a X . \mathscr{F}(\mathfrak{f})(x)$

Here, $\mathscr{F}$ is of type $(et \to et) \to et$. That is, $\mathscr{F}$ denotes a relation between adjectives (i.e., modifiers of common nouns) on the one hand and individuals on the other, with X a variable over sums of individuals and $\mathfrak{f}$ a variable over *choice functions* (a choice function is a function that takes a set as argument and returns as output a singleton set containing a member of that set). Roughly speaking, *same* converts a relation between functors on some property on the one hand and an individual on the other into a re-

(ii) Sue and Bob like Fred.

Thus, we see no reason for excluding (i) in the combinatoric component of grammar.

lation between inhabitants of that property on the one hand and sums of individuals on the other, guaranteeing a unique inhabitant of that property to which each individual in the sum is mapped. Thus, for example, in the case of (228), an abstraction first on a variable over individual types and then over adjective types yields the relation $\lambda\xi\lambda y.\mathbf{read}(\iota(\xi(\mathbf{book}))(y))$.

(228) John and Bill read the same book.

The *same* operator in (227) then maps this relation to a relation between the sum of individuals $\mathbf{j}\oplus\mathbf{b}$ on the one hand and a single element of the set **book** such that each member of the sum is in the **read** relation to that element.

It should be clear from the above that our own analysis takes Barker's work as its basis. In particular, we take Barker's double abstraction treatment of *same* as the core of our own compositional analysis, though the specific semantic analyses differ in important ways. We aim at a unitary analysis of symmetrical, “respective,” and summative predicates; hence, the key semantic commonality we have identified in these three cases—the mapping relationship between elements of two (or more) different composite data structures—correspond to a single source, the **resp** operator, which crosscuts the specific semantic (and pragmatic) properties of the three. By contrast, in Barker's analysis, the operation corresponding to our **resp** is directly encoded in the lexical meaning of symmetrical predicates, effectively ruling out a unified analysis of the larger class of predicates discussed above.

But quite apart from this issue, the lack of a recursive mechanism that keeps track of the structure of a sum/tuple-type object entails severe empirical difficulties when multiple instances of symmetrical predicates are present. We illustrate this problem with (229), for which Barker's analysis yields a particularly strange semantics.[19]

(229) John and Bill gave different things to different people.

Barker (2007) gives the semantics of *different* as in (230),

(230) $\lambda\mathscr{F}\lambda X\forall\mathfrak{g}\forall z,v<_a X.\ [\mathscr{F}(\mathfrak{g})(z)\wedge\mathscr{F}(\mathfrak{g})(v)]\rightarrow[z=v]$

with which the translation in (231b) is assigned to (231a) (ε here is the meaning of the indefinite article *a*; since the choice function returns a singleton set, the choice of the article [between *the* for *same* and *a* for *different*] is immaterial in Barker's analysis).

(231) a. John and Bill read a different book.

19. Barker (2012) partially addresses the multiple symmetrical predicate issue by revising the translation for *same* in Barker (2007) slightly, removing the distributive operator from the meaning of *same* (and instead assuming that it is implicit in the lexical meaning of the verb). However, this approach does not seem to work for the case of *different* (within the set of assumptions that Barker [2007, 2012] makes), and Barker (2012) remains silent about cases like (229).

b. $\forall\mathfrak{f}\forall z, v <_a \mathbf{j} \oplus \mathbf{b}[\mathbf{read}(\varepsilon(\mathfrak{f}(\mathbf{book})))(z) \wedge \mathbf{read}(\varepsilon(\mathfrak{f}(\mathbf{book})))(v)] \rightarrow [z = v]$

To paraphrase, (231b) says that whatever choice function one chooses, the only way in which two (potentially distinct) people out of the set $\{\mathbf{j}, \mathbf{b}\}$ read the book that the choice function returns is when the two people are the same ones. In other words, there is no single common book that John and Bill both read.

Assuming Barker's semantics for *different*, and following the procedure for multiple *same* discussed in Barker (2012), we wind up with the translation for the VP for (229) in (232).

(232) $\lambda U \forall w, y <_a U \forall\mathfrak{f}\forall\mathfrak{g}$
$\lambda W[\forall z, v <_a W[\mathbf{gave}(\varepsilon(\mathfrak{f}(\mathbf{thing})))(\varepsilon(\mathfrak{g}(\mathbf{person})))(z) \wedge$
$\mathbf{gave}(\varepsilon(\mathfrak{f}(\mathbf{thing})))(\varepsilon(\mathfrak{g}(\mathbf{person})))(v)] \rightarrow [z = v]](w) \wedge$
$\lambda W[\forall z, v <_a W[\mathbf{gave}(\varepsilon(\mathfrak{f}(\mathbf{thing})))(\varepsilon(\mathfrak{g}(\mathbf{person})))(z) \wedge$
$\mathbf{gave}(\varepsilon(\mathfrak{f}(\mathbf{thing})))(\varepsilon(\mathfrak{g}(\mathbf{person})))(v)] \rightarrow [z = v]](y) \rightarrow [y = w]$

We see here a subtyping mismatch problem whose resolution leads to a severe mischaracterization of the truth conditions of the sentence. The problem in a nutshell is that each token of *different* introduces an abstraction on a sum type, each of whose atoms are to be related to a member of some set of entities which is identical to no other member of that set. But only the wider-scoping token of *different* will get an actual sum (in this case, $\mathbf{john} \oplus \mathbf{bill}$) supplied as its argument; the narrower-scoping token will be able to apply only to the universally bound atomic elements introduced by the wider-scoping instance of *different*. The only way we can see to resolve this apparent incoherence in the semantics of such examples is to treat the "part-whole" relation $<_a$ as simple equality in the case where the second relatum is an atom, as indeed intimated in Barker (2012) in his treatment of the *same*/*same* examples. But the assumption that $x <_a u$ entails $u = x$ has, as a corollary, the consequence that $x, y <_a u$ entails $u = x = y$. The result is that (232) reduces to (233):

(233) $\lambda U \forall w, y <_a U \forall\mathfrak{f}\forall\mathfrak{g}\ [[\mathbf{gave}(\varepsilon(\mathfrak{f}(\mathbf{thing})))(\varepsilon(\mathfrak{g}(\mathbf{person})))(w)] \rightarrow [w = w] \wedge$
$[\mathbf{gave}(\varepsilon(\mathfrak{f}(\mathbf{thing})))(\varepsilon(\mathfrak{g}(\mathbf{person})))(y)] \rightarrow [y = y]] \rightarrow [y = w]$

But this result makes no sense. What we have in (233) is an implication, whose antecedent is a tautology (itself composed of a conjunction of tautologies of the same general form $\psi \rightarrow (\alpha = \alpha)$), which means that the whole conditional statement is equivalent to its consequent $y = w$. The variables w and y range over the atoms of the sum that (233) takes as its argument. Thus, it is predicted that (229) means that John and Bill are the same person.[20]

20. Similar difficulties arise in an only slightly less striking fashion in *John and Bill put the same object in different boxes*, where Barker's analysis predicts that on the inverse scoping of the two symmetrical

In summary, Barker's analysis of symmetrical predicates loses generality in two directions, and these problems, we believe, essentially derive from the same limitation in his analysis. On the one hand, unlike G&K's and our proposal, Barker's analysis lacks a mechanism for making the internal structure of a sum simultaneously visible to multiple tokens of *same*/*different*. For this reason, it does not extend to multiple *same*/*different* sentences fully generally. On the other hand, the fundamentally parallel semantic action of "respective" interpretations and summative predicates cannot be captured in Barker's implementation because the crucial sum-to-individual mapping is directly encoded in the lexical meaning of the symmetrical predicate operators in his proposal. To remove these obstacles, a different strategy seems to be needed, in which a mapping between composite objects is mediated by a separate general operator that allows for recursive application, as in G&K's and our own proposal.[21]

5.4.1.3 Chaves (2012) Chaves's (2012) account has the virtue of identifying "respective," symmetrical, and summative interpretations as unitary phenomena (see especially pp. 319–321)—a view we inherit in our own analysis. The mechanism Chaves proposes for the compositional analysis of these predicates is, however, fundamentally different from our approach; Chaves takes "respective" readings in cases such as *Bill and Tom invited Sue and Anne to the party (respectively)* to be nothing more than particular instances of the so-called cumulative reading (Scha 1981), along the lines discussed in section 5.1.

But as noted by Gawron and Kehler (2004) in their critique of Schwarzschild's (1996) analysis of "respective" readings, such an approach does not extend to examples like (234) (= (153)), in which one of the sums related in the "respective" manner is a sum of predicates rather than a sum of entities:

(234) John and Bill sang and danced, respectively. (= 'John sang and Bill danced')

Chaves therefore proposes the translation in (235) for the coordination marker *and*, which, according to him, has the effect of providing two possible interpretations for (234) and similar examples (we have modified Chaves's [2012] original translation

predicates it is impossible for John to have put *any* object in a box that Bill put some other, distinct object in. While the surface scope (*same* > *different*) does yield the correct interpretation for this example, the picture changes when the subject is singular rather than plural: in the case of *John put the same object in different boxes*, the surface scoping yields a tautology predicting that the sentence is true in all conceivable circumstances.

21. Given the parallel semantic action of symmetrical predicates on the one hand and "respective" readings on the other, it is worth observing that Kubota's (2015) extension of Barker's (2007) analysis of *same* to "respective" readings fails to generalize to multiple "respective" readings. The problem in these cases is the same dilemma with type mismatch blocking recursive application of operators: after the first application of the "respective" operator, the result is a boolean conjunction whose parts are no longer accessible as sum components, making further application of the same operator in principle impossible.

slightly to accommodate it with the description of the *and* operator he gives in the text—note that the event variable e isn't existentially bound in our reformulation; nothing crucially hinges on this modification).

(235) $\lambda P \lambda Q \lambda z_0 \ldots \lambda z_n \lambda e.[e = (e_1 \oplus e_2) \wedge Q(x_0)\ldots(x_n)(e_1) \wedge P(y_0)\ldots(y_n)(e_2) \wedge z_0 = (x_0 \oplus y_0) \wedge \ldots \wedge z_n = (x_n \oplus y_n)]$

This operator conjoins two relations, and either identifies (i.e., if $x_n = y_n$) or distributes (i.e., if $x_n \neq y_n$) their conjoined shared dependents. With (235), (234) receives the following interpretation (after the event variable e is existentially closed):

(236) $\exists e''.e'' = (e_1 \oplus e_2) \wedge \mathbf{sang}(x_0)(e_1) \wedge \mathbf{danced}(y_0)(e_2) \wedge (\mathbf{j} \oplus \mathbf{b}) = (x_0 \oplus y_0)$

The idea is that if $x_n = y_n$, then both John and Bill sang and both danced, whereas if $x_n \neq y_n$, then either John danced and Bill sang or Bill danced and John sang. The adverb *respectively* imposes a further constraint on the interpretation obtained above, to force the pairings $\mathbf{j} = x_0, \mathbf{b} = y_0$ (which effectively restricts the interpretation to the $x_n \neq y_n$ case).

Note that, in this analysis, except for complicating the meaning of *and*, no special mechanism is needed in the grammar to license "respective" readings (and related phenomena), giving us an overall very simple analysis of a complex class of phenomena. But the success of this approach is only apparent; once we extend the data pool beyond the most simple class of examples (such as (234)), Chaves's analysis quickly becomes problematic. NCC/"respectively" interaction examples such as (237) illustrate the point persuasively:

(237) I bet $50 and $100 with John on the football game and (with) Mary on the basketball game (respectively).

Since (237), by virtue of its nonconstituent conjuncts, cannot be directly interpreted, the syntactic source of this sentence must be presumed to arise under the prosodic ellipsis analysis Chaves explicitly assumes (as per Beavers and Sag 2004; Chaves 2008; and Hofmeister 2010; see section 4.3.2), with (238) the necessary input to the semantic interpretation:[22]

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22. Chaves (2012) extensively relies on the ellipsis strategy, even in cases like the following that do not involve nonconstituent coordination:

(i) Different newspapers are running conflicting reports. The *Guardian* and the *Telegraph* reported that Michael Phelps won the silver medal and the gold medal respectively. (Chaves 2012, 316)

According to Chaves (2012), the "respective" reading of (i) is obtained from the underlying structure in (ii):

(ii) The *Guardian* and the *Telegraph* reported [that Michael Phelps won the silver medal] and [~~that Michael Phelps won~~ the gold medal] respectively.

(238) I bet \$50 and \$100 with John on the football game and ~~(I) bet \$50 and \$100~~ (with) Mary on the basketball game (respectively).

No cumulative interpretations are available for the conjoined clauses or verb phrases in (238). Thus, the source of the "respective" reading in (237) must arise from the action of the *and* operator in (235). But the necessary conditions on *and* are not satisfied in (238). In order for Chaves's setup to work as required, it is crucial that the arguments corresponding to x_k, y_k be actual conjuncts, but this critical condition is not fulfilled in (238), where the terms that need to enter into the "respective" relation belong to completely different clauses/VPs, appearing (on the surface string) to be parts of conjoined expressions only via the strictly prosodic deletion operation which yields the surface string (237). The operator in (235) therefore provides no account of how the "respective" readings arise in examples of this type.

In a sense, Chaves's proposal can be thought of as an attempt to lexicalize (in the meanings of conjoined predicates) the effects of the "respective" operator of the sort posited in G&K's and our approach. While a strictly lexical approach may be attractive if it can handle all the relevant data uniformly, the discussion above suggests that such an approach is not general enough.

5.4.2 A Note on the Treatment of Plurality

One might wonder how the tuple-based analysis of "respective" readings and related phenomena presented above extends (or does not extend) to other interpretations of plural and conjoined expressions, such as collective and cumulative readings. These phenomena are themselves quite complex, and each of them deserves a treatment on its own. Thus, addressing them fully is clearly beyond the scope of our coverage in this chapter. But given that the phenomena treated above are clearly related to the more general empirical domain of plurality, some comments seem to be necessary, and we will try to explicate our position here.

In a comparison of our tuple-based approach with a sum-based alternative (which is more standard, at least for the treatment of plurality), it is useful to distinguish three properties of different types of formal objects that are (or can be) used for modeling entities having complex internal structures, so as to avoid confusion about points of (non-)controversy. Tuples have more complex structures than sums or sets in that (i) they have ordering, (ii) they allow for identical elements to appear twice (iterability), and (iii) they can be nested (nestability). A comparison of different data structures with respect to these properties is as follows:

(239)

	Ordering	Iterability	Nestability
Tuple	Yes	Yes	Yes
Multiset	No	Yes	Yes
Set	No	No	Yes
Sum	No	No	No

To state the conclusion first, the only property we crucially need for our unified analysis of the three phenomena is iterability. We have chosen tuples over multisets purely for the sake of simplifying the technical exposition, and there is no fundamental conceptual or empirical reason for us to favor a tuple-based formulation over a multiset-based formulation. As we discuss below, many apparently problematic aspects of our analysis can be eliminated by adopting a multiset-based reformulation.

Nestability also complicates the analysis of plurals in a nontrivial manner. Here, we have to say that this is an unfortunate consequence. As we have already discussed in relation to G&K's proposal, we have adopted tuples/multisets instead of sums since iterability is crucially needed for extending the analysis to symmetrical predicates. Ideally, we would want some formal object with iterability but not nestability. But as the table in (239) makes clear, there is no known formal object that has the right property, at least none that we are aware of.[23] Thus, it seems that we have to live with the artificial complication introduced by the nestability property of tuples/multisets, that is, the so-called overrepresentation problem in the plurality literature (discussed below). However, we do not find this to be a serious problem, since overrepresentation, by its very nature, does not constitute any empirical problem. It only means that the theoretical distinctions that one makes are *unnecessary*, and eliminating these distinctions can always be done uniquely and unambiguously.

Regarding the overrepresentation issue, we find Schwarzschild's (1996) argument against groups convincing. The argument runs roughly as follows. An example like (240) apparently unambiguously means that the separation was done by kind. But things are not so clear-cut once we take into consideration more complex examples like (241).

(240) The cows and the pigs were separated.

(241) a. The cows and the pigs were separated by age.

23. We could, of course, add constraints on multisets or tuples so that no nesting is allowed. This can be done by explicitly imposing typing restrictions on membership. But again, we have not chosen to implement this explicitly here since this option does not seem to be very different from choosing tuples or multisets as the underlying mathematical structure but not making use of their nestability property.

b. The animals were separated by age. That is, the cows and the pigs were separated.

In a world in which there are only cows and pigs, the second sentence of (241b) means the same thing as (241a). Schwarzschild (1996) concludes from this that the subgrouping of a sum in sentences like (240) is provided by a contextual parameter (which he calls "covers") rather than explicitly represented at the level of semantics. It indeed seems that, if one limits one's attention to the treatment of plurality (in the nominal domain), the overrepresentation problem of the group-based approach (which our tuple/multiset-based approach inherits) speaks in favor of Schwarzschild's neo-Linkean sum-based approach.

There are, however, other points of consideration that come into play once we extend our empirical domain to a wider range of linguistic phenomena. First, as noted by G&K, though Schwarzschild (1996) sketches an extension of his cover-based analysis to the NP-NP cases of "respective" readings (e.g., (242a)), his analysis does not generalize fully to other types of "respective" readings (e.g., (242b); see the discussion of Chaves's [2012] proposal above).

(242) a. John and Bill married Mary and Sue, respectively.
b. John and Bill walked and talked, respectively.

It is unclear whether an extension of Schwarzschild's (1996) cover-based analysis is motivated for examples like (242b) and, more generally, for a still larger (and more complex) data set encompassing examples involving interactions with NCC such as (156c,d).

Another, perhaps more important, point is that, as we have discussed in section 5.4.1.1, a tuple-based analysis enables a straightforward extension to the analysis of symmetrical predicates, whereas a sum-based analysis doesn't. To be fair, Schwarzschild's (1996) proposal was not intended to cover symmetrical predicates, but to the extent that one finds the parallel between "respective" readings and symmetrical predicates (of the sort noted in the previous section) to be intriguing, a unified analysis seems more preferable.

For these reasons, we tentatively conclude that overrepresentation in the domain of nominal plurality is a price that has to be paid in view of the overall generality of the analysis in a wider empirical domain. We recognize that this is a potentially controversial claim but believe that the burden of proof is on those who would subscribe to the neo-Linkean sum-based treatment of plurality to develop an explicit account that has the same empirical coverage as ours (or else show that the empirical generalization that we have drawn across the three phenomena is in fact a false generalization).

Coming back to the "ordering" issue, note first that, as noted by Lasersohn (1988, 87–88), representing the meanings of conjoined NPs in the form of tuples complicates the semantics of collective readings in examples like the following:

(243) Lennon and McCartney wrote "Across the Universe" and "Sexy Sadie."
(= 'They both coauthored')

The ordering of elements doesn't make any truth-conditional difference for collective readings, and to capture this fact on a tuple-based approach, one would either need to write a bunch of meaning postulates for the lexical meanings of verbs that induce collective readings or posit an empty operator that eliminates the ordering information by converting tuples to sums. This indeed seems to be a purely artificial complication introduced in the theory.

Even more problematic for the tuple-based approach are examples like (244), where an order-insensitive bijective relation is established between two conjoined expressions:

(244) a. The front and the back of the ship are called the bow and the stern, but which is which?
b. We know houses four and five are the Swede and the German, but which is which? (Chaves 2012)

To account for these examples, a tuple-based analysis would have to assume an operator that reorders the elements of a tuple and underspecifies the ordering.

In view of the above observations, we think that reformulating our analysis by replacing tuples with multisets and relocating the ordering information to a contextual parameter along the lines of G&K's proposal is ultimately more plausible (at least for the treatment of nominal plurality). Multisets are different from tuples in that they do not encode ordering (but the two are similar in not collapsing two occurrences of an identical element to a single object; thus, this reformulation retains the extendability to symmetrical predicates), and, for this reason, examples like those in (243) and (244) become unproblematic. However, we have refrained from reformulating the analysis presented above since relocating the ordering information to a contextual parameter makes the formulation of the recursive compositional mechanism of "respective" predication nontrivially more complex. It should, however, be kept in mind that this decision is purely for expository ease.

Finally, we would like to discuss briefly how one might go about extending the present tuple- (or multiset-)based analysis of "respective" readings to cumulative predication. With a slight extension, the tuple-based analysis of "respective" predication that we have proposed offers a simple way of characterizing cumulative readings. Specifically, all we need to do is to assume that tuples corresponding to plural terms can contain elements that are themselves sums of individuals rather than just atomic individuals. We sketch here a basic analysis of (245) and then discuss some implications.

(245) A total of four students read a total of five books.

Assuming that we have four students $\mathbf{s1}, \mathbf{s2}, \mathbf{s3}, \mathbf{s4}$ and five books $\mathbf{b1}, \mathbf{b2}, \mathbf{b3}, \mathbf{b4}, \mathbf{b5}$ and that the reading relation that holds between the two sets is given by the following,

(246) $\{\langle \mathbf{s1}, \mathbf{b1} \rangle, \langle \mathbf{s1}, \mathbf{b2} \rangle, \langle \mathbf{s2}, \mathbf{b1} \rangle, \langle \mathbf{s2}, \mathbf{b2} \rangle, \langle \mathbf{s2}, \mathbf{b3} \rangle, \langle \mathbf{s3}, \mathbf{b2} \rangle, \langle \mathbf{s3}, \mathbf{b4} \rangle, \langle \mathbf{s4}, \mathbf{b5} \rangle\}$

then the situation can be modeled by a “respective” predication between two tuples $X_\times = \langle \mathbf{s1}, \mathbf{s2}, \mathbf{s3}, \mathbf{s4} \rangle$ and $Y_\times = \langle \mathbf{b1} \oplus \mathbf{b2}, \mathbf{b1} \oplus \mathbf{b2} \oplus \mathbf{b3}, \mathbf{b2} \oplus \mathbf{b4}, \mathbf{b5} \rangle$. Thus, the following translation that is assigned to the sentence compositionally by the present analysis suffices to capture the cumulative reading of (245):

(247) $\exists S.|S| = 4 \wedge \mathbf{student}(S) \wedge \exists X_\times \sum_i^n \pi_i(X_\times) = S \wedge \exists S'.|S'| = 5 \wedge \mathbf{book}(S') \wedge$
$\exists Y_\times . \sum_i^n \pi_i(Y_\times) = S' \wedge \mathbf{resp}(X_\times)(Y_\times)(\mathbf{read})$

This extension offers a promising approach to characterizing the more complex reading for sentences involving two occurrences of *different*, such as the following (cf. section 5.3.2).

(248) Different students read different books.

The relevant reading links students to sets of books that they read and asserts that for no two students, the sets of books that they respectively read are completely identical. Thus, (248) is true on this reading in a situation (call it situation 1) described in (246) but false in a situation where **s1** read **b3** in addition (call it situation 2), since in situation 2, the sets of books that **s1** and **s2** read are exactly identical. By assuming that the tuple of students consists of atomic students but that the tuple of books can consist of sums of books, we can model this reading with our **resp** operator and the semantics for *different* already introduced above. The sentence comes out true in situation 1 but false in situation 2, since, according to the semantics of *different*, each element of the book tuple needs to be distinct from each other, a condition satisfied in situation 1 but not in situation 2.

The analysis of cumulativity sketched above, although preliminary, is promising in that it already extends straightforwardly to quite complex examples such as the following, a type of sentence originally discussed by Schein (1993), where cumulativity and distributivity interact:

(249) A total of three ATMs gave a total of one thousand customers two new passwords.

There is a reading of this sentence in which *three ATMs* is related to *one thousand customers* in the cumulative manner, and *two new passwords* distributes over each ATM-customer pair (thus involving two thousand distinct passwords issued).

To derive this reading, all we need to assume is that the plural term *two new passwords* denotes an ordinary cardinal quantifier that scopes below the “respective” operator that establishes the cumulative relation between the other two plural terms (by alternating scope, we can account for other scope readings for the sentence too). The full derivation is given in (261) in section 5.6. The translation obtained is as follows:

(250) $\mathbf{total}(\mathbf{3\text{-}atms})(\lambda X_{\times}.\mathbf{total}(\mathbf{1k\text{-}cus})$
$(\lambda W_{\times}.\mathbf{bool}(\mathbf{resp}(\lambda x.\mathbf{dist}(\lambda y.\mathbf{two\text{-}pw}(\lambda z.\mathbf{gave}(y)(z)(x))))(X_{\times})(W_{\times}))))$

Assuming that the sum of ATMs consists of three ATMs **atm1**, **atm2**, and **atm3** and that the tuple corresponding to this sum consists of atomic ATMs as its members in this order, that is, $X_{\times} = \langle \mathbf{atm1}, \mathbf{atm2}, \mathbf{atm3} \rangle$, the final translation reduces to the following:

(251) $\exists W_{\times_3}. \sum_{1 \leq i \leq 3} \pi_i(W_{\times_3}) = \mathbf{1k\text{-}cus} \wedge$
$\mathbf{dist}(\lambda y.\mathbf{two\text{-}pw}(\lambda z.\mathbf{gave}(y)(z)(x)))(\mathbf{atm1})(\pi_1(W_{\times_3})) \wedge$
$\mathbf{dist}(\lambda y.\mathbf{two\text{-}pw}(\lambda z.\mathbf{gave}(y)(z)(x)))(\mathbf{atm2})(\pi_2(W_{\times_3})) \wedge$
$\mathbf{dist}(\lambda y.\mathbf{two\text{-}pw}(\lambda z.\mathbf{gave}(y)(z)(x)))(\mathbf{atm3})(\pi_3(W_{\times_3}))$

This means that the total of one thousand customers can be partitioned into three groups such that for each of these groups, one of the three ATMs gave two distinct passwords to each individual in that group. This corresponds to the relevant reading of the sentence.

5.5 Conclusion

Our analysis of "respective" readings and related phenomena incorporates ideas from both G&K's analysis of "respective" readings and Barker's analysis of symmetrical predicates. While the strictly local approach in G&K's original formulation and the nonlocal approach by Barker via "parasitic scope" may initially look quite different, the effects of the two types of operations (or series of operations) that they respectively invoke are rather similar: they both establish some correspondence between the internal structures of two terms that do not necessarily appear adjacent to each other in the surface form of the sentence. The main difference is *how* this correspondence is established: G&K opt for a series of local composition operations (somewhat reminiscent of the way long-distance dependencies are handled in lexicalist frameworks such as CCG and G/HPSG), whereas Barker does it by a single step of nonlocal mechanism (in a way analogous to a movement-based analysis of long-distance dependencies).

A question that arises at this point is whether we gain any deeper understanding of the relationship between the respective solutions proposed by these authors, by recasting them within the general syntax-semantics interface of Hybrid TLCG. We do think that we have. Note first that, by recasting these proposals in our setup, we have a clearer picture of the core mechanism underlying these phenomena. This in turn has enabled us to overcome the major empirical limitations of both G&K's analysis (with respect to NCC) and Barker's analysis (with respect to iterated symmetrical predicates).

But we can go even further. As discussed in detail in Kubota and Levine (2014b), building on some key ideas originally proposed by Bekki (2006), the local and nonlocal modeling of "respective" predication from the two previous works can be shown to have a very close relationship formally, since in Hybrid TLCG, the local composition rules for "percolating up" the tuple structure from coordination that are crucially involved in G&K's setup can be derived as theorems in a grammar that essentially implements Barker's approach of nonlocal "respective" predication via hypothetical reasoning. More specifically, by introducing some auxiliary assumptions, the following two rules (where Rule 1 corresponds to G&K's **Dist** operator and Rule 2 corresponds to the **Dist**′ operator needed but apparently missing from G&K's setup) are both derivable as theorems in the system we presented in section 5.3.1 (for proofs, see Kubota and Levine [2014b]):

(252) a. Rule 1

$$\frac{\mathsf{a}; \mathcal{F}; A/B \qquad \mathsf{b}; \langle a_1, \ldots, a_l \rangle; B}{\mathsf{a} \circ \mathsf{b}; \langle \mathcal{F}(a_1), \ldots, \mathcal{F}(a_l) \rangle; A}$$

b. Rule 2

$$\frac{\mathsf{a}; \langle \mathcal{F}_1, \ldots, \mathcal{F}_n \rangle; A/B \qquad \mathsf{b}; a; B}{\mathsf{a} \circ \mathsf{b}; \langle \mathcal{F}_1(a), \ldots, \mathcal{F}_n(a) \rangle; A}$$

It can moreover be formally proven that the local and nonlocal modelings of "respective" predication make exactly the same predictions as to the range of available "respective" readings and internal readings for symmetrical predicates: in both approaches, it is possible to relate two (or more) terms embedded arbitrarily deeply in different parts of the sentence in the "respective" manner. This is an interesting result, since one might a priori be inclined to think that the local modeling would be inherently less powerful than the nonlocal modeling. It is of course conceivable to entertain a constrained version of local modeling in which percolation of a tuple structure is blocked in certain syntactic environments (such as islands and complements of certain types of predicates). But similar effects can probably be achieved in the nonlocal modeling as well, by constraining the steps of hypothetical reasoning involved in "respective" predication in some way or other (in relation to this, see Pogodalla and Pompigne [2012] for an implementation of scope islands in Abstract Categorial Grammar, a framework of CG closely related to Hybrid TLCG).

Choosing between these two alternative approaches on empirical grounds seems to be a complex matter. But whatever conclusion one draws on this issue, we believe that the kind of general setup we have offered in this chapter should be useful for comparing different hypotheses about them, as it enables one to formulate both the local and nonlocal modeling of "respective" predication within a single platform. At the very least, we believe that the unifying perspective we have offered on these two approaches is interesting in that it relativizes the debate between "derivational" and "non-derivational" theories (where the difference between the two architectures may at times have been overemphasized by proponents of each): so far as the semantics of "respective" predicates is concerned, our analysis shows that the extra machinery one needs to introduce in the grammar in each setup is largely equivalent, and that the difference in the two types of strategies representative in the two theories is more superficial than real.

5.6 Ancillary Derivations

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$$\dfrac{\dfrac{\dfrac{[\varphi_3; R; \mathrm{VP/NP}]^3 \quad \mathsf{robin}; \mathbf{r}; \mathrm{NP}}{\varphi_3 \circ \mathsf{robin}; R(\mathbf{r}); \mathrm{VP}}/\mathrm{E} \quad \begin{array}{l}\mathsf{on}\circ\mathsf{thursday};\\ \mathbf{onTh}; \mathrm{VP}\backslash\mathrm{VP}\end{array}}{\varphi_3 \circ \mathsf{robin}\circ\mathsf{on}\circ\mathsf{thursday}; \mathbf{onTh}(R(\mathbf{r})); \mathrm{VP}}\backslash\mathrm{E}}{\mathsf{robin}\circ\mathsf{on}\circ\mathsf{thursday}; \lambda R.\mathbf{onTh}(R(\mathbf{r})); (\mathrm{VP/NP})\backslash\mathrm{VP}}\backslash\mathrm{I}^3$$

(254)

$$\dfrac{\dfrac{\dfrac{[\varphi_1; x; \mathrm{NP}]^1 \quad \dfrac{\mathsf{met}; \mathbf{met}; \mathrm{VP/NP} \quad [\varphi_2; \mathscr{P}; (\mathrm{VP/NP})\backslash\mathrm{VP}]^2}{\mathsf{met}\circ\varphi_2; \mathscr{P}(\mathbf{met}); \mathrm{VP}}\backslash\mathrm{E}}{\varphi_1\circ\mathsf{met}\circ\varphi_2; \mathscr{P}(\mathbf{met})(x); \mathrm{S}}\backslash\mathrm{E}}{\lambda\varphi_2.\varphi_1\circ\mathsf{met}\circ\varphi_2; \lambda\mathscr{P}.\mathscr{P}(\mathbf{met})(x); \mathrm{S}{\upharpoonright}((\mathrm{VP/NP})\backslash\mathrm{VP})}{\upharpoonright}\mathrm{I}^2}{\lambda\varphi_1\lambda\varphi_2.\varphi_1\circ\mathsf{met}\circ\varphi_2; \lambda x\lambda\mathscr{P}.\mathscr{P}(\mathbf{met})(x); \mathrm{S}{\upharpoonright}((\mathrm{VP/NP})\backslash\mathrm{VP}){\upharpoonright}\mathrm{NP}}{\upharpoonright}\mathrm{I}^1$$

(255)

$$\dfrac{\begin{array}{l}\mathsf{Di}\circ\mathsf{and}\circ\mathsf{Th};\\ \langle\mathbf{di},\mathbf{th}\rangle; \mathrm{NP}\end{array} \quad \dfrac{\begin{array}{l}\mathsf{AK}\circ\mathsf{and}\circ\mathsf{Id};\\ \langle\mathbf{ak},\mathbf{id}\rangle; \mathrm{NP}\end{array} \quad \dfrac{\begin{array}{l}\lambda\sigma_0\lambda\varphi_1\lambda\varphi_2.\sigma_0(\varphi_1)(\varphi_2);\\ \mathbf{resp};\\ (Z{\upharpoonright}X{\upharpoonright}Y){\upharpoonright}(Z{\upharpoonright}X{\upharpoonright}Y)\end{array} \quad \begin{array}{l}\vdots\\ \lambda\varphi_1\lambda\varphi_2\lambda\varphi_3.\\ \quad\varphi_3\circ\mathsf{sent}\circ\\ \quad\varphi_1\circ\mathsf{to}\circ\varphi_2;\\ \mathbf{sent};\\ \mathrm{S}{\upharpoonright}\mathrm{NP}{\upharpoonright}\mathrm{NP}{\upharpoonright}\mathrm{NP}\end{array}}{\begin{array}{l}\lambda\varphi_1\lambda\varphi_2\lambda\varphi_3.\varphi_3\circ\mathsf{sent}\circ\varphi_1\circ\mathsf{to}\circ\varphi_2;\\ \mathbf{resp}(\mathbf{sent}); \mathrm{S}{\upharpoonright}\mathrm{NP}{\upharpoonright}\mathrm{NP}{\upharpoonright}\mathrm{NP}\end{array}}{\upharpoonright}\mathrm{E}}{\begin{array}{l}\lambda\varphi_2\lambda\varphi_3.\varphi_3\circ\mathsf{sent}\circ\mathsf{AK}\circ\mathsf{and}\circ\mathsf{Id}\circ\mathsf{to}\circ\varphi_2;\\ \mathbf{resp}(\mathbf{sent})(\langle\mathbf{ak},\mathbf{id}\rangle); \mathrm{S}{\upharpoonright}\mathrm{NP}{\upharpoonright}\mathrm{NP}\end{array}}{\upharpoonright}\mathrm{E}}{\begin{array}{l}\lambda\varphi_3.\varphi_3\circ\mathsf{sent}\circ\mathsf{AK}\circ\mathsf{and}\circ\mathsf{Id}\circ\mathsf{to}\circ\mathsf{Di}\circ\mathsf{and}\circ\mathsf{Th};\\ \mathbf{resp}(\mathbf{sent})(\langle\mathbf{ak},\mathbf{id}\rangle)(\langle\mathbf{di},\mathbf{th}\rangle); \mathrm{S}{\upharpoonright}\mathrm{NP}\\ \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\\ \lambda\varphi_3.\varphi_3\circ\mathsf{sent}\circ\mathsf{AK}\circ\mathsf{and}\circ\mathsf{Id}\circ\mathsf{to}\circ\mathsf{Di}\circ\mathsf{and}\circ\mathsf{Th};\\ \langle\mathbf{sent}(\mathbf{ak})(\mathbf{di}),\mathbf{sent}(\mathbf{id})(\mathbf{th})\rangle; \mathrm{S}{\upharpoonright}\mathrm{NP}\end{array}}{\upharpoonright}\mathrm{E}$$

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$$\dfrac{\begin{array}{l}\lambda\rho\lambda\sigma\lambda\varphi.\rho(\sigma)(\varphi);\\ \lambda\mathcal{R}\lambda\mathcal{T}_\times\lambda\mathcal{U}_\times.\prod_i\mathcal{R}(\pi_i(\mathcal{T}_\times))(\pi_i(\mathcal{U}_\times));\\ (Z{\upharpoonright}X{\upharpoonright}Y){\upharpoonright}(Z{\upharpoonright}X{\upharpoonright}Y)\end{array} \quad \dfrac{\dfrac{\dfrac{[\sigma; f; \mathrm{S}{\upharpoonright}\mathrm{NP}]^1 \quad [\varphi; x; \mathrm{NP}]^2}{\sigma(\varphi); f(x); \mathrm{S}}{\upharpoonright}\mathrm{E}}{\lambda\varphi.\sigma(\varphi); \lambda x.f(x); \mathrm{S}{\upharpoonright}\mathrm{NP}}{\upharpoonright}\mathrm{I}^2}{\lambda\sigma\lambda\varphi.\sigma(\varphi); \lambda f\lambda x.f(x); (\mathrm{S}{\upharpoonright}\mathrm{NP}){\upharpoonright}(\mathrm{S}{\upharpoonright}\mathrm{NP})}{\upharpoonright}\mathrm{I}^1}{\lambda\sigma_1\lambda\varphi_1.\sigma_1(\varphi_1); \lambda P_\times\lambda X_\times.\prod_i\pi_i(P_\times)(\pi_i(X_\times)); (\mathrm{S}{\upharpoonright}\mathrm{NP}){\upharpoonright}(\mathrm{S}{\upharpoonright}\mathrm{NP})}{\upharpoonright}\mathrm{E}$$

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$$\lambda\varphi_0\lambda\sigma_0.\sigma_0(\mathsf{the}\circ\mathsf{same}\circ\varphi_0);\ \mathbf{same};\ S{\upharpoonright}(S{\upharpoonright}NP){\upharpoonright}N \qquad \mathsf{book};\ \mathbf{book};\ N$$

$$\overline{\lambda\sigma_0.\sigma_0(\mathsf{the}\circ\mathsf{same}\circ\mathsf{book});\ \mathbf{same}(\mathbf{book});\ S{\upharpoonright}(S{\upharpoonright}NP)}\ {\upharpoonright}E$$

$$\lambda\sigma_0\lambda\varphi_1\lambda\varphi_2.\sigma_0(\varphi_1)(\varphi_2);\ \mathbf{resp};\ (Z{\upharpoonright}X{\upharpoonright}Y){\upharpoonright}(Z{\upharpoonright}X{\upharpoonright}Y) \qquad \vdots\ \ \lambda\varphi_3\lambda\varphi_4.\varphi_4\circ\mathsf{read}\circ\varphi_3;\ \mathbf{read};\ S{\upharpoonright}NP{\upharpoonright}NP$$

$$\overline{\lambda\varphi_1\lambda\varphi_2.\varphi_2\circ\mathsf{read}\circ\varphi_1;\ \mathbf{resp}(\mathbf{read});\ S{\upharpoonright}NP{\upharpoonright}NP}\ {\upharpoonright}E$$

$$\begin{bmatrix}\varphi;\\ X_\times;\\ NP\end{bmatrix}^1 \qquad \lambda\varphi_1\lambda\varphi_2.\varphi_2\circ\mathsf{read}\circ\varphi_1;\ \mathbf{resp}(\mathbf{read});\ S{\upharpoonright}NP{\upharpoonright}NP$$

$$\overline{\lambda\varphi_2.\varphi_2\circ\mathsf{read}\circ\varphi;\ \mathbf{resp}(\mathbf{read})(X_\times);\ S{\upharpoonright}NP}\ {\upharpoonright}E$$

$$\mathsf{john}\circ\mathsf{and}\circ\mathsf{bill};\ \langle\mathbf{j},\mathbf{b}\rangle;\ NP \qquad \lambda\varphi_2.\varphi_2\circ\mathsf{read}\circ\varphi;\ \mathbf{resp}(\mathbf{read})(X_\times);\ S{\upharpoonright}NP$$

$$\overline{\mathsf{john}\circ\mathsf{and}\circ\mathsf{bill}\circ\mathsf{read}\circ\varphi;\ \mathbf{resp}(\mathbf{read})(X_\times)(\langle\mathbf{j},\mathbf{b}\rangle);\ S}\ {\upharpoonright}E$$

$$\lambda\varphi_1.\varphi_1;\ \lambda p_\times.\textstyle\bigwedge_i \pi_i(p_\times);\ S{\upharpoonright}S \qquad \mathsf{john}\circ\mathsf{and}\circ\mathsf{bill}\circ\mathsf{read}\circ\varphi;\ \mathbf{resp}(\mathbf{read})(X_\times)(\langle\mathbf{j},\mathbf{b}\rangle);\ S$$

$$\overline{\mathsf{john}\circ\mathsf{and}\circ\mathsf{bill}\circ\mathsf{read}\circ\varphi;\ \textstyle\bigwedge_i \pi_i(\mathbf{resp}(\mathbf{read})(X_\times)(\langle\mathbf{j},\mathbf{b}\rangle));\ S}\ {\upharpoonright}E$$

$$\overline{\lambda\varphi.\mathsf{john}\circ\mathsf{and}\circ\mathsf{bill}\circ\mathsf{read}\circ\varphi;\ \lambda X_\times.\textstyle\bigwedge_i \pi_i(\mathbf{resp}(\mathbf{read})(X_\times)(\langle\mathbf{j},\mathbf{b}\rangle));\ S{\upharpoonright}NP}\ {\upharpoonright}I^1$$

$$\lambda\sigma_0.\sigma_0(\mathsf{the}\circ\mathsf{same}\circ\mathsf{book});\ \mathbf{same}(\mathbf{book});\ S{\upharpoonright}(S{\upharpoonright}NP) \qquad \lambda\varphi.\mathsf{john}\circ\mathsf{and}\circ\mathsf{bill}\circ\mathsf{read}\circ\varphi;\ \lambda X_\times.\textstyle\bigwedge_i \pi_i(\mathbf{resp}(\mathbf{read})(X_\times)(\langle\mathbf{j},\mathbf{b}\rangle));\ S{\upharpoonright}NP$$

$$\overline{\mathsf{john}\circ\mathsf{and}\circ\mathsf{bill}\circ\mathsf{read}\circ\mathsf{the}\circ\mathsf{same}\circ\mathsf{book};\ \mathbf{same}(\mathbf{book})(\lambda X_\times.\textstyle\bigwedge_i \pi_i(\mathbf{resp}(\mathbf{read})(X_\times)(\langle\mathbf{j},\mathbf{b}\rangle)));\ S}\ {\upharpoonright}E$$

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$$\vdots$$

$$\lambda\varphi_1\lambda\varphi_2\lambda\varphi_3.\ \varphi_2 \circ \mathsf{gave} \circ \varphi_1 \circ \mathsf{to} \circ \varphi_3;\ \lambda x\lambda y\lambda w.\ \mathbf{gave}(x)(w)(y);\ S{\upharpoonright}NP{\upharpoonright}NP{\upharpoonright}NP$$

$$\lambda\sigma_0\lambda\varphi_4\lambda\varphi_5\ \sigma_0(\varphi_4)(\varphi_5);\ \lambda\mathcal{R}\lambda\mathcal{T}_{\times_n}\lambda\mathcal{U}_{\times_n}.\ \textstyle\prod_i^n \mathcal{R}(\pi_i(\mathcal{T}_{\times_n}))(\pi_i(\mathcal{U}_{\times_n}));\ (Z{\upharpoonright}X{\upharpoonright}Y){\upharpoonright}(Z{\upharpoonright}X{\upharpoonright}Y)$$

${\upharpoonright}$E

$$\lambda\varphi_4\lambda\varphi_5\lambda\varphi_3.\varphi_5 \circ \mathsf{gave} \circ \varphi_4 \circ \mathsf{to} \circ \varphi_3;\ \lambda\mathcal{T}_\times\lambda\mathcal{U}_\times \textstyle\prod_i^n \lambda w.\ \mathbf{gave}(\pi_i(\mathcal{T}_\times))(w)(\pi_i(\mathcal{U}_\times));\ S{\upharpoonright}NP{\upharpoonright}NP{\upharpoonright}NP$$

$$\begin{bmatrix}\varphi_6; \\ X_\times; \\ NP\end{bmatrix}^6$$

${\upharpoonright}$E

$$\lambda\varphi_5\lambda\varphi_3.\varphi_5 \circ \mathsf{gave} \circ \varphi_6 \circ \varphi_3;\ \lambda\mathcal{U}_\times \textstyle\prod_i^n \lambda w.\mathbf{gave}(\pi_i(X_\times))(w)(\pi_i(\mathcal{U}_\times));\ S{\upharpoonright}NP{\upharpoonright}NP$$

$$\mathsf{john} \circ \mathsf{and} \circ \mathsf{bill};\ \langle \mathbf{j}, \mathbf{b}\rangle;\ NP$$

${\upharpoonright}$E

$$\lambda\varphi_3.\mathsf{john} \circ \mathsf{and} \circ \mathsf{bill} \circ \mathsf{gave} \circ \varphi_6 \circ \mathsf{to} \circ \varphi_3;\ \langle \lambda w.\mathbf{gave}(\pi_1(X_\times))(w)(\mathbf{j}), \lambda w.\mathbf{gave}(\pi_2(X_\times))(w)(\mathbf{b})\rangle;\ S{\upharpoonright}NP$$

$$\lambda\sigma_2\lambda\varphi_7.\ \sigma_2(\varphi_7);\ \lambda P_\times\lambda W_\times.\ \textstyle\prod_i \pi_i(P_\times)(\pi_i(W_\times));\ (S{\upharpoonright}NP){\upharpoonright}(S{\upharpoonright}NP)$$

${\upharpoonright}$E

$$\lambda\varphi_3.\mathsf{john} \circ \mathsf{and} \circ \mathsf{bill} \circ \mathsf{gave} \circ \varphi_6 \circ \mathsf{to} \circ \varphi_3;\ \lambda W_\times.\langle \mathbf{gave}(\pi_1(X_\times))(\pi_1(W_\times))(\mathbf{j}), \mathbf{gave}(\pi_2(X_\times))(\pi_2(W_\times))(\mathbf{b})\rangle;\ S{\upharpoonright}NP$$

$$\begin{bmatrix}\varphi_8; \\ Y_\times; \\ NP\end{bmatrix}^8$$

${\upharpoonright}$E

$$\mathsf{john} \circ \mathsf{and} \circ \mathsf{bill} \circ \mathsf{gave} \circ \varphi_6 \circ \mathsf{to} \circ \varphi_8;\ \langle \mathbf{gave}(\pi_1(X_\times))(\pi_1(Y_\times))(\mathbf{j}), \mathbf{gave}(\pi_2(X_\times))(\pi_2(Y_\times))(\mathbf{b})\rangle;\ S$$

$$\lambda\varphi.\varphi;\ \lambda p_\times.\textstyle\bigwedge_i \pi_i(p_\times);\ X{\upharpoonright}X$$

${\upharpoonright}$E

$$\mathsf{john} \circ \mathsf{and} \circ \mathsf{bill} \circ \mathsf{gave} \circ \varphi_6 \circ \mathsf{to} \circ \varphi_8;\ \mathbf{gave}(\pi_1(X_\times))(\pi_1(Y_\times))(\mathbf{j}) \wedge \mathbf{gave}(\pi_2(X_\times))(\pi_2(Y_\times))(\mathbf{b});\ S$$

$$\vdots$$

$$\mathsf{john} \circ \mathsf{and} \circ \mathsf{bill} \circ \mathsf{gave} \circ \varphi_6 \circ \mathsf{to} \circ \varphi_8;\ \mathbf{gave}(\pi_1(X_\times))(\pi_1(Y_\times))(\mathbf{j}) \wedge \mathbf{gave}(\pi_2(X_\times))(\pi_2(Y_\times))(\mathbf{b});\ S$$

${\upharpoonright}$I^8

$$\lambda\varphi_8.\mathsf{john} \circ \mathsf{and} \circ \mathsf{bill} \circ \mathsf{gave} \circ \varphi_6 \circ \mathsf{to} \circ \varphi_8;\ \lambda Y_\times.\mathbf{gave}(\pi_1(X_\times))(\pi_1(Y_\times))(\mathbf{j}) \wedge \mathbf{gave}(\pi_2(X_\times))(\pi_2(Y_\times))(\mathbf{b});\ S{\upharpoonright}NP$$

$$\vdots$$

$$\lambda\sigma_3.\sigma_3(\mathsf{the} \circ \mathsf{same} \circ \mathsf{man});\ \mathbf{same}(\mathbf{man});\ S{\upharpoonright}(S{\upharpoonright}NP)$$

${\upharpoonright}$E

$$\mathsf{john} \circ \mathsf{and} \circ \mathsf{bill} \circ \mathsf{gave} \circ \varphi_6 \circ \mathsf{to} \circ \mathsf{the} \circ \mathsf{same} \circ \mathsf{man};\ \mathbf{same}(\mathbf{man})(\lambda Y_\times.\mathbf{gave}(\pi_1(X_\times))(\pi_1(Y_\times))(\mathbf{j}) \wedge \mathbf{gave}(\pi_2(X_\times))(\pi_2(Y_\times))(\mathbf{b}));\ S$$

${\upharpoonright}$I^6

$$\lambda\varphi_6.\mathsf{john} \circ \mathsf{and} \circ \mathsf{bill} \circ \mathsf{gave} \circ \varphi_6 \circ \mathsf{to} \circ \mathsf{the} \circ \mathsf{same} \circ \mathsf{man};\ \lambda X_\times.\mathbf{same}(\mathbf{man})(\lambda Y_\times.\mathbf{gave}(\pi_1(X_\times))(\pi_1(Y_\times))(\mathbf{j}) \wedge \mathbf{gave}(\pi_2(X_\times))(\pi_2(Y_\times))(\mathbf{b}));\ S{\upharpoonright}NP$$

$$\vdots$$

$$\lambda\sigma_4.\sigma_4(\mathsf{the} \circ \mathsf{same} \circ \mathsf{book});\ \mathbf{same}(\mathbf{book});\ S{\upharpoonright}(S{\upharpoonright}NP)$$

${\upharpoonright}$E

$$\mathsf{john} \circ \mathsf{and} \circ \mathsf{bill} \circ \mathsf{gave} \circ \mathsf{the} \circ \mathsf{same} \circ \mathsf{book} \circ \mathsf{to} \circ \mathsf{the} \circ \mathsf{same} \circ \mathsf{man};\ \mathbf{same}(\mathbf{book})(\lambda X_\times.\mathbf{same}(\mathbf{man})(\lambda Y_\times.\mathbf{gave}(\pi_1(X_\times))(\pi_1(Y_\times))(\mathbf{j}) \wedge \mathbf{gave}(\pi_2(X_\times))(\pi_2(Y_\times))(\mathbf{b})));\ S$$

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$$\dfrac{\text{gave}; \mathbf{gave}; \mathrm{VP/PP/NP} \qquad \begin{bmatrix}\varphi_1;\\ x;\\ \mathrm{NP}\end{bmatrix}^1}{\text{gave} \circ \varphi_1; \mathbf{gave}(x); \mathrm{VP/PP}}\,/\mathrm{E}$$

$$\dfrac{\text{gave} \circ \varphi_1; \mathbf{gave}(x); \mathrm{VP/PP} \qquad \begin{bmatrix}\varphi_2;\\ y;\\ \mathrm{PP}\end{bmatrix}^2}{\text{gave} \circ \varphi_1 \circ \varphi_2; \mathbf{gave}(x)(y); \mathrm{VP}}\,/\mathrm{E}$$

$$\dfrac{\text{gave} \circ \varphi_1 \circ \varphi_2; \mathbf{gave}(x)(y); \mathrm{VP} \qquad \begin{bmatrix}\varphi_3;\\ \mathscr{F};\\ \mathrm{VP\backslash VP}\end{bmatrix}^3}{\text{gave} \circ \varphi_1 \circ \varphi_2 \circ \varphi_3; \mathscr{F}(\mathbf{gave}(x)(y)); \mathrm{VP}}\,/\mathrm{E}$$

$$\dfrac{\text{terry}; \mathbf{t}; \mathrm{NP} \qquad \text{gave} \circ \varphi_1 \circ \varphi_2 \circ \varphi_3; \mathscr{F}(\mathbf{gave}(x)(y)); \mathrm{VP}}{\text{terry} \circ \text{gave} \circ \varphi_1 \circ \varphi_2 \circ \varphi_3; \mathscr{F}(\mathbf{gave}(x)(y))(\mathbf{t}); \mathrm{S}}\,\backslash\mathrm{E}$$

$$\dfrac{\text{terry} \circ \text{gave} \circ \varphi_1 \circ \varphi_2 \circ \varphi_3; \mathscr{F}(\mathbf{gave}(x)(y))(\mathbf{t}); \mathrm{S}}{\lambda\varphi_3.\text{terry} \circ \text{gave} \circ \varphi_1 \circ \varphi_2 \circ \varphi_3; \lambda\mathscr{F}.\mathscr{F}(\mathbf{gave}(x)(y))(\mathbf{t}); \mathrm{S}{\upharpoonright}(\mathrm{VP\backslash VP})}\,{\upharpoonright}\mathrm{I}^3$$

$$\dfrac{}{\lambda\varphi_2\lambda\varphi_3.\text{terry} \circ \text{gave} \circ \varphi_1 \circ \varphi_2 \circ \varphi_3; \lambda y\lambda\mathscr{F}.\mathscr{F}(\mathbf{gave}(x)(y))(\mathbf{t}); \mathrm{S}{\upharpoonright}(\mathrm{VP\backslash VP}){\upharpoonright}\mathrm{PP}}\,{\upharpoonright}\mathrm{I}^2$$

$$\dfrac{}{\lambda\varphi_1\lambda\varphi_2\lambda\varphi_3.\text{terry} \circ \text{gave} \circ \varphi_1 \circ \varphi_2 \circ \varphi_3; \lambda x\lambda y\lambda\mathscr{F}.\mathscr{F}(\mathbf{gave}(x)(y))(\mathbf{t}); \mathrm{S}{\upharpoonright}(\mathrm{VP\backslash VP}){\upharpoonright}\mathrm{PP}{\upharpoonright}\mathrm{NP}}\,{\upharpoonright}\mathrm{I}^1$$

$$\dfrac{\lambda\sigma_0\lambda\varphi_1\lambda\varphi_2.\sigma_0(\varphi_1)(\varphi_2); \mathbf{resp}; (Z{\upharpoonright}X{\upharpoonright}Y){\upharpoonright}(Z{\upharpoonright}X{\upharpoonright}Y) \qquad \lambda\varphi_1\lambda\varphi_2\lambda\varphi_3.\text{terry} \circ \text{gave} \circ \varphi_1 \circ \varphi_2 \circ \varphi_3; \lambda x\lambda y\lambda\mathscr{F}.\mathscr{F}(\mathbf{gave}(x)(y))(\mathbf{t}); \mathrm{S}{\upharpoonright}(\mathrm{VP\backslash VP}){\upharpoonright}\mathrm{PP}{\upharpoonright}\mathrm{NP}}{\lambda\varphi_1\lambda\varphi_2\lambda\varphi_3.\text{terry} \circ \text{gave} \circ \varphi_1 \circ \varphi_2 \circ \varphi_3; \mathbf{resp}(\lambda x\lambda y\lambda\mathscr{F}.\mathscr{F}(\mathbf{gave}(x)(y))(\mathbf{t})); \mathrm{S}{\upharpoonright}(\mathrm{VP\backslash VP}){\upharpoonright}\mathrm{PP}{\upharpoonright}\mathrm{NP}}\,{\upharpoonright}\mathrm{E}$$

$$\dfrac{\lambda\varphi_1\lambda\varphi_2\lambda\varphi_3.\text{terry} \circ \text{gave} \circ \varphi_1 \circ \varphi_2 \circ \varphi_3; \mathbf{resp}(\lambda x\lambda y\lambda\mathscr{F}.\mathscr{F}(\mathbf{gave}(x)(y))(\mathbf{t})); \mathrm{S}{\upharpoonright}(\mathrm{VP\backslash VP}){\upharpoonright}\mathrm{PP}{\upharpoonright}\mathrm{NP} \qquad \begin{bmatrix}\varphi_4;\\ X_\times;\\ \mathrm{NP}\end{bmatrix}^4}{\lambda\varphi_2\lambda\varphi_3.\text{terry} \circ \text{gave} \circ \varphi_4 \circ \varphi_2 \circ \varphi_3; \mathbf{resp}(\lambda x\lambda y\lambda\mathscr{F}.\mathscr{F}(\mathbf{gave}(x)(y))(\mathbf{t}))(X_\times); \mathrm{S}{\upharpoonright}(\mathrm{VP\backslash VP}){\upharpoonright}\mathrm{PP}}\,{\upharpoonright}\mathrm{E}$$

$$\dfrac{\lambda\varphi_2\lambda\varphi_3.\text{terry} \circ \text{gave} \circ \varphi_4 \circ \varphi_2 \circ \varphi_3; \mathbf{resp}(\lambda x\lambda y\lambda\mathscr{F}.\mathscr{F}(\mathbf{gave}(x)(y))(\mathbf{t}))(X_\times); \mathrm{S}{\upharpoonright}(\mathrm{VP\backslash VP}){\upharpoonright}\mathrm{PP} \qquad \text{to} \circ \text{bill} \circ \text{and} \circ \text{sue}; \langle\mathbf{b},\mathbf{s}\rangle; \mathrm{PP}}{\lambda\varphi_3.\text{terry} \circ \text{gave} \circ \varphi_4 \circ \text{to} \circ \text{bill} \circ \text{and} \circ \text{sue} \circ \varphi_3; \mathbf{resp}(\lambda x\lambda y\lambda\mathscr{F}.\mathscr{F}(\mathbf{gave}(x)(y))(\mathbf{t}))(X_\times)(\langle\mathbf{b},\mathbf{s}\rangle); \mathrm{S}{\upharpoonright}(\mathrm{VP\backslash VP})}\,{\upharpoonright}\mathrm{E}$$

$$\cdots\cdots\cdots\cdots\cdots\cdots$$

$$\lambda\varphi_3.\text{terry} \circ \text{gave} \circ \varphi_4 \circ \text{to} \circ \text{bill} \circ \text{and} \circ \text{sue} \circ \varphi_3; \langle\lambda\mathscr{F}.\mathscr{F}(\mathbf{gave}(\pi_1(X_\times))(\mathbf{b}))(\mathbf{t}), \lambda\mathscr{F}.\mathscr{F}(\mathbf{gave}(\pi_2(X_\times))(\mathbf{s}))(\mathbf{t})\rangle; \mathrm{S}{\upharpoonright}(\mathrm{VP\backslash VP})$$

$$\dfrac{\begin{array}{l}\vdots\\ \lambda\sigma_1\lambda\varphi_1.\\ \quad\sigma_1(\varphi_1);\\ \lambda Y_\times\lambda P_\times.\\ \quad\prod_i \pi_i(P_\times)\\ \quad(\pi_i(Y_\times));\\ (X{\restriction}Y){\restriction}(X{\restriction}Y)\end{array}\qquad \begin{array}{l}\vdots\\ \lambda\varphi_3.\text{terry}\circ\text{gave}\circ\\ \quad\varphi_4\circ\text{to}\circ\text{bill}\circ\\ \quad\text{and}\circ\text{sue}\circ\varphi_3;\\ \langle\lambda\mathscr{F}.\mathscr{F}\\ \quad(\mathbf{gave}(\pi_1(X_\times))\\ \quad(\mathbf{b}))(\mathbf{t}),\lambda\mathscr{F}.\\ \quad\mathscr{F}(\mathbf{gave}(\pi_2(X_\times))\\ \quad(\mathbf{s}))(\mathbf{t})\rangle;\\ S{\restriction}(VP\backslash VP)\end{array}}{\begin{array}{l}\lambda\varphi_3.\text{terry}\circ\text{gave}\circ\\ \quad\varphi_4\circ\text{to}\circ\text{bill}\circ\text{and}\circ\text{sue}\circ\varphi_3;\\ \lambda Y_\times.\prod_i\pi_i(\langle\lambda\mathscr{F}.\\ \quad\mathscr{F}(\mathbf{gave}(\pi_1(X_\times))(\mathbf{b}))(\mathbf{t}),\\ \quad\lambda\mathscr{F}.\mathscr{F}(\mathbf{gave}(\pi_2(X_\times))(\mathbf{s}))\\ \quad(\mathbf{t})\rangle)(\pi_i(Y_\times));\\ S{\restriction}(VP\backslash VP)\end{array}}{\restriction}E$$

$$\dfrac{\begin{array}{l}\text{as}\circ\text{a}\circ\text{christmas}\circ\\ \quad\text{present}\circ\text{on}\circ\\ \quad\text{thursday}\circ\text{and}\circ\text{as}\circ\\ \quad\text{a}\circ\text{new}\circ\text{year's}\circ\text{gift}\circ\\ \quad\text{on}\circ\text{saturday};\\ \langle\lambda P.\mathbf{onTh}(\mathbf{asChP}(P)),\\ \quad\lambda P.\mathbf{onS}(\mathbf{asNYG}(P))\rangle;\\ VP\backslash VP\end{array}\qquad \begin{array}{l}\lambda\varphi_3.\text{terry}\circ\text{gave}\circ\varphi_4\circ\text{to}\circ\text{bill}\circ\text{and}\circ\text{sue}\circ\varphi_3;\ \ldots;\\ S{\restriction}(VP\backslash VP)\end{array}}{\begin{array}{l}\text{terry}\circ\text{gave}\circ\varphi_4\circ\text{to}\circ\text{bill}\circ\text{and}\circ\text{sue}\circ\text{as}\circ\\ \quad\text{a}\circ\text{christmas}\circ\text{present}\circ\text{on}\circ\text{thursday}\circ\text{and}\circ\\ \quad\text{as}\circ\text{a}\circ\text{new}\circ\text{year's}\circ\text{gift}\circ\text{on}\circ\text{saturday};\\ \langle\mathbf{onTh}(\mathbf{asChP}(\mathbf{gave}(\pi_1(X_\times)(\mathbf{b}))))(\mathbf{t}),\\ \quad\mathbf{onS}(\mathbf{asNYG}(\mathbf{gave}(\pi_2(X_\times)(\mathbf{s}))))(\mathbf{t})\rangle;S\end{array}}{\restriction}E$$

$$\dfrac{\begin{array}{l}\lambda\varphi_1.\varphi_1;\\ \lambda p_\times.\bigwedge_i\\ \quad\pi_i(p_\times);\\ S{\restriction}S\end{array}\qquad \begin{array}{l}\text{terry}\circ\text{gave}\circ\varphi_4\circ\ldots\circ\text{saturday};\ \ldots;S\end{array}}{\begin{array}{l}\text{terry}\circ\text{gave}\circ\varphi_4\circ\text{to}\circ\text{bill}\circ\text{and}\circ\text{sue}\circ\text{as}\circ\text{a}\circ\text{christmas}\circ\text{present}\circ\\ \quad\text{on}\circ\text{thursday}\circ\text{and}\circ\text{as}\circ\text{a}\circ\text{new}\circ\text{year's}\circ\text{gift}\circ\text{on}\circ\text{saturday};\\ \mathbf{onTh}(\mathbf{asChP}(\mathbf{gave}(\pi_1(X_\times)(\mathbf{b}))))(\mathbf{t})\wedge\\ \quad\mathbf{onS}(\mathbf{asNYG}(\mathbf{gave}(\pi_2(X_\times)(\mathbf{s}))))(\mathbf{t});S\end{array}}{\restriction}E$$

$$\dfrac{\ldots;S}{\begin{array}{l}\lambda\varphi_4.\text{terry}\circ\text{gave}\circ\varphi_4\circ\text{to}\circ\text{bill}\circ\text{and}\circ\text{sue}\circ\text{as}\circ\text{a}\circ\text{christmas}\circ\text{present}\circ\\ \quad\text{on}\circ\text{thursday}\circ\text{and}\circ\text{as}\circ\text{a}\circ\text{new}\circ\text{year's}\circ\text{gift}\circ\text{on}\circ\text{saturday};\\ \lambda X_\times.\mathbf{onTh}(\mathbf{asChP}(\mathbf{gave}(\pi_1(X_\times)(\mathbf{b}))))(\mathbf{t})\wedge\\ \quad\mathbf{onS}(\mathbf{asNYG}(\mathbf{gave}(\pi_2(X_\times)(\mathbf{s}))))(\mathbf{t});S{\restriction}NP\end{array}}{\restriction}I^4$$

$$\dfrac{\begin{array}{l}\text{the}\circ\\ \quad\text{same}\circ\\ \quad\text{gift};\\ \mathbf{same}(\mathbf{gift});\\ S{\restriction}(S{\restriction}NP)\end{array}\qquad \begin{array}{l}\lambda\varphi_4.\text{terry}\circ\ldots;\ \ldots;S{\restriction}NP\end{array}}{\begin{array}{l}\text{terry}\circ\text{gave}\circ\text{the}\circ\text{same}\circ\text{gift}\circ\text{to}\circ\text{bill}\circ\text{and}\circ\text{sue}\circ\text{as}\circ\text{a}\circ\text{christmas}\circ\text{present}\circ\\ \quad\text{on}\circ\text{thursday}\circ\text{and}\circ\text{as}\circ\text{a}\circ\text{new}\circ\text{year's}\circ\text{gift}\circ\text{on}\circ\text{saturday};\\ \mathbf{same}(\mathbf{gift})(\lambda X_\times.\mathbf{onTh}(\mathbf{asChP}(\mathbf{gave}(\pi_1(X_\times)(\mathbf{b}))))(\mathbf{t})\wedge\\ \quad\mathbf{onS}(\mathbf{asNYG}(\mathbf{gave}(\pi_2(X_\times)(\mathbf{s}))))(\mathbf{t}));S\end{array}}{\restriction}E$$

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$$\dfrac{\begin{array}{l}\lambda\sigma\lambda\varphi_1\lambda\varphi_2.\sigma(\varphi_1)(\varphi_2);\\ \mathbf{resp};\\ (Z{\restriction}X{\restriction}Y){\restriction}(Z{\restriction}X{\restriction}Y)\end{array}\qquad \dfrac{\dfrac{\dfrac{[\varphi_1;f;S/NP]^1\quad[\varphi_2;x;NP]^2}{\varphi_1\circ\varphi_2;\ f(x);\ S}{\restriction}E}{\lambda\varphi_2.\varphi_1\circ\varphi_2;\ \lambda x.f(x);\ S{\restriction}NP}{\restriction}I^2}{\lambda\varphi_1\lambda\varphi_2.\varphi_1\circ\varphi_2;\ \lambda f\lambda x.f(x);\ S{\restriction}NP{\restriction}(S/NP)}{\restriction}I^1}{\lambda\varphi_1\lambda\varphi_2.\varphi_1\circ\varphi_2;\ \lambda P_\times\lambda X_\times.\prod_i\pi_i(P_\times)(\pi_i(X_\times));\ S{\restriction}NP{\restriction}(S/NP)}{\restriction}E$$

$$\frac{\lambda\varphi_1\lambda\varphi_2.\varphi_1\circ\varphi_2;\ \lambda P_\times\lambda X_\times.\prod_i \pi_i(P_\times)(\pi_i(X_\times));\ S{\upharpoonright}NP{\upharpoonright}(S/NP) \qquad \text{john}\circ\text{spent}\circ\text{and}\circ\text{bill}\circ\text{lost};\ \langle\lambda x.\mathbf{spent}(\mathbf{j},x), \lambda x.\mathbf{lost}(\mathbf{b},x)\rangle;\ S/NP}{\lambda\varphi_2.\text{john}\circ\text{spent}\circ\text{and}\circ\text{bill}\circ\text{lost}\circ\varphi_2;\ \lambda X_\times.\prod_i \pi_i(\langle\lambda x.\mathbf{spent}(\mathbf{j},x), \lambda x.\mathbf{lost}(\mathbf{b},x)\rangle)(\pi_i(X_\times));\ S{\upharpoonright}NP}{\upharpoonright}E$$

$$\frac{\lambda\varphi_2.\text{john}\circ\text{spent}\circ\text{and}\circ\text{bill}\circ\text{lost}\circ\varphi_2;\ \ldots;\ S{\upharpoonright}NP \qquad [\varphi_3; X_\times; NP]^3}{\text{john}\circ\text{spent}\circ\text{and}\circ\text{bill}\circ\text{lost}\circ\varphi_3;\ \prod_i \pi_i(\langle\lambda x.\mathbf{spent}(\mathbf{j},x), \lambda x.\mathbf{lost}(\mathbf{b},x)\rangle)(\pi_i(X_\times));\ S}{\upharpoonright}E$$

$$\frac{\lambda\varphi_1.\varphi_1;\ \lambda p_\times.\bigwedge_i \pi_i(p_\times);\ S{\upharpoonright}S \qquad \text{john}\circ\text{spent}\circ\text{and}\circ\text{bill}\circ\text{lost}\circ\varphi_3;\ \prod_i \pi_i(\langle\lambda x.\mathbf{spent}(\mathbf{j},x), \lambda x.\mathbf{lost}(\mathbf{b},x)\rangle)(\pi_i(X_\times));\ S}{\text{john}\circ\text{spent}\circ\text{and}\circ\text{bill}\circ\text{lost}\circ\varphi_3;\ \mathbf{spent}(\mathbf{j},\pi_1(X_\times))\wedge\lambda x.\mathbf{lost}(\mathbf{b},\pi_2(X_\times));\ S}{\upharpoonright}E$$

$$\frac{\text{john}\circ\text{spent}\circ\text{and}\circ\text{bill}\circ\text{lost}\circ\varphi_3;\ \mathbf{spent}(\mathbf{j},\pi_1(X_\times))\wedge\lambda x.\mathbf{lost}(\mathbf{b},\pi_2(X_\times));\ S}{\lambda\varphi_3.\text{john}\circ\text{spent}\circ\text{and}\circ\text{bill}\circ\text{lost}\circ\varphi_3;\ \lambda X_\times.\mathbf{spent}(\mathbf{j},\pi_1(X_\times))\wedge\lambda x.\mathbf{lost}(\mathbf{b},\pi_2(X_\times));\ S{\upharpoonright}NP}{\upharpoonright}I^3$$

$$\frac{\lambda\varphi\lambda\sigma.\sigma(\text{a}\circ\text{total}\circ\text{of}\circ\varphi);\ \mathbf{total};\ S{\upharpoonright}(S{\upharpoonright}NP){\upharpoonright}N \qquad \$10\text{k};\ \mathbf{\$10k};\ N}{\lambda\sigma.\sigma(\text{a}\circ\text{total}\circ\text{of}\circ\$10\text{k});\ \mathbf{total}(\mathbf{\$10k});\ S{\upharpoonright}(S{\upharpoonright}NP)}{\upharpoonright}E$$

$$\frac{\lambda\sigma.\sigma(\text{a}\circ\text{total}\circ\text{of}\circ\$10\text{k});\ \mathbf{total}(\mathbf{\$10k});\ S{\upharpoonright}(S{\upharpoonright}NP) \qquad \lambda\varphi_3.\text{john}\circ\text{spent}\circ\text{and}\circ\text{bill}\circ\text{lost}\circ\varphi_3;\ \lambda X_\times.\mathbf{spent}(\mathbf{j},\pi_1(X_\times))\wedge\lambda x.\mathbf{lost}(\mathbf{b},\pi_2(X_\times));\ S{\upharpoonright}NP}{\text{john}\circ\text{spent}\circ\text{and}\circ\text{bill}\circ\text{lost}\circ\text{a}\circ\text{total}\circ\text{of}\circ\$10\text{k};\ \mathbf{total}(\mathbf{\$10k})(\lambda X_\times.\mathbf{spent}(\mathbf{j},\pi_1(X_\times))\wedge\mathbf{lost}(\mathbf{b},\pi_2(X_\times)));\ S}{\upharpoonright}E$$

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$$\frac{\text{gave};\ \mathbf{gave};\ VP/NP/NP \qquad [\varphi_2; y; NP]^2}{\text{gave}\circ\varphi_2;\ \mathbf{gave}(y);\ VP/NP}/E$$

$$\frac{\text{gave}\circ\varphi_2;\ \mathbf{gave}(y);\ VP/NP \qquad [\varphi_3; z; NP]^3}{\text{gave}\circ\varphi_2\circ\varphi_3;\ \mathbf{gave}(y)(z);\ VP}/E$$

$$\frac{[\varphi_1; x; NP]^1 \qquad \text{gave}\circ\varphi_2\circ\varphi_3;\ \mathbf{gave}(y)(z);\ VP}{\varphi_1\circ\text{gave}\circ\varphi_2\circ\varphi_3;\ \mathbf{gave}(y)(z)(x);\ S}\backslash E$$

$$\frac{\varphi_1\circ\text{gave}\circ\varphi_2\circ\varphi_3;\ \mathbf{gave}(y)(z)(x);\ S}{\lambda\varphi_3.\varphi_1\circ\text{gave}\circ\varphi_2\circ\varphi_3;\ \lambda z.\mathbf{gave}(y)(z)(x);\ S{\upharpoonright}NP}{\upharpoonright}I^3$$

$$\frac{\text{two}\circ\text{passwords};\ \mathbf{two\text{-}pw};\ S{\upharpoonright}(S{\upharpoonright}NP) \qquad \lambda\varphi_3.\varphi_1\circ\text{gave}\circ\varphi_2\circ\varphi_3;\ \lambda z.\mathbf{gave}(y)(z)(x);\ S{\upharpoonright}NP}{\varphi_1\circ\text{gave}\circ\varphi_2\circ\text{two}\circ\text{passwords};\ \mathbf{two\text{-}pw}(\lambda z.\mathbf{gave}(y)(z)(x));\ S}{\upharpoonright}E$$

$$\frac{\varphi_1\circ\text{gave}\circ\varphi_2\circ\text{two}\circ\text{passwords};\ \mathbf{two\text{-}pw}(\lambda z.\mathbf{gave}(y)(z)(x));\ S}{\lambda\varphi_2.\varphi_1\circ\text{gave}\circ\varphi_2\circ\text{two}\circ\text{passwords};\ \lambda y.\mathbf{two\text{-}pw}(\lambda z.\mathbf{gave}(y)(z)(x));\ S{\upharpoonright}NP}{\upharpoonright}I^2$$

$$\frac{\lambda\varphi.\varphi;\ \mathbf{dist};\ (S{\upharpoonright}NP){\upharpoonright}(S{\upharpoonright}NP) \qquad \lambda\varphi_2.\varphi_1\circ\text{gave}\circ\varphi_2\circ\text{two}\circ\text{passwords};\ \lambda y.\mathbf{two\text{-}pw}(\lambda z.\mathbf{gave}(y)(z)(x));\ S{\upharpoonright}NP}{\lambda\varphi_2.\varphi_1\circ\text{gave}\circ\varphi_2\circ\text{two}\circ\text{passwords};\ \mathbf{dist}(\lambda y.\mathbf{two\text{-}pw}(\lambda z.\mathbf{gave}(y)(z)(x)));\ S{\upharpoonright}NP}{\upharpoonright}E$$

$$\frac{\lambda\varphi_2.\varphi_1\circ\text{gave}\circ\varphi_2\circ\text{two}\circ\text{passwords};\ \mathbf{dist}(\lambda y.\mathbf{two\text{-}pw}(\lambda z.\mathbf{gave}(y)(z)(x)));\ S{\upharpoonright}NP}{\lambda\varphi_1\lambda\varphi_2.\varphi_1\circ\text{gave}\circ\varphi_2\circ\text{two}\circ\text{passwords};\ \lambda x.\mathbf{dist}(\lambda y.\mathbf{two\text{-}pw}(\lambda z.\mathbf{gave}(y)(z)(x)));\ S{\upharpoonright}NP{\upharpoonright}NP}{\upharpoonright}I^1$$

$$\vdots$$

$\lambda\sigma_0\lambda\varphi_1\lambda\varphi_2.\sigma_0(\varphi_1)(\varphi_2)$; **resp**; $(Z{\upharpoonright}X{\upharpoonright}Y){\upharpoonright}(Z{\upharpoonright}X{\upharpoonright}Y)$

$\lambda\varphi_1\lambda\varphi_2.\varphi_1 \circ$ gave $\circ\ \varphi_2 \circ$ two $\circ$ passwords; $\lambda x.\mathbf{dist}(\lambda y.\mathbf{two\text{-}pw}(\lambda z.\mathbf{gave}(y)(z)(x)))$; $S{\upharpoonright}NP{\upharpoonright}NP$

—————————————————— ${\upharpoonright}$E

$\lambda\varphi_1\lambda\varphi_2.\varphi_1 \circ$ gave $\circ\ \varphi_2 \circ$ two $\circ$ passwords; $\mathbf{resp}(\lambda x.\mathbf{dist}(\lambda y.\mathbf{two\text{-}pw}(\lambda z.\mathbf{gave}(y)(z)(x))))$; $S{\upharpoonright}NP{\upharpoonright}NP$

$\left[\varphi_1;\ X_\times;\ NP\right]^4$

—————————————————— ${\upharpoonright}$E

$\lambda\varphi_2.\varphi_1 \circ$ gave $\circ\ \varphi_2 \circ$ two $\circ$ passwords; $\mathbf{resp}(\lambda x.\mathbf{dist}(\lambda y.\mathbf{two\text{-}pw}(\lambda z.\mathbf{gave}(y)(z)(x))))(X_\times)$; $S{\upharpoonright}NP$

$\left[\varphi_2;\ W_\times;\ NP\right]^5$

—————————————————— ${\upharpoonright}$E

$\varphi_1 \circ$ gave $\circ\ \varphi_2 \circ$ two $\circ$ passwords; $\mathbf{resp}(\lambda x.\mathbf{dist}(\lambda y.\mathbf{two\text{-}pw}(\lambda z.\mathbf{gave}(y)(z)(x))))(X_\times)(W_\times)$; S

$\lambda\varphi.\varphi$; **bool**; $S{\upharpoonright}S$

—————————————————— ${\upharpoonright}$E

$\varphi_1 \circ$ gave $\circ\ \varphi_2 \circ$ two $\circ$ passwords; $\mathbf{bool}(\mathbf{resp}(\lambda x.\mathbf{dist}(\lambda y.\mathbf{two\text{-}pw}(\lambda z.\mathbf{gave}(y)(z)(x))))(X_\times)(W_\times))$; S

—————————————————— ${\upharpoonright}$I[5]

$\lambda\varphi_2.\varphi_1 \circ$ gave $\circ\ \varphi_2 \circ$ two $\circ$ passwords; $\lambda W_\times.\mathbf{bool}(\mathbf{resp}(\lambda x.\mathbf{dist}(\lambda y.\mathbf{two\text{-}pw}(\lambda z.\mathbf{gave}(y)(z)(x))))(X_\times)(W_\times))$; $S{\upharpoonright}NP$

$\lambda\sigma.\sigma$(a $\circ$ total $\circ$ of $\circ$ 1000 $\circ$ customers); $\mathbf{total}(\mathbf{1k\text{-}cus})$; $S{\upharpoonright}(S{\upharpoonright}NP)$

—————————————————— ${\upharpoonright}$E

$\varphi_1 \circ$ gave $\circ$ a $\circ$ total $\circ$ of $\circ$ 1000 $\circ$ customers $\circ$ two $\circ$ passwords; $\mathbf{total}(\mathbf{1k\text{-}cus})(\lambda W_\times.\mathbf{bool}(\mathbf{resp}(\lambda x.\mathbf{dist}(\lambda y.\mathbf{two\text{-}pw}(\lambda z.\mathbf{gave}(y)(z)(x))))(X_\times)(W_\times)))$; S

—————————————————— ${\upharpoonright}$I[4]

$\lambda\varphi_1.\varphi_1 \circ$ gave $\circ$ a $\circ$ total $\circ$ of $\circ$ 1000 $\circ$ customers $\circ$ two $\circ$ passwords; $\lambda X_\times.\mathbf{total}(\mathbf{1k\text{-}cus})(\lambda W_\times.\mathbf{bool}(\mathbf{resp}(\lambda x.\mathbf{dist}(\lambda y.\mathbf{two\text{-}pw}(\lambda z.\mathbf{gave}(y)(z)(x))))(X_\times)(W_\times)))$; $S{\upharpoonright}NP$

$\lambda\sigma.\sigma$(a $\circ$ total $\circ$ of $\circ$ 3 $\circ$ atms); $\mathbf{total}(\mathbf{3\text{-}atms})$; $S{\upharpoonright}(S{\upharpoonright}NP)$

—————————————————— ${\upharpoonright}$E

a $\circ$ total $\circ$ of $\circ$ 3 $\circ$ atms $\circ$ gave $\circ$ a $\circ$ total $\circ$ of $\circ$ 1000 $\circ$ customers $\circ$ two $\circ$ passwords; $\mathbf{total}(\mathbf{3\text{-}atms})(\lambda X_\times.\mathbf{total}(\mathbf{1k\text{-}cus})(\lambda W_\times.\mathbf{bool}(\mathbf{resp}(\lambda x.\mathbf{dist}(\lambda y.\mathbf{two\text{-}pw}(\lambda z.\mathbf{gave}(y)(z)(x))))(X_\times)(W_\times))))$; S

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