COORDINATION IN HYBRID TYPE-LOGICAL CATEGORIAL GRAMMAR

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Abstract

We formulate explicit analyses of certain non-standard coordination examples discussed in Levine (2011) in a variant of categorial grammar called *Hybrid Type-Logical Categorial Grammar* (Kubota 2010; Kubota & Levine 2012; Kubota to appear). These examples are of theoretical importance since they pose significant challenges to the currently most explicit and most comprehensive analysis of coordination, formulated in a variant of HPSG called Linearization-based HPSG (Reape 1996; Kathol 1995) and advocated by various authors in the recent literature (Yatabe 2001; Crysmann 2003; Beavers & Sag 2004; Chaves 2007; Sag & Chaves 2008). This approach, which we call the Linearization-Based Ellipsis (LBE) approach to coordination, builds on the key idea that apparent non-standard coordination all reduce to constituent coordination under surface ellipsis. The seemingly heterogeneous set of data catalogued in Levine (2011), involving different types of non-standard coordination, uniformly point to an analysis in which the apparently incomplete constituents that are coordinated in the overt string are in fact complete (i.e. non-elliptical) constituents with full-fledged semantic interpretation, thus directly counterexemplifying the predictions of ellipsis-based approaches including the LBE variant. The sophisticated syntax-semantics interface of the framework

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we propose in this paper straightforwardly captures the interactions between such non-standard coordination and various scopal expressions, demonstrating the real empirical payoff of the direct coordination analysis of non-standard coordination (of the kind widely adopted in categorial grammar) that has not been fully recognized in the previous literature.

1 Introduction

Levine (2011) provides a thorough critique of an approach to coordination that has become prominent in the recent literature of HPSG. The key idea of this approach, which we call the Linearization-Based Ellipsis (LBE) approach to coordination (Yatabe 2001; Crysmann 2003; Beavers & Sag 2004; Chaves 2007; Sag & Chaves 2008), is to analyze a wide range of coordination examples that apparently pose problems for phrase structure-based theories of syntax such as HPSG via a single mechanism of surface ellipsis. The analysis is technically implemented in a variant of HPSG that relaxes the mapping between the combinatoric structure and surface string known as Linearization-based HPSG (Reape 1996; Kathol 1995). In this paper, we take up some of the key examples from Levine (2011), which pose serious problems for the LBE approach and provide explicit analyses of them within a variant of categorial grammar called *Hybrid Type-Logical Categorial Grammar*. (Kubota 2010; Kubota & Levine 2012; Kubota to appear). While building heavily on ideas from previous literature of categorial grammar (CG), the proposed framework is novel in that it recognizes *both* the directionality-sensitive mode of implication (i.e. forward and backward slashes) familiar from the tradition of Lambek (1958) and the directionality-insensitive mode of implication employed in some of the more recent variants of CG pioneered by Oehrle (1994). This hybrid implication architecture enables a flexible and sophisticated syntax-semantics interface that is not available in previous variants of CG, and we show below that the analyses of the empirical phenomena taken up in this paper crucially exploits this flexibility and systematicity of the proposed framework. As will become clear below, due to the generality of the underlying logic, the present framework is not amenable to the kinds of criticisms that have been occasionally raised against previous variants of CG (especially CCG), which, for various reasons, do not entertain the flexibility of the logic-based syntax-semantics interface characteristic to CG in a fully general way.

The key hypothesis of the LBE approach to coordination, in its strongest version, is that a wide range of non-standard coordination such as the following (dependent cluster coordination (DCC) in (1a), right-node raising (RNR) in (1b), agreement anomaly in nominal head coordination in (1c) and unlike category coordination (UCC) in (1d)) can all be reduced to ordinary constituent coordination via surface ellipsis along the lines of (2).

(1) a. I gave Robin a book and Terry a pair of pliars.
b. I gave Robin, and Leslie offered Terry, a pair of pliars.
c. That man and woman are arguing again.
d. Robin is a Republican and proud of it.

(2) a. [$_{\text{S}}$ [$_{\text{S}}$ I gave Robin a book on Thursday] and [$_{\text{S}}$ ~~I gave~~ Leslie a book on Friday.]]
b. [$_{\text{S}}$ [$_{\text{S}}$ I gave Robin ~~a pair of pliars~~] and [$_{\text{S}}$ Leslie offered Terry, a pair of pliars]].
c. [$_{\text{NP}}$ [$_{\text{NP}}$ That man] and [$_{\text{NP}}$ ~~that~~ woman]] are arguing again.
d. [$_{\text{S}}$ [$_{\text{S}}$ Robin is a Republican] and [$_{\text{S}}$ ~~Robin is~~ proud of it.]]

The strikeout in (2) is meant to represent purely phonological deletion which is licensed on the condition that the same string appears in the other conjunct. This deletion operator (at least on the null hypothesis) is supposed to affect only the pronunciation of the sentence and not its semantic interpretation.

It should be noted that not all advocates of the LBE approach endorse an elliptical analysis for all of these cases (see, for example, Yatabe (2012), who expresses the view that an ellipsis-based approach is not appropriate for the latter two cases). However, since the plausibility of the hypothesis in part depends on its generality and since ellipsis-based analyses along the lines of (2) have been suggested for all of these phenomena by at least some authors advocating the LBE approach, we include them all here for completeness.

Following Levine (2011), we point out below that *none* of these cases are amenable to ellipsis-based analyses once we extend the dataset to cases in which the semantics of the coordinated expressions have non-trivial consequences for the compositional semantics of the whole sentence. The relevant examples involve the interactions between coordination and scopal expressions that appear outside the coordinate structure. We show below that the predictions of the LBE approach is systematically falsified in each such case. We then present explicit compositional analyses of these phenomena in Hybrid TLCG. We show that independently motivated analyses of each of these constructions interact properly with analyses of scopal elements in the proposed framework to yield the correct predictions in the relevant examples straightforwardly. Besides providing a general argument for a CG-based analysis of coordination, the data discussed in this paper thus provides strong empirical evidence for the proposed variant of categorial grammar (among other variants) in that the interactions between coordination and scopal expressions that they manifest call for exactly the sort of hybrid architecture of the syntax-semantics interface that is unique to it.

2 Contraindications for Linearization-Based Ellipsis (LBE)

2.1 Symmetrical, respective and summative predicates and nonconstituent coordination

Perhaps the strongest piece of evidence against ellipsis-based approaches to coordination comes from data such as (3a) and (4a), long known in the literature as a paradigm case which demonstrates the inadequacies of ellipsis-based analyses of nonconstituent coordination such as DCC and RNR (Abbott 1976; Jackendoff 1977; Gazdar 1981).

(3) a. I said $\left\{\begin{array}{l}\text{the same thing}\\ \text{different things}\end{array}\right\}$ to Robin on Thursday and (to) Leslie on Friday.

b. I said $\left\{\begin{array}{l}\text{the same thing}\\ \text{different things}\end{array}\right\}$ to Robin on Thursday and $\underline{\text{(I) said} \left\{\begin{array}{l}\text{the same thing}\\ \text{different things}\end{array}\right\} \text{to}}$ Leslie on Friday.

(4) a. Robin reviewed, and Leslie read, $\left\{\begin{array}{l}\text{the same book}\\ \text{different books}\end{array}\right\}$.

b. Robin reviewed $\underline{\left\{\begin{array}{l}\text{the same book}\\ \text{different books}\end{array}\right\}}$, and Leslie read $\left\{\begin{array}{l}\text{the same book}\\ \text{different books}\end{array}\right\}$.

Ellipsis-based analyses predict that the NCC examples in (3a) and (4b) are synonymous to the their constituent coordination counterparts in (3b) and (4b) (from which the NCC examples are derived by deleting the underlined parts—underlines in examples mean the same thing in all of the examples below), but this prediction is not borne out. (3a) and (4b) exhibit the so-called *internal reading* of *same* and *different* (Carlson 1987), which simply asserts the (non-)identity of the thing(s) in question. The constituent coordination counterparts in (3b) and (4b) have only the anaphoric, *external reading*, which presupposes the existence of some entity already salient in the discourse and asserts the (non-)identity between the things in question and that discourse-salient entity.

This type of non-parallel between NCC and their alleged clausal counterparts is not limited to symmetrical predicates, but is actually much more widespread. As noted, for example, by Abbott (1976) and Chaves (2012), essentially the same pattern is observed with the so-called 'respect readings' of sentences involving the adverb *respectively*, and the summative interpretations of numerical expressions such as *a total of $1000*. Examples of DCC are given in (5) and (6). Similar examples of RNR can be constructed easily.

(5) a. I lent *Barriers* and *Syntactic Structures* to Robin on Thursday and (to) Leslie on Friday, respectively.

b. I lent *Barriers* and *Syntactic Structures* to Robin on Thursday and $\underline{\text{I lent } \textit{Barriers} \text{ and } \textit{Syntactic Structures}}$ (to) Leslie on Friday, respectively.

(6) a. I lent *$1000 in total* to Robin on Thursday and (to) Leslie on Friday.

b. I lent *$1000 in total* to Robin on Thursday and $\underline{\text{I lent } \textit{\$1000 in total}}$ (to) Leslie on Friday.

Here, too, the NCC examples have meanings that are not available in their alleged clausal counterparts, and this fact remains a mystery for ellipsis-based approaches to coordination.

It turns out that working out an explicit compositional semantics for this type of examples poses a significant challenge for any type of approach to NCC, be it ellipsis-based or not. In fact, as far as we are aware, except for Kubota (2010), there is no explicit proposal in the literature that provides a completely satisfactory solution for this problem. We reproduce in section 3 Kubota's (2010) analysis of examples like (3a) and (4a) (involving symmetrical predicates), which exploits the hybrid implication architecture of the present framework.

2.2 UCC and extraction

The use of ellipsis to derive examples like (7a) from underlying 'source' structures like (7b) and thereby eliminate the 'unlikeness' of UCC was suggested by Beavers & Sag (2004) and then advocated more extensively by Chaves (2006).

(7) a. Robin is a Republican and proud of it.
b. Robin is a Republican and (Robin) is proud of it.

However, such an analysis leads to severe mispredictions once one considers more complex examples. Note first that strings like *rich and a Republican*, which exemplify the unlike category coordination, can be topicalized as in (8a):

(8) a. Rich and a Republican, Robin definitely is t.
b. Rich Robin definitely is t and a Republican Robin definitely is t.

The only way to derive (8a) from ellipsis is to assume an underlying source of the form in (8b) involving conjunction of full-fledged clauses. On this type of analysis, the following examples turn out to be crucially problematic:

(9) a. (Both) poor and a Republican, you can't possibly be t.
b. (Both) poor you can't possibly be t and a Republican you can't possibly be t.

(10) a. Dead drunk but in complete control of the situation, no one can be t.
b. Dead drunk no one can be t but in total control of the situation, no one can be t.

The ellipsis-based approach demands (9a) and (10a) to be derived from (9b) and (10b), but there is a mismatch in semantic interpretation that is essentially parallel to the symmetrical predicate data from the previous section. In (9a) and (10a), the modal scopes over the whole coordinated string *rich and a Republican*; in other words, in (9a), what is negated is the property of simultaneously being poor and a Republican. The non-elliptical sources in (9b) and (10a) lack that interpretation totally; they can only be interpreted as a conjunction of negation, which has a stricter truth conditions than their alleged elided counterparts.

The same observation can be replicated in yet another displacement construction, namely, pseudocleft. In (11a), a conjoined unlike category occupies the focus position of a pseudocleft sentence. On the ellipsis-based analysis, this example has to be derived from the underlying source in (11b), but again, there is a semantic mismatch between the UCC example and its alleged underlying source.

(11) a. What you cannot become (simultaneously) is highly intelligent and (yet) a raving fundamentalist.

b. What you cannot (simultaneously) become is highly intelligent and (yet) what you cannot (simultaneously) become is a raving fundamentalist.

2.3 Nominal head coordination under a singular determiner

Finally, we consider the case of nominal head coordination under a singular determiner exemplified by data such as (12):

(12) That man and woman are arguing again.

Chaves (2007) and Sag & Chaves (2008) suggest the possibility of deriving (12) from an underlying source of the form of (13). An apparent advantage of such an analysis is that it provides an immediate (and simple) solution for the seemingly anomalous agreement pattern in (12) (where a singular determiner is used for an NP which clearly refers to multiple individuals).

(13) That man and that woman are arguing again.

Consideration of a wider range of data, however, once again reveals that such an ellipsis-based analysis is too simplistic. Examples like the following noted by Heycock & Zamparelli (2005) in which a symmetrical modifier appears in the the 'ellipsis' environment resist an analysis along the lines of (13).

(14) a. That ill-matched man and woman are fighting again.

b. *That ill matched man and that ill-matched woman are fighting again.

(15) a. That mutually hostile judge and defense attorney were constantly sniping at each other during the trial.

b. *That mutually hostile judge and that mutually hostile defense attorney were constantly sniping at each other during the trial.

The alleged underlying sources for (14a) and (15a), given in (14b) and (15b), are simply ungrammatical. Here again, the problem essentially stems from the fact that an ellipsis-based analysis gets the semantic scope wrong. For example, to derive the right meaning for

(14a), the symmetrical predicate *ill-matched* has to scope over the conjoined noun *man and woman* so as to establish the right relation between the man and the woman in question. Such an interpretation cannot be obtained from the 'source' structure (14b), where two distinct tokens of *ill-matched* modify the nouns *man* and *woman* separately within each conjunct.

2.4 Summary

The LBE approach to coordination at first sight appears to provide a simple and uniform solution for a wide range of apparently heterogeneous set of non-standard coordination phenomena. However, as we have seen above, the success is illusory. Once we look beyond the simplest cases exemplified by (1), the ellipsis-based approach faces several severe difficulties. Specifically, in all of the cases discussed in this section, whose key examples are repeated in (the a.-examples of) (16)–(18), we see a systematic interaction between the coordinated expression and scopal operators that appear *outside* the coordinate structure in the overt string.

(16) a. I said $\left\{\begin{array}{c}\text{the same thing}\\ \text{different things}\end{array}\right\}$ to Robin on Thursday and (to) Leslie on Friday.

b. I said $\left\{\begin{array}{c}\text{the same thing}\\ \text{different things}\end{array}\right\}$ to Robin on Thursday and ~~(I) said~~ $\left\{\begin{array}{c}\text{\sout{\textbf{the same thing}}}\\ \text{\sout{\textbf{different things}}}\end{array}\right\}$ ~~to~~ Leslie on Friday.

(17) a. (Both) poor and a Republican, you can't possibly be t.

b. (Both) poor ~~you **can't possibly** be *t*~~ and a Republican you can't possibly be t.

(18) a. That ill-matched man and woman are fighting again.

b. That ill-matched man and ~~that **ill-matched**~~ woman are fighting again.

In all these cases, the observed empirical pattern is that the operator scopes over the whole coordinate structure in a way that mirrors the surface form of the sentence. The LBE approach systematically mispredicts in such cases, since, on the ellipsis-based analysis, the scopal operator is part of the elided string (as in b. above) and hence appears *inside* each conjunct, in effect reversing the scopal relation between the operator and the coordinate structure from what is actually observed.

3 Hybrid Type-Logical Categorial Grammar

The central characteristic of the variant of CG that we propose in this paper is that it recognizes two kinds of implication, namely, the order-sensitive forward and backward slashes familiar from the tradition of Type-Logical Categorial Grammar originating from Lambek's (1958) work, and the order-insensitive mode of implication tied to phonological λ-binding in more recent variants of CG (stemming from Oehrle's (1994) work) that relegate word order-related information from the combinatoric component of syntax to a separate morpho-phonological component. As will become clear below, the hybrid architecture of the present framework is exploited crucially in capturing the interactions between coordination and various scopal expressions. Directional variants of categorial grammar provide an elegant analysis of non-standard coordination (especially nonconstituent coordination including both DCC and RNR), while they are subotimal for scopal phenomena due to the inherently directional nature of the underlying calculus. By contrast, variants of CG that relegate word order entirely to a separate prosodic component enables a straightforward treatment of scopal phenomena, but they have the drawback that the elegant analysis of (non-standard) coordination in directional variants of CG is lost, due to the fact that syntactic categories of linguistic expressions do not carry order-related information (an aspect of directional variants of CG that is crucially exploited in the analysis of coordination). Hybrid TLCG entertains the advantages of both directional and non-directional variants of CG, by recognizing both kinds of implication within a single calculus. The complex interactions between coordination and scopal expressions exhibited by the data observed in section 2 requires exactly this kind of architecture, providing empirical evidence for the novel architecture of CG embodied in the proposed framework.

3.1 Hybrid Implication System as an Underlying Logic

Following Oehrle (1994), we write linguistic expressions as tuples of phonological form, semantic interpretation and syntactic category (written in that order). Our system recognizes both directional modes of implication ($/$ and $\backslash$) and a non-directional mode of implication that we call the *vertical slash* ($|$, for which we write the argument to its right, just as with $/$). The full set of inference rules posited in the calculus, consisting of the Introduction and Elimination rules for the three kinds of slashes, are given in (19).

(19) **Connective** **Introduction** **Elimination**

$/$

$$\dfrac{\dfrac{\begin{array}{ccc}\vdots & [\varphi; x; A]^n & \vdots \\ \vdots & \vdots & \vdots\end{array}}{b \circ \varphi; \boldsymbol{f}; B}}{b; \lambda x.\boldsymbol{f}; B/A}/\mathrm{I}^n \qquad \dfrac{a; \boldsymbol{f}; A/B \quad b; \boldsymbol{g}; B}{a \circ b; \boldsymbol{f}(\boldsymbol{g}); A}/\mathrm{E}$$

$\backslash$

$$\dfrac{\dfrac{\begin{array}{ccc}\vdots & [\varphi; x; A]^n & \vdots \\ \vdots & \vdots & \vdots\end{array}}{\varphi \circ b; \boldsymbol{f}; B}}{b; \lambda x.\boldsymbol{f}; A\backslash B}\backslash\mathrm{I}^n \qquad \dfrac{b; \boldsymbol{g}; B \quad a; \boldsymbol{f}; B\backslash A}{b \circ a; \boldsymbol{f}(\boldsymbol{g}); A}\backslash\mathrm{E}$$

$|$

$$\dfrac{\dfrac{\begin{array}{ccc}\vdots & [\varphi; x; A]^n & \vdots \\ \vdots & \vdots & \vdots\end{array}}{b; \boldsymbol{f}; B}}{\lambda\varphi.b; \lambda x.\boldsymbol{f}; B|A}|\mathrm{I}^n \qquad \dfrac{a; \boldsymbol{f}; A|B \quad b; \boldsymbol{g}; B}{a(b); \boldsymbol{f}(\boldsymbol{g}); A}|\mathrm{E}$$

The key difference between the directional slashes ($/$ and $\backslash$) and the non-directional slash ($|$) is that while the Introduction and Elimination rules for the former refer to the phonological forms of the input and output strings (so that, for example, the applicability of the /I rule is conditioned on the presence of the phonology of the hypothesis φ on the right periphery of the phonology of the input $b \circ \varphi$),[1] the rules for the latter are not constrained that way. For reasoning involving $|$, the phonological terms themselves fully specify the ways in which the output phonology is constructed from the input phonologies. Specifically, for $|$, the phonological operations associated with the Introduction and Elimination rules mirror exactly the semantic operations for these rules: function application and λ-abstraction, respectively. We assume that the binary connective $\circ$ in the phonological term calculus represents the string concatenation operation and that $\circ$ is associative in both directions. For notational convenience, we implicitly assume the associativity axiom $(\varphi_1 \circ \varphi_2) \circ \varphi_3 \equiv \varphi_1 \circ (\varphi_2 \circ \varphi_3)$ and leave out all the brackets indicating the internal constituency of complex phonological terms.[2] The phonological term calculus is a lambda calculus, and we also take the equivalence between β-reduced and unreduced terms to be an axiom.[3]

It should be clear from the way the above rules are formulated that the present system without the rules for $|$ is equivalent to the Lambek calculus (Lambek 1958), while the system with only the rules for $|$ is essentially equivalent to the term-labelled calculus of Oehrle (1994), Lambda Grammar (Muskens 2003), Abstract Categorial Grammar (de Groote 2001), and Linear Grammar (Pollard 2011), with some irrelevant implementational details aside.

3.2 Basic Analyses of Scope and Coordination

As was first demonstrated by Oehrle (1994), λ-binding in the phonological component enables an insightful analysis of quantifier scope, a problem whose general solution has turned out to pose significant theoretical challenges to directional variants of

[1] In this respect, the present calculus follows most closely Morrill & Solias (1993) and Morrill (1994); see Moortgat (1997) and Bernardi (2002) for an alternative formulation where sensitivity to directionality is mediated through a presumed correspondence between surface string and the form of structured antecedents in the sequent-style notation of natural deduction.

[2] For a more fine-grained control of surface morpho-phonological constituency, see Kubota & Pollard (2010) (and also Muskens (2007) for a related approach), which formalizes the notion of multi-modality from the earlier TLCG literature (Moortgat & Oehrle 1994; Morrill 1994) by modelling the mapping from syntax to phonology by means of an interpretation of (phonological) λ-terms into preorders.

[3] Note that the equivalence enforced by the associativity axiom is a property of the prosodic calculus directly reflecting the structures of the objects that the prosodic terms are supposed to model whereas equivalence under β-reduction is a formal property of the calculus itself. In this sense, the two equivalence relations we implicitly assume here are of somewhat different nature. In particular, the latter assumption underlies the fundamentally hybrid nature of the proposed system of tripartite inference as a whole in that β-reductions of prosodic terms that result from inferences involving the vertical slash sometimes play a crucial role for the applicability of subsequent inferences involving the directional slashes. A deductive system with such a radically hybrid property is unheard of and is surely unorthodox, and its formal underpinnings need to be investigated more closely, but we leave this task for future study.

CG.[4] As will become clear below, Oehrle's analysis illuminates the fundamental nature of scope-taking expressions by capturing the tight correlation between λ-binding in semantics and the corresponding binding of the 'gap' in the phonology, which is merely enforced by a bunch of coincidental stipulations in Montague's syncategorematic treatment of quantifying-in (which in turn is modelled in various ways in Lambek calculus-based variants of TLCG essentially carrying over the stipulative nature of Montague's solution as is). Unlike Montague's original treatment, in Oehrle's (1994) analysis the mismatch between linear position and scopal domain is a predicted *consequence* of hypothetical reasoning in the underlying logic.

The following analysis of the inverse-scope ($\forall > \exists$) reading of the sentence *Someone talked to everyone yesterday* illustrates how this works. We first hypothetically assume NPs in the surface positions in which the quantifiers appear. After the whole sentence is built up, withdrawing one of the hypotheses and binding the variables (in both phonology and semantics) via Vertical Slash Introduction produces a lambda-abstracted meaning/phonology pair that can be given to a quantifier as an argument. Combining the quantifier with such a lambda abstract has the effect that semantically the quantifier scopes over the whole expression but phonologically the string of the quantifier is inserted to the variable slot that is explicitly kept track of in the sentence's phonology via phonological lambda binding. The order in which the quantifiers are introduced in the derivation corresponds to their relative scope. Thus, in (20), since the universal quantifier in the object position is introduced in the derivation after the subject position quantifier, the inverse-scope interpretation is derived.

(20)

$$\dfrac{\begin{matrix}\lambda\sigma.\sigma(\mathsf{everyone});\\ \forall_{\mathbf{person}};\\ \mathrm{S}|(\mathrm{S}|\mathrm{NP})\end{matrix} \quad \dfrac{\dfrac{\begin{matrix}\lambda\sigma.\sigma(\mathsf{someone});\\ \exists_{\mathbf{person}};\\ \mathrm{S}|(\mathrm{S}|\mathrm{NP})\end{matrix} \quad \dfrac{\dfrac{\dfrac{\begin{bmatrix}\varphi_2;\\ y;\mathrm{NP}\end{bmatrix}^2 \quad \dfrac{\begin{matrix}\mathsf{talked}\circ\mathsf{to};\\ \textbf{talk-to};\\ (\mathrm{NP}\backslash\mathrm{S})/\mathrm{NP}\end{matrix} \quad \begin{bmatrix}\varphi_1;\\ x;\mathrm{NP}\end{bmatrix}^1}{\begin{matrix}\mathsf{talked}\circ\mathsf{to}\circ\varphi_1;\\ \textbf{talk-to}(x);\mathrm{NP}\backslash\mathrm{S}\end{matrix}}/\mathrm{E}}{\begin{matrix}\varphi_2\circ\mathsf{talked}\circ\mathsf{to}\circ\varphi_1;\\ \textbf{talk-to}(x)(y);\mathrm{S}\end{matrix}}\backslash\mathrm{E} \quad \begin{matrix}\mathsf{yesterday};\\ \textbf{yest};\mathrm{S}\backslash\mathrm{S}\end{matrix}}{\begin{matrix}\varphi_2\circ\mathsf{talked}\circ\mathsf{to}\circ\varphi_1\circ\mathsf{yesterday};\\ \textbf{yest}(\textbf{talk-to}(x)(y));\mathrm{S}\end{matrix}}\backslash\mathrm{E}}{\begin{matrix}\lambda\varphi_2.\varphi_2\circ\mathsf{talked}\circ\mathsf{to}\circ\varphi_1\circ\mathsf{yesterday};\\ \lambda y.\textbf{yest}(\textbf{talk-to}(x)(y));\mathrm{S}|\mathrm{NP}\end{matrix}}|\mathrm{I}^2}{\begin{matrix}\mathsf{someone}\circ\mathsf{talked}\circ\mathsf{to}\circ\varphi_1\circ\mathsf{yesterday};\\ \exists_{\mathbf{person}}(\lambda y.\textbf{yest}(\textbf{talk-to}(x)(y)));\mathrm{S}\end{matrix}}|\mathrm{E}}{\begin{matrix}\lambda\varphi_1.\mathsf{someone}\circ\mathsf{talked}\circ\mathsf{to}\circ\varphi_1\circ\mathsf{yesterday};\\ \lambda x.\exists_{\mathbf{person}}(\lambda y.\textbf{yest}(\textbf{talk-to}(x)(y)));\mathrm{S}|\mathrm{NP}\end{matrix}}|\mathrm{I}^1}{\begin{matrix}\mathsf{someone}\circ\mathsf{talked}\circ\mathsf{to}\circ\mathsf{everyone}\circ\mathsf{yesterday};\\ \forall_{\mathbf{person}}(\lambda x.\exists_{\mathbf{person}}(\lambda y.\textbf{yest}(\textbf{talk-to}(x)(y))));\mathrm{S}\end{matrix}}|\mathrm{E}$$

As we have seen above, the use of the non-directional mode of implication enables a perspicuous treatment of scope, which essentially involves hypothetical reasoning

[4]Independent motivation for this technique comes from an analysis of extraction (see section 4.2 below) and Gapping (Kubota & Levine 2012).

for which the information of word order is in principle irrelevant. However, in a system with the non-directional mode of implication alone (such as Oehrle's (1994) original term-labelled calculus as well as Lambda Grammar (Muskens 2003), Abstract Categorial Grammar (de Groote 2001) and Linear Grammar (Pollard 2011)), coordination turns out to pose a significant challenge. This point was already noted by Muskens (2001) (see also Kubota (2010:section 3.2.1) for a more extended discussion on this point), but no satisfactory solution has been proposed for this problem in the literature until the present. The problem essentially comes from the fact that such frameworks recognize linguistic expressions with functional phonologies, and semantically functional expressions such as verbs come with functional phonologies which specify the way in which the phonologies of the arguments are combined with the phonology provided by the verb. However, the standard analysis of coordination in CG rests on the assumption that the phonologies of all linguistic expressions are simply strings (and not functions over strings). Thus, even the simplest cases of coordination involving lexical verbs such as *John saw and kissed Mary* turns out to be extremely problematic for such approaches. To analyze the coordination of expressions with functional phonologies (with different arity), we need to posit a series of prosodically distinct entries of *and* (and *or*). Working this out technically is by no means a trivial issue, but the more serious problem is that non-directional variants of CG do not distinguish between left-looking from right-looking functors. Thus, with an entry for *and* which coordinates type $str \to str$ conjuncts (which is needed for the analysis of Right-Node Raising examples like *John saw, and Bill hit, Peter*), an S|NP expression *John saw* __ will be able to be coordinated with an expression __ *hit Peter* of the same type, resulting in quite serious overgeneration.

Since an analysis of (non-standard) coordination is central to our account of the interaction between coordination and scope, rather than attempting to solve this recalcitrant theoretical problem within a non-directional variant of CG, we propose to extend such a system by recognizing both the directional and non-directional modes of implication within a single calculus, incorporating the insights of the Lambek-inspired tradition of TLCG. Since our calculus recognizes the Introduction and Elimination rules for forward and backward slashes from standard TLCG, the analysis of NCC in it straightforwardly carries over to the present setup, which we illustrate below.

With the Introduction and Elimination rules for directional slashes, the analysis of nonconstituent coordination originally due to Dowty's (1988) and Steedman's (1985) CCG analyses and later incorporated in TLCG by Morrill (1994) carries over to the present setup straightforwardly. The idea behind this analysis is essentially that, in the setup of TLCG, hypothetical reasoning with forward and backward slashes enables us to reanalyze any substring of a sentence as a full-fledged 'constituent' (with an appropriate, higher-order semantic interpretation) that has the right combinatorial property such that it returns a sentence when it combines with the rest of the sentence. The derivation in (22) shows how the string *Bill the book* in (21) is reanalyzed as such a non-standard constituent.

(21) Mary gave [Bill the book] and [John the record].

(22)

$$\dfrac{\dfrac{\dfrac{[\varphi; f; \mathrm{VP/NP/NP}\,]^1 \quad \mathsf{bill}; \mathbf{b}; \mathrm{NP}}{\varphi \circ \mathsf{bill}; f(\mathbf{b}); \mathrm{VP/NP}}\,/\mathrm{E} \qquad \mathsf{the} \circ \mathsf{book}; \mathbf{the\text{-}book}; \mathrm{NP}}{\varphi \circ \mathsf{bill} \circ \mathsf{the} \circ \mathsf{book}; f(\mathbf{b})(\mathbf{the\text{-}book}); \mathrm{VP}}\,/\mathrm{E}}{\mathsf{bill} \circ \mathsf{the} \circ \mathsf{book}; \lambda f.f(\mathbf{b})(\mathbf{the\text{-}book}); (\mathrm{VP/NP/NP})\backslash\mathrm{VP}}\,\backslash\mathrm{I}^1$$

The key step in the above derivation is the hypothetical assumption of a ditransitive verb. This hypothetical verb combines with the two object NPs *Bill* and *the book* just like ordinary ditransitive verbs and forms a VP. Then, the hypothesis is withdrawn to assign the category $(\mathrm{VP/NP/NP})\backslash\mathrm{VP}$ to the string *Bill the book*. Intuitively, this is saying that this string is something that becomes a VP if it finds a ditransitive verb to its left. Once this complex category is assigned to the string *Bill the book*, the rest just involves coordinating this non-standard constituent with another constituent with the same syntactic category via the standard generalized conjunction category for the coordinator *and* (where $\sqcap$ denotes generalized conjunction *a la* Partee & Rooth (1983)), and then putting the whole coordinated expression together with the verb and the subject NP as in (23).

(23)

$$\dfrac{\begin{matrix}\mathsf{mary};\\ \mathbf{m}; \mathrm{NP}\end{matrix} \quad \dfrac{\begin{matrix}\mathsf{gave};\\ \mathbf{give};\\ \mathrm{VP/NP/NP}\end{matrix} \quad \dfrac{\begin{matrix}\mathsf{bill} \circ \mathsf{the} \circ \mathsf{book};\\ \lambda f.f(\mathbf{b})(\mathbf{the\text{-}book});\\ (\mathrm{VP/NP/NP})\backslash\mathrm{VP}\end{matrix} \quad \dfrac{\begin{matrix}\mathsf{and};\\ \lambda V \lambda W.W \sqcap V;\\ (X\backslash X)/X\end{matrix} \quad \begin{matrix}\mathsf{john} \circ \mathsf{the} \circ \mathsf{record};\\ \lambda f.f(\mathbf{j})(\mathbf{the\text{-}record});\\ (\mathrm{VP/NP/NP})\backslash\mathrm{VP}\end{matrix}}{\begin{matrix}\mathsf{and} \circ \mathsf{john} \circ \mathsf{the} \circ \mathsf{record};\\ \lambda W.W \sqcap \lambda f.f(\mathbf{j})(\mathbf{the\text{-}record});\\ ((\mathrm{VP/NP/NP})\backslash\mathrm{VP})\backslash((\mathrm{VP/NP/NP})\backslash\mathrm{VP})\end{matrix}}\,/\mathrm{E}}{\begin{matrix}\mathsf{bill} \circ \mathsf{the} \circ \mathsf{book} \circ \mathsf{and} \circ \mathsf{john} \circ \mathsf{the} \circ \mathsf{record};\\ \lambda f.f(\mathbf{b})(\mathbf{the\text{-}book}) \sqcap \lambda f.f(\mathbf{j})(\mathbf{the\text{-}record});\\ (\mathrm{VP/NP/NP})\backslash\mathrm{VP}\end{matrix}}\,\backslash\mathrm{E}}{\begin{matrix}\mathsf{gave} \circ \mathsf{bill} \circ \mathsf{the} \circ \mathsf{book} \circ \mathsf{and} \circ \mathsf{john} \circ \mathsf{the} \circ \mathsf{record};\\ \mathbf{give}(\mathbf{b})(\mathbf{the\text{-}book}) \sqcap \mathbf{give}(\mathbf{j})(\mathbf{the\text{-}record}); \mathrm{VP}\end{matrix}}\,\backslash\mathrm{E}}{\begin{matrix}\mathsf{mary} \circ \mathsf{gave} \circ \mathsf{bill} \circ \mathsf{the} \circ \mathsf{book} \circ \mathsf{and} \circ \mathsf{john} \circ \mathsf{the} \circ \mathsf{record};\\ \mathbf{give}(\mathbf{b})(\mathbf{the\text{-}book})(\mathbf{m}) \wedge \mathbf{give}(\mathbf{j})(\mathbf{the\text{-}record})(\mathbf{m}); \mathrm{S}\end{matrix}}\,\backslash\mathrm{E}$$

Thus, positing both directional and non-directional modes of implication within a single calculus enables straightforward analyses of two kinds of major empirical phenomena (i.e. coordination and scopal expressions) that pose problems for previous variants of CG, which recognizes only one of these two types of implication. But the real strength of the hybrid implication architecture of the present framework becomes fully apparent in the analyses of phenomena like those discussed in section 2 in which coordination interacts with scopal expressions. These phenomena call for a system in which the mechanisms dealing with word order-related inferences (for coordination) and those dealing with order-insensitive reasoning (for scope) interact with one another systematically. The present framework provides precisely such an architecture, and we will see in the next section that the proper analysis of these more complex cases in fact falls out straightforwardly from the hybrid architecture of the present framework.

4 Coordination in Hybrid Type-Logical Categorial Grammar

4.1 NCC and symmetrical predicates

For the analysis of symmetrical predicates, we adopt the proposal by Barker (2007) in terms of *parasitic scope*. Pollard (2009) (described in Pollard & Smith (to appear)) implements this analysis in a term-labelling system with phonological λ-abstraction like Oehrle's (1994) setup. We adopt this implementation in our account of the interaction between NCC and symmetrical predicates. Barker's analysis of symmetrical predicates involves the following three elements as the key components in the semantic analysis of symmetrical predicates such as *(the) same*:[5]

(i) a property provided by the 'head noun' modified by the symmetrical predicate

(ii) a sum-denoting expression

(iii) a relation provided by the rest of the sentence (i.e. a structure obtained by abstracting over the NP containing the symmetrical predicate and the sum-denoting expression from the whole sentence)

For an example like (24), (i)–(iii) above are instantiated by the noun *waiter*, the coordinated NP *John and Bill*, and the transitive verb *served*, respectively.

(24) The same waiter served John and Bill.

The semantic contribution of *(the) same* on the internal reading is to assert the existence of some unique waiter (i.e. an individual satisfying the property (i)) such that the x-served-y relation (i.e. the relation provided by (iii)) holds between that individual and each atomic subpart of the plurality of John and Bill (i.e. the sum denoted by (ii)). Technically, the denotation of the symmetrical predicate *the same* is formulated as in (25), as a relation between its three semantic arguments (i)–(iii):

[5]We adopt this three-place function analysis of *same* due to Barker (2007) here for expository purposes. Note, however, that this analysis does not easily generalize to cases involving multiple occurrences of *same* invoking the internal reading with respect to the same plural entity at the same time, as exemplified by the following example:

(i) John and Bill bought the same book at the same store (on the same day . . .).

In Kubota & Levine (2013), we provide a more complete analysis of symmetrical predicates which can deal with iterated *same* examples like (i). This latter analysis is superior to the one we adopt here also in that it extends straightforwardly to related expressions such as 'respective' and summative predicates observed above in (5) and (6), and captures the complex (yet systematic) interactions between these three classes of phenomena in a uniform manner.

(25) $\lambda P \lambda Q \lambda X. \exists y[P(y) \wedge \forall x. x <_a X \rightarrow Q(y)(x)]$

Syntactically, the key steps of the derivation involves forming constituents that respectively provide the three semantic arguments to the symmetrical predicate and combining them in the right order. Specifically, the relation-denoting expression can be obtained by abstracting over the positions corresponding to the NP containing *same* and the sum-denoting expression via successive applications of the Vertical Slash introduction rule (cf. the steps down to the fifth line of the rightmost chunk in (26)). This creates a doubly abstracted proposition of syntactic category $(\mathrm{S}|\mathrm{NP})|\mathrm{NP}$ and this doubly abstracted proposition is then given as an argument to the expression *the same*, together with the other two arguments. Crucially, the phonology of the symmetrical predicate is specified as a higher-order functional phonological term which, if it takes the three arguments it semantically requires in the right order, produces the string of words corresponding to the surface form of the sentence.

(26)

$$\dfrac{\dfrac{\vdots \quad \vdots}{\mathsf{john} \circ \mathsf{and} \circ \mathsf{bill};\ \mathbf{j} \oplus \mathbf{b}; \mathrm{NP}} \qquad \dfrac{\dfrac{\lambda\psi\lambda\sigma.\sigma(\mathsf{the} \circ \mathsf{same} \circ \psi);\ \mathbf{same}; ((\mathrm{S}|X)|((\mathrm{S}|X)|\mathrm{NP}))|\mathrm{N} \quad \mathsf{waiter}; \mathbf{waiter}; \mathrm{N}}{\lambda\sigma.\sigma(\mathsf{the} \circ \mathsf{same} \circ \mathsf{waiter});\ \mathbf{same}(\mathbf{waiter}); (\mathrm{S}|X)|((\mathrm{S}|X)|\mathrm{NP})}|\mathrm{E} \quad \dfrac{\dfrac{\dfrac{\begin{bmatrix}\psi; \\ y; \mathrm{NP}\end{bmatrix}^2 \quad \dfrac{\mathsf{served}; \mathbf{serve}; \mathrm{VP}/\mathrm{NP} \quad \begin{bmatrix}\varphi; \\ x; \mathrm{NP}\end{bmatrix}^1}{\mathsf{served} \circ \varphi;\ \mathbf{serve}(x); \mathrm{VP}}/\mathrm{E}}{\psi \circ \mathsf{served} \circ \varphi;\ \mathbf{serve}(x)(y); \mathrm{S}}\backslash\mathrm{E}}{\lambda\varphi.\psi \circ \mathsf{served} \circ \varphi;\ \lambda x.\mathbf{serve}(x)(y); \mathrm{S}|\mathrm{NP}}|\mathrm{I}^1}{\lambda\psi\lambda\varphi.\psi \circ \mathsf{served} \circ \varphi;\ \lambda x.\mathbf{serve}(x)(y); \mathrm{S}|\mathrm{NP}|\mathrm{NP}}|\mathrm{I}^2}{\lambda\varphi.\mathsf{the} \circ \mathsf{same} \circ \mathsf{waiter} \circ \mathsf{served} \circ \varphi;\ \mathbf{same}(\mathbf{waiter})(\lambda y \lambda x.\mathbf{serve}(x)(y)); \mathrm{S}|\mathrm{NP}}|\mathrm{E}}{\mathsf{the} \circ \mathsf{same} \circ \mathsf{waiter} \circ \mathsf{served} \circ \mathsf{john} \circ \mathsf{and} \circ \mathsf{bill};\ \mathbf{same}(\mathbf{waiter})(\lambda y \lambda x.\mathbf{serve}(x)(y))(\mathbf{j} \oplus \mathbf{b}); \mathrm{S}}|\mathrm{E}$$

(In the above derivation, the variables abstracted over happen to correspond to subject and object arguments of the transitive verb, and thus these two abstraction steps might appear to be (semantically) superfluous. However, as will become clear in more complicated derivations below, this is not generally the case, and we need the two abstraction steps for the vertical slash in order to provide a general treatment of symmetrical predicates.) By unpacking the final translation for the sentence derived in (26), we get the following truth conditions:

(27) $\mathbf{same}(\mathbf{waiter})(\lambda y \lambda x.\mathbf{serve}(x)(y))(\mathbf{j} \oplus \mathbf{b}) = \exists y[\mathbf{waiter}(y) \wedge \forall x. x <_a \mathbf{j} \oplus \mathbf{b} \rightarrow \mathbf{serve}(x)(y)]$

This says that there is a waiter such that for both of John and Bill, it is the case that that waiter served him. In other words, there is a unique waiter who served both John and Bill. This correctly captures the meaning of the sentence on the relevant reading.

This analysis of symmetrical predicates by Barker implemented in a system with phonological lambda abstraction interacts straightforwardly with the direct licensing analysis of NCC from directional CG to assign the right interpretations for sentences like (28).

(28) Terry said the same thing to Robin on Thursday and to Leslie on Friday.

The crucial assumption that enables a straightforward extension of the analysis of symmetrical predicates for the simpler case involving coordination of simple NPs (denoting sums of type e objects) above to more complex cases like (28) is that in the lexical entry for *the same* in (27), the type of the sum-denoting expression (and, correspondingly, of the relation that takes subparts of that sum as one of its arguments) is polymorphic. Specifically, in the case of (28), the sum involved is a sum of higher-order semantic objects of type $e \to (e \to e \to e \to t) \to e \to t$. Other than this slight complication in the semantic type, the function of the symmetrical predicate *the same* is the same as in the previous case: it asserts that an identical relation holds between each subpart of this sum and some unique entity satisfying the descriptive content provided by the nominal head that the symmetrical predicate combines with. Thus, the analysis is essentially parallel to the simpler case involving coordination of ordinary NPs in (24). The derivation for (28) is given in (29).

(29)

$$
\dfrac{\dfrac{\dfrac{\begin{array}{l}\mathsf{terry};\\ \mathbf{t};\mathrm{NP}\end{array} \quad \dfrac{\begin{array}{l}\mathsf{said};\\ \mathbf{say};\mathrm{VP/PP/NP}\end{array} \quad \dfrac{[\varphi_1; x; \mathrm{NP}]^1 \quad [\varphi_2; f; \mathrm{NP}\backslash(\mathrm{VP/PP/NP})\backslash\mathrm{VP}]^2}{\varphi_1 \circ \varphi_2; f(x); (\mathrm{VP/PP/NP})\backslash\mathrm{VP}}\backslash\mathrm{E}}{\mathsf{said} \circ \varphi_1 \circ \varphi_2; f(x)(\mathbf{say}); \mathrm{VP}}\backslash\mathrm{E}}{\mathsf{terry} \circ \mathsf{said} \circ \varphi_1 \circ \varphi_2; f(x)(\mathbf{say})(\mathbf{t}); \mathrm{S}}\backslash\mathrm{E}}{\lambda\varphi_2.\mathsf{terry} \circ \mathsf{said} \circ \varphi_1 \circ \varphi_2; \lambda x.f(x)(\mathbf{say})(\mathbf{t}); \mathrm{S}|(\mathrm{NP}\backslash(\mathrm{VP/PP/NP})\backslash\mathrm{VP})}|\mathrm{I}^1}{\lambda\varphi_2\lambda\varphi_1.\mathsf{terry} \circ \mathsf{said} \circ \varphi_1 \circ \varphi_2; \lambda x\lambda f.f(x)(\mathbf{say})(\mathbf{t}); \mathrm{S}|(\mathrm{NP}\backslash(\mathrm{VP/PP/NP})\backslash\mathrm{VP})|\mathrm{NP}}|\mathrm{I}^2
$$

$$
\dfrac{\begin{array}{l}\vdots \quad \vdots\\ \mathsf{to} \circ \mathsf{robin} \circ \mathsf{on} \circ \mathsf{thursday};\\ \lambda x\lambda P.\mathbf{onTh}(P(x)(\mathbf{r}));\\ \mathrm{NP}\backslash(\mathrm{VP/PP/NP})\backslash\mathrm{VP}\end{array} \quad \dfrac{\begin{array}{l}\mathsf{and};\\ \lambda X\lambda Y.X \oplus Y;\\ (X\backslash X)/X\end{array} \quad \begin{array}{l}\vdots \quad \vdots\\ \mathsf{to} \circ \mathsf{leslie} \circ \mathsf{on} \circ \mathsf{friday};\\ \lambda x\lambda P.\mathbf{onFr}(P(x)(\mathbf{l}));\\ \mathrm{NP}\backslash(\mathrm{VP/PP/NP})\backslash\mathrm{VP}\end{array}}{\begin{array}{l}\mathsf{and} \circ \mathsf{to} \circ \mathsf{robin} \circ \mathsf{on} \circ \mathsf{thursday};\\ \lambda X.X \oplus [\lambda x\lambda P.\mathbf{onFr}(P(x)(\mathbf{l}))];\\ (\mathrm{NP}\backslash(\mathrm{VP/PP/NP})\backslash\mathrm{VP})\backslash(\mathrm{NP}\backslash(\mathrm{VP/PP/NP})\backslash\mathrm{VP})\end{array}}/\mathrm{E}}{\begin{array}{l}\mathsf{to} \circ \mathsf{robin} \circ \mathsf{on} \circ \mathsf{thursday} \circ \mathsf{and} \circ \mathsf{to} \circ \mathsf{leslie} \circ \mathsf{on} \circ \mathsf{friday};\\ \lambda x\lambda P\mathbf{onFr}(P(x)(\mathbf{l})) \oplus \lambda x\lambda P.\mathbf{onTh}(P(x)(\mathbf{r})); \mathrm{NP}\backslash(\mathrm{VP/PP/NP})\backslash\mathrm{VP}\end{array}}\backslash\mathrm{E}
$$

$$\dfrac{\begin{array}{l}\vdots\quad\vdots\\ \textsf{to} \circ \textsf{robin} \circ \textsf{on} \circ \textsf{thursday} \circ \\ \textsf{and} \circ \textsf{to} \circ \textsf{leslie} \circ \textsf{on} \circ \textsf{friday};\\ [\lambda x \lambda P \lambda z.\textbf{onFr}(P(x)(\textbf{l}))(z)]\\ \oplus[\lambda x \lambda P \lambda z.\textbf{onTh}(P(x)(\textbf{r}))(z)];\\ \mathrm{NP}\backslash(\mathrm{VP/PP/NP})\backslash\mathrm{VP}\end{array} \quad \dfrac{\begin{array}{l}\lambda\sigma.\sigma(\textsf{the} \circ \\ \textsf{same} \circ \textsf{thing});\\ \textbf{same}(\textbf{thing});\\ (\mathrm{S|X})|(\mathrm{S|X|NP})\end{array} \quad \begin{array}{l}\vdots\quad\vdots\\ \lambda\varphi_1\lambda\varphi_2.\textsf{terry} \circ \textsf{said} \circ \varphi_1 \circ \varphi_2;\\ \lambda x \lambda f.f(x)(\textbf{say})(\textbf{t});\\ \mathrm{S|(NP\backslash(VP/PP/NP)\backslash VP)|NP}\end{array}}{\begin{array}{l}\lambda\varphi_2.\textsf{terry} \circ \textsf{said} \circ \textsf{the} \circ \textsf{same} \circ \textsf{thing} \circ \varphi_2;\\ \textbf{same}(\textbf{thing})(\lambda x \lambda f.f(x)(\textbf{say})(\textbf{t}));\\ \mathrm{S|(NP\backslash(VP/PP/NP)\backslash VP)}\end{array}}{|\mathrm{E}}}{\begin{array}{l}\textsf{terry} \circ \textsf{said} \circ \textsf{the} \circ \textsf{same} \circ \textsf{thing} \circ \\ \textsf{to} \circ \textsf{robin} \circ \textsf{on} \circ \textsf{thursday} \circ \textsf{and} \circ \textsf{to} \circ \textsf{leslie} \circ \textsf{on} \circ \textsf{friday};\\ \textbf{same}(\textbf{thing})(\lambda x \lambda f.f(x)(\textbf{say})(\textbf{t}))([\lambda x \lambda P \lambda z.\textbf{onFr}(P(x)(\textbf{l}))(z)]\\ \oplus[\lambda x \lambda P \lambda z.\textbf{onTh}(P(x)(\textbf{r}))(z)]); \mathrm{S}\end{array}}{|\mathrm{E}}$$

What is crucial in this derivation is the part that derives the NCC involving the strings *to Robin on Thursday* and *to Leslie on Friday*. These strings are analyzed as (nonstandard) constituents via hypothetical reasoning in the same way as other examples above. They are then coordinated with the generalized sum meaning of *and* to form a (generalized) sum of type $e \to (e \to e \to e \to t) \to e \to t$ objects. The rest of the derivation involves creating a doubly-abstracted proposition by abstracting over the positions corresponding to the NP containing *same* and the (higher-order) sum-denoting expression and giving this proposition as an argument to the symmetrical predicate together with its other two arguments, namely, the (higher-order) sum derived above and the noun that provides the descriptive content for the unique entity involved. The translation for the whole sentence is unpacked and simplified in (30):

(30) $\textbf{same}(\textbf{thing})(\lambda x \lambda f.f(x)(\textbf{say})(\textbf{t}))([\lambda x \lambda P \lambda z.\textbf{onFr}(P(x)(\textbf{l}))(z)] \oplus [\lambda x \lambda P \lambda z.\textbf{onTh}(P(x)(\textbf{r}))(z)])$

$= \exists y[\textbf{thing}(y) \wedge \forall R.R <_a [\lambda x LPLz.\textbf{onFr}(P(x)(\textbf{l}))(z)]$
$\quad \oplus[\lambda x LP\lambda z.\textbf{onTh}(P(x)(\textbf{r}))(z)] \to R(y)(\textbf{say})(\textbf{t})]$

$= \exists y[\textbf{thing}(y) \wedge \lambda x \lambda P \lambda z.[\textbf{onFr}(P(x)(\textbf{l}))(z)](y)(\textbf{say})(\textbf{t}) \wedge$
$\quad \lambda x \lambda P \lambda z.[\textbf{onTh}(P(x)(\textbf{r}))(z)](y)(\textbf{say})(\textbf{t})]$

$= \exists y[\textbf{thing}(y) \wedge \textbf{onFr}(\textbf{say}(y)(\textbf{l}))(\textbf{t}) \wedge \textbf{onTh}(\textbf{say}(y)(\textbf{r}))(\textbf{t})]$

This asserts the existence of some unique entity which was said by Terry both to Robin on Thursday and to Leslie on Friday. This correctly corresponds to the internal reading of the sentence where the matters communicated to the two people by Robin on different days are identical to each other.

4.2 UCC and extraction

The interaction between UCC and extraction also receives a straightforward solution in our approach. For the analysis of UCC, we adopt the proposal by Morrill (1994) and Bayer (1996) that involves extending the syntactic type system with the $\vee$ (join) connective. $\vee$ is a two place connective and the complex syntactic category $A \vee B$ intuitively means that the linguistic expression that is assigned this category belongs to either category A or B. For the join connective, we posit the following two Introduction rules in our system:

(31) a. *Right Join Introduction*

$$\frac{\mathsf{a}; \boldsymbol{f}; A}{\mathsf{a}; \boldsymbol{f}; A \vee B}\vee\mathrm{I}$$

b. *Left Join Introduction*

$$\frac{\mathsf{a}; \boldsymbol{f}; B}{\mathsf{a}; \boldsymbol{f}; A \vee B}\vee\mathrm{I}$$

Intuitively, these rules say that if something is an A (or a B), then we are entitled to conclude a weaker statement that it is $A \vee B$ (i.e. A or B).

The key assumption in the Morrill/Bayer analysis of UCC is the specification of the copula given in (32):

(32) $\mathsf{is}; \lambda f.f; \mathrm{VP}/(\mathrm{NP}\vee\mathrm{AP})$

This says that *is* is looking for either an NP or an AP as its complement to become a VP. With the $\vee$-Introduction rule in (31), the derivation for a sentence in which the copula combines with an NP complement (without UCC) goes as follows:

(33)

$$\dfrac{\mathsf{pat}; \mathrm{NP} \quad \dfrac{\mathsf{is}; \mathrm{VP}/(\mathrm{NP}\vee\mathrm{AP}) \quad \dfrac{\mathsf{a} \circ \mathsf{republican}; \mathrm{NP}}{\mathsf{a} \circ \mathsf{republican}; \mathrm{NP}\vee\mathrm{AP}}\vee\mathrm{I}}{\mathsf{is} \circ \mathsf{a} \circ \mathsf{republican}; \mathrm{VP}}/\mathrm{E}}{\mathsf{pat} \circ \mathsf{is} \circ \mathsf{a} \circ \mathsf{republican}; \mathrm{S}}\backslash\mathrm{E}$$

The key point here is that, with $\vee$-Introduction, we can assign the category $\mathrm{NP}\vee\mathrm{AP}$ to the string *a Republican* and this satisfies the subcategorization requirement of the copula.

From this, it should already be clear how examples of UCC like *Pat is a Republican and proud of it* are derived. The derivation is given in (34).

(34)

$$\dfrac{\mathsf{pat}; \mathrm{NP} \quad \dfrac{\mathsf{is}; \mathrm{VP}/(\mathrm{NP}\vee\mathrm{AP}) \quad \dfrac{\dfrac{\mathsf{a} \circ \mathsf{republican}; \mathrm{NP}}{\mathsf{a} \circ \mathsf{republican}; \mathrm{NP}\vee\mathrm{AP}}\vee\mathrm{I} \quad \dfrac{\mathsf{and}; (X\backslash X)/X \quad \dfrac{\mathsf{proud} \circ \mathsf{of} \circ \mathsf{it}; \mathrm{AP}}{\mathsf{proud} \circ \mathsf{of} \circ \mathsf{it}; \mathrm{NP}\vee\mathrm{AP}}\vee\mathrm{I}}{\mathsf{and} \circ \mathsf{proud} \circ \mathsf{of} \circ \mathsf{it}; (\mathrm{NP}\vee\mathrm{AP})\backslash(\mathrm{NP}\vee\mathrm{AP})}/\mathrm{E}}{\mathsf{a} \circ \mathsf{republican} \circ \mathsf{and} \circ \mathsf{proud} \circ \mathsf{of} \circ \mathsf{it}; \mathrm{NP}\vee\mathrm{AP}}\backslash\mathrm{E}}{\mathsf{is} \circ \mathsf{a} \circ \mathsf{republican} \circ \mathsf{and} \circ \mathsf{proud} \circ \mathsf{of} \circ \mathsf{it}; \mathrm{VP}}/\mathrm{E}}{\mathsf{pat} \circ \mathsf{is} \circ \mathsf{a} \circ \mathsf{republican} \circ \mathsf{and} \circ \mathsf{proud} \circ \mathsf{of} \circ \mathsf{it}; \mathrm{S}}\backslash\mathrm{E}$$

Here, both of the two conjuncts (i.e. the NP *a Republican* and the AP *proud of it*) are derived as NP$\vee$AP via $\vee$-Introduction. Then, with the standard generalized conjunction category for *and*, they are coordinated to form a larger constituent of category NP$\vee$AP. Since this category exactly matches the category that the copula is looking for as its argument, this UCC constituent can be directly combined with the copula via Slash Elimination to complete the derivation. Unlike the ellipsis-based approach of the kind advocated in the LBE literature, the Morrill/Bayer analysis of UCC in CG treats strings like *a Republican and proud of it* as full-fledged surface constituents without any deletion operation or dummy syntactic head of any kind. As will become clear below, this turns out to be crucial in the analysis of the interactions between UCC and extraction.

For the analysis of extraction, we adopt the proposal by Muskens (2003) that exploits the order-insensitive nature of the non-directional mode of implication (i.e. our vertical slash). In the TLCG literature, the treatment of extraction has long been known as a problematic issue. Essentially, the problem is that modelling extraction by means of forward and backward slashes makes it difficult treat cases of extraction from non-peripheral positions. This is because Slash Introduction can apply for the forward and backward slashes only when (the phonology of) the hypothesis appears at a peripheral position. (An analogous problem is found with CCG, which deals with non-peripheral extraction via order-disrupting, non-harmonic function composition rules.) Various mechanisms have been proposed in the TLCG literature to overcome this problem, but they all involve significant complications in the mapping between syntax and surface morpho-phonology. Muskens's proposal is unique in that it solves this problem by directly representing the phonology of gapped sentences via a higher-order functional phonological term, using a mechanism independently needed in the grammar, namely, λ-binding in phonology. This simplifies the treatment of filler-gap dependency in the CG-based setup considerably.

The core idea of Muskens's (2003) approach to extraction involves analyzing (incomplete) sentences with gaps like *Kim likes* in the topicalization sentence in (35) as a sentence missing some expression somewhere inside, with hypothetical reasoning for the vertical slash, as in the derivation in (36).

(35) Bagels$_i$, Kim likes t_i

(36)

$$\dfrac{\begin{matrix}\textsf{bagels};\\ \mathbf{b}; \mathrm{NP}\end{matrix} \quad \dfrac{\begin{matrix}\lambda\sigma\lambda\varphi.\varphi \circ \sigma(\boldsymbol{\epsilon});\\ \lambda f.f; (\mathrm{S}|\mathrm{X})|(\mathrm{S}|\mathrm{X})\end{matrix} \quad \dfrac{\dfrac{\begin{matrix}\textsf{kim};\\ \mathbf{k}; \mathrm{NP}\end{matrix} \quad \dfrac{\begin{matrix}\textsf{likes};\\ \mathbf{like}; (\mathrm{NP}\backslash\mathrm{S})/\mathrm{NP}\end{matrix} \quad \begin{bmatrix}\varphi;\\ x; \mathrm{NP}\end{bmatrix}^1}{\textsf{likes} \circ \varphi; \mathbf{like}(x); \mathrm{NP}\backslash\mathrm{S}}/\mathrm{E}}{\textsf{kim} \circ \textsf{likes} \circ \varphi; \mathbf{like}(x)(\mathbf{k}); \mathrm{S}}\backslash\mathrm{E}}{\lambda\varphi.\textsf{kim} \circ \textsf{likes} \circ \varphi; \lambda x.\mathbf{like}(x)(\mathbf{k}); \mathrm{S}|\mathrm{NP}}|\mathrm{I}^1}{\lambda\varphi.\varphi \circ \textsf{kim} \circ \textsf{likes}; \lambda x.\mathbf{like}(x)(\mathbf{k}); \mathrm{S}|\mathrm{NP}}}{\textsf{bagels} \circ \textsf{kim} \circ \textsf{likes}; \lambda x.\mathbf{like}(\mathbf{b})(\mathbf{k}); \mathrm{S}}|\mathrm{E}$$

In (36), an NP is hypothesized in the object position of the transitive verb, and by withdrawing this hypothesis after the whole sentence is built, the position of the gap in the whole string is explicitly represented by the phonology of the hypothesized NP bound by the λ-operator, namely, the variable φ. (Note also that this gapped sentence is assigned the right meaning, that is, the property of being an object that Kim likes, with lambda abstraction of the variable x over the meaning of the whole sentence.) Since hypothetical reasoning for the vertical slash can be carried out regardless of the position of the variable in the surface string (unlike for the directionality-sensitive, forward and backward slashes), this approach can treat filler-gap dependency in a fully general manner wherever the gap appears within the sentence.

For topicalization, the filler that corresponds to the gap appears in a position immediately to the left of the gapped sentence in the surface string. There is thus a mismatch between the surface form of the sentence and the phonology of the gapped constituent (which takes some string as an argument and embeds it in the original gap site), and this mismatch is mediated by the following phonologically empty topicalization operator:

(37) $\lambda\sigma\lambda\varphi.\varphi \circ \sigma(\epsilon); \lambda f.f; (\mathrm{S}|\mathrm{X})|(\mathrm{S}|\mathrm{X})$

The topicalization operator in (37) does not have any effect on either syntactic category or semantics; it only changes the phonology of the expression it combines with in such a way that, by combining with this topicalization operator, an empty string ϵ is embedded in the original gap site and the host sentence now concatenates the phonology of its argument (i.e. the filler) immediately to the left of its own phonology.

With this analysis of topicalization, sentences like (38) in which a coordinate structure involving UCC gets topicalized can be analyzed as in (39).

(38) [(Both) poor and a Republican]$_i$ you can't possibly be t_i.

(39)

$$\dfrac{\begin{array}{c}\vdots \quad \vdots \\ \textsf{both} \circ \textsf{poor} \circ \textsf{and} \circ \\ \textsf{a} \circ \textsf{republican}; \\ \mathrm{NP}\vee\mathrm{AP}\end{array} \quad \dfrac{\begin{array}{c}\lambda\sigma\lambda\varphi.\varphi \circ \sigma(\epsilon); \\ (\mathrm{S}|\mathrm{X})|(\mathrm{S}|\mathrm{X})\end{array} \quad \dfrac{\dfrac{\begin{array}{c}\textsf{you}; \\ \mathrm{NP}\end{array} \quad \dfrac{\begin{array}{c}\textsf{can't} \circ \textsf{be}; \\ \mathrm{VP}/(\mathrm{NP}\vee\mathrm{AP})\end{array} \quad [\varphi; \mathrm{NP}\vee\mathrm{AP}]^1}{\textsf{can't} \circ \textsf{be} \circ \varphi; \mathrm{VP}}/\mathrm{E}}{\textsf{you} \circ \textsf{can't} \circ \textsf{be} \circ \varphi; \mathrm{S}}\backslash\mathrm{E}}{\lambda\varphi.\textsf{you} \circ \textsf{can't} \circ \textsf{be} \circ \varphi; \mathrm{S}|(\mathrm{NP}\vee\mathrm{AP})}|\mathrm{I}^1}{\lambda\varphi.\varphi \circ \textsf{you} \circ \textsf{can't} \circ \textsf{be}; \mathrm{S}|(\mathrm{NP}\vee\mathrm{AP})}|\mathrm{E}}{\textsf{both} \circ \textsf{poor} \circ \textsf{and} \circ \textsf{a} \circ \textsf{republican} \circ \textsf{you} \circ \textsf{can't} \circ \textsf{be}; \mathrm{S}}|\mathrm{E}$$

The key step in this derivation is the hypothetical assumption of an expression of category $\mathrm{NP}\vee\mathrm{AP}$ in the gap position. Via hypothetical reasoning for the vertical slash, a gapped sentence of category $\mathrm{S}|(\mathrm{NP}\vee\mathrm{AP})$ can then be derived, which is missing an expression of category $\mathrm{NP}\vee\mathrm{AP}$, i.e., the complement of the copula. As already shown in the derivation of a simpler UCC sentence above in (34), the string *both poor and a Republican*, which appears in the filler position in (39), can be assigned the category $\mathrm{NP}\vee\mathrm{AP}$. Thus, the gap and the filler match in syntactic category and the two can be combined by means of the topicalization operator in the same way as the previous NP topicalization example in (36).

The (truth-conditional) meaning of a topicalization sentence is obtained simply by substituting the meaning of the filler in the gap position of the host sentence. Thus, in (39), the correct meaning is assigned to the whole sentence in which a conjunction of the two properties is predicated of the subject under the scope of modal and negation.

The analysis of pseudo-cleft is similarly straightforward. Again, the key assumption is the treatment of the gapped sentence with the vertical slash. The gapped sentence is derived in the category $\mathrm{S}|X$, a sentence missing an *X* somewhere inside. We assign the syntactic category $X|(\mathrm{S}|X)$ to the word *what*, which combines with this gapped sentence and forms the constituent that occupies the precopular position. As illustrated in the following derivation, by assigning this category to *what*, the constituent in the precopular position ends up having the same syntactic category as the gap. Then, with the syntactic category $(X\backslash\mathrm{S})/X$ for the copula, which identifies the categories of its left-hand and right-hand arguments, it follows that the syntactic categories of the gap and the postcopular expression are required to match with one another, capturing the basic syntactic properties of the pseudo-cleft construction. The derivation for the sentence *What Robin wanted was a textbook* is shown in (40):

(40)

$$\dfrac{\dfrac{\lambda\sigma.\mathsf{what}\circ\sigma(\epsilon);\ \mathrm{X}|(\mathrm{S}|\mathrm{X}) \quad \dfrac{\dfrac{\mathsf{robin};\ \mathrm{NP} \quad \dfrac{\mathsf{wanted};\ (\mathrm{NP}\backslash\mathrm{S})/\mathrm{NP} \quad [\varphi;\mathrm{NP}]^1}{\mathsf{wanted}\circ\varphi;\ \mathrm{NP}\backslash\mathrm{S}}/\mathrm{E}}{\mathsf{robin}\circ\mathsf{wanted}\circ\varphi;\ \mathrm{S}}\backslash\mathrm{E}}{\lambda\varphi.\mathsf{robin}\circ\mathsf{wanted}\circ\varphi;\ \mathrm{S}|\mathrm{NP}}|\mathrm{I}^1}{\mathsf{what}\circ\mathsf{robin}\circ\mathsf{wanted};\ \mathrm{NP}}|\mathrm{E} \quad \dfrac{\mathsf{was};\ (\mathrm{X}\backslash\mathrm{S})/\mathrm{X} \quad \mathsf{a}\circ\mathsf{textbook};\ \mathrm{NP}}{\mathsf{was}\circ\mathsf{a}\circ\mathsf{textbook};\ \mathrm{NP}\backslash\mathrm{S}}/\mathrm{E}}{\mathsf{what}\circ\mathsf{robin}\circ\mathsf{wanted}\circ\mathsf{was}\circ\mathsf{a}\circ\mathsf{textbook};\ \mathrm{S}}|\mathrm{E}$$

As in the analysis of topicalization, the interaction between pseudocleft and UCC is straightforward. By assuming an expression of the complex syntactic category $\mathrm{NP}\vee\mathrm{AP}$ in the gap position, the precopular constituent headed by *what* is derived in the same category as the gap, namely, $\mathrm{NP}\vee\mathrm{AP}$. And then, with the polymorphic syntactic category for the copula, the syntactic category of the precopular and postcopular expressions (which is a UCC of category $\mathrm{NP}\vee\mathrm{AP}$) are identified with each other to complete the derivation. Again, with the assumption that the UCC category denotes a conjunction of two properties, the right semantics is assigned for (11a), where the conjunction of two properties scopes below the negation and the modal.

(41)

$$\dfrac{\dfrac{\lambda\sigma.\mathsf{what}\circ\sigma(\epsilon);\ \mathrm{X}|(\mathrm{S}|\mathrm{X}) \quad \dfrac{\dfrac{\mathsf{you};\ \mathrm{NP} \quad \dfrac{\mathsf{can't}\circ\mathsf{be};\ \mathrm{VP}/(\mathrm{NP}\vee\mathrm{AP}) \quad [\varphi;\mathrm{NP}\vee\mathrm{AP}]^1}{\mathsf{can't}\circ\mathsf{be}\circ\varphi;\ \mathrm{VP}}/\mathrm{E}}{\mathsf{you}\circ\mathsf{can't}\circ\mathsf{be}\circ\varphi;\ \mathrm{S}}\backslash\mathrm{E}}{\lambda\varphi.\mathsf{you}\circ\mathsf{can't}\circ\mathsf{be}\circ\varphi;\ \mathrm{S}|(\mathrm{NP}\vee\mathrm{AP})}|\mathrm{I}^1}{\mathsf{what}\circ\mathsf{you}\circ\mathsf{can't}\circ\mathsf{be};\ \mathrm{NP}\vee\mathrm{AP}}|\mathrm{E} \quad \dfrac{\mathsf{is};\ (\mathrm{X}\backslash\mathrm{S})/\mathrm{X} \quad \begin{matrix}\vdots\quad\vdots\\ \mathsf{intelligentoand}\\ \mathsf{aofundamentalist};\ \mathrm{NP}\vee\mathrm{AP}\end{matrix}}{\mathsf{is}\circ\mathsf{intelligent}\circ\mathsf{and}\circ\mathsf{a}\circ\mathsf{fundamentalist};\ (\mathrm{NP}\vee\mathrm{AP})\backslash\mathrm{S}}/\mathrm{E}}{\mathsf{what}\circ\mathsf{youcan't}\circ\mathsf{be}\circ\mathsf{is}\circ\mathsf{intelligent}\circ\mathsf{and}\circ\mathsf{a}\circ\mathsf{fundamentalist};\ \mathrm{S}}|\mathrm{E}$$

The join connective introduced above in the analysis of UCC has as its dual the meet connective. We will show in Appendix A that the use of this meet connective enables an analysis of examples of UCC with different subcategorization frames such as the following, first noted by Crysmann (2003) and taken to exemplify the superiority of an ellipsis-based analysis of coordination over the direct coordination analysis in CG.

(42) John gave Mary a book and to Peter a record.

4.3 Nominal head coordination

Finally, we analyze the apparent agreement mismatch between the determiner and the verb in nominal head coordination in examples like the following:

(43) That man and woman are arguing again.

Note first that the acceptability of this nominal head coordination pattern partly depends on the semantic/pragmatic properties of the conjoined nominals; as shown in the following examples, combinations of nouns that can naturally be thought of as forming pairs (e.g. *man and woman*, *boy and girl*, *table and chair*) can felicitously appear in this construction, whereas random combinations of nouns (e.g. *man and chair*, *table and boy*) that cannot naturally be construed as forming pairs are generally infelicitous in this construction.

(44) a. This $\left\{\begin{array}{c}\text{man and woman}\\ \text{boy and girl}\\ \text{table and chair}\end{array}\right\}$ are in perfect match.

b.??This $\left\{\begin{array}{c}\text{man and chair}\\ \text{table and boy}\end{array}\right\}$ are in perfect match.

We take this to indicate that the coordinated nominals such as *man and woman* in (43) are a special kind of pair-denoting nominals rather than simply an elliptical version of coordination of full-fledged NPs. (That is, if these examples were derived via ellipsis from coordination of full-fledged NPs, the acceptability contrast in (44) would be puzzling.)

The simplest way to capture this special property of nominal head coordination is to assume that the relevant semantic/pragmatic restriction is encoded in the definition of the covert operator that is responsible for converting the original meanings of such coordinated nominals to the appropriate pair-denoting meanings. With the generalized sum meaning for *and*, ‘property sum’ meanings of the following form are freely available for coordinated nominals like *man and woman*:

(45) $[\![\text{man and woman}]\!] = \lambda f \lambda g.[f \oplus g](\mathbf{man})(\mathbf{woman}) = \mathbf{man} \oplus \mathbf{woman}$

We posit a following phonologically empty pair-forming operator in (46) that takes such property sums as arguments and returns a property that holds of a pair of individuals just in case the pair in question each satisfy one of the two properties that are parts of the original property sum. The pair-forming operator additionally imposes a semantic/pragmatic restriction such that the original property sum constitutes a ‘natural pair’ (via the primitive predicate **natural-pair**, which we do not attempt to analyze further here).

(46) $\lambda\varphi.\varphi$; $\lambda P \lambda X.$**resp**$(X)(P) \wedge$ **natural-pair**(P) ; $X|X$

The pair-forming operator has as its core meaning the definition of the **resp** operator that is essentially identical to the one employed by Gawron & Kehler (2004) for the analysis of 'respective' sentences. The **resp** operator is defined as in (47):

(47) **resp**$(X)(P) = 1$ iff
$\exists x, y[$**atom**$(x) \wedge$ **atom**$(y) \wedge x \neq y \wedge X = x \oplus y \wedge \exists p, q <_a P[p \neq q \wedge p(x) \wedge q(y)]]$

resp$(X)(P)$ is true of a sum of individuals X and a sum of properties P just in case there is a bijective relation between the set of individuals that are atomic subparts of X and the set of properties that are atomic subparts of P, such that for each such pair, the individual in question satisfies the property in question.

By applying the pair-forming operator to the property sum meaning of the nominal head coordination *man and woman*, we get the following set of pairs of individuals as output, which is a set of man-woman pairs:

(48) ⟦(46)⟧(⟦man and woman⟧)
= $\lambda P \lambda X.[$**resp**$(X)(P) \wedge$ **natural-pair**$(P)]($**man** $\oplus$ **woman**$)$
= $\lambda X.[$**resp**$(X)($**man** $\oplus$ **woman**$) \wedge$ **natural-pair**$($**man** $\oplus$ **woman**$)]$

On this approach, symmetrical modifiers such as *mutually incompatible*, which pose problems for the ellipsis-based analysis, can be treated simply as intersective modifiers that restrict the set of pairs (or groups) of individuals denoted by the head noun. Specifically, the meaning of *mutually incompatible* is given in (49), which takes a set of pairs (or groups) of individuals and imposes on these pairs (or groups) the further condition that they consist of members that are incompatible with each other.

(49) mutually ∘ incompatible; $\lambda P \lambda X.P(X) \wedge$ **incompatible**(X); N/N

With these assumptions about the denotations of coordinated nominal heads and symmetrical modifiers, the analysis for (14) goes as in (50):

(50)

$$\dfrac{\text{mutually} \circ \text{incompatible};\ \lambda P \lambda X.P(X) \wedge \mathbf{incmptbl}(X); \mathrm{N/N} \qquad \dfrac{\dfrac{\vdots}{\text{man} \circ \text{and} \circ \text{woman};\ \mathbf{man} \oplus \mathbf{woman}; \mathrm{N}} \qquad \dfrac{\vdots}{\lambda\varphi_1.\varphi_1;\ \lambda P \lambda X.\mathbf{resp}(X)(P); X|X}}{\text{man} \circ \text{and} \circ \text{woman};\ \lambda X.\mathbf{resp}(X)(\mathbf{man} \oplus \mathbf{woman}); \mathrm{N}}|\mathrm{E}}{\text{mutually} \circ \text{incompatible} \circ \text{man} \circ \text{and} \circ \text{woman};\ \lambda X.\mathbf{resp}(X)(\mathbf{man} \oplus \mathbf{woman}) \wedge \mathbf{incmptbl}(X); \mathrm{N}}/\mathrm{E}$$

This denotes a set of man-woman pairs such that for each pair, the two individuals constituting the pair are incompatible with one another. The determiner *this* picks up a unique member from this set that is proximal to the speaker.

We take the apparent agreement mismatch between the determiner and the verb to receive a semantic account along the following lines. The singular agreement between the determiner and the coordinated nominal reflects the selectional restriction that the singular determiner imposes on the head noun such that the number of object(s) that satisfy the property denoted by the (coordinated) head noun is one. The plural agreement between the whole NP and the verb, on the other hand, reflects the number of object(s) (in terms of atomic individuals of type e) for which the verbal predicate holds. The man-woman pair that the subject NP denotes is semantically a sum of individuals (just like other plural NPs such as *John and Bill*), and thus triggers plural verb agreement. In short, there is an (apparent) agreement mismatch here since, for pair-denoting nominals, the determiner counts the number of pairs whereas the verb counts the number of members that constitute the pair(s).[6]

To summarize, here again, the right analysis that enables a systematic treatment of a wider range of facts involving symmetrical modifiers is not in terms of ellipsis, but one which directly assigns meanings to such apparently anomalous coordinate structures by means of (slight extensions of) independently motivated mechanisms of grammar such as the generalized sum meaning for *and* and the **resp** operator used in the analysis of 'respectively' sentences. Furthermore, the apparently anomalous agreement pattern, which at first sight appears to motivate an ellipsis-based analysis, receives a fully coherent account by means of an interaction between relevant syntactic and semantic factors.

5 Conclusion

In this paper, we discussed three cases in which non-standard coordination interacts with scopal expressions. The empirical generalization that emerges in these three cases is uniform: the scopal operator that appears outside the coordinate structure in the overt string always takes scope over the whole coordinate structure—in other words, the surface form of the sentence transparently reflects the relevant scopal relation. The null hypothesis in such a situation is that the syntactic constituency relevant for semantic interpretation mirrors this surface constituency between the coordinate structure and the scopal expression.

An ellipsis-based analysis of coordination like the LBE approach in the recent

[6]Heycock & Zamparelli (2005) argue against an analysis of data like (43) which posits an empty pair-forming operator (superficially) similar to our (46), by giving five reasons for rejecting such an analysis. All of their arguments crucially rest on the assumption that the inaudible pair-forming operator has exactly the same syntactic, semantic and morphological properties as the overt word *pair*. But note that such an assumption is dubious given that the distribution of expressions like *this man and woman (are)* is rather restricted (i.e. limited to cases that can be informally described by the notion of 'natural pair', as discussed in the main text) as compared to the overt noun *pair*, which does not come with any such restriction. For this reason, we take it that the facts discussed by Heycock and Zamparelli do not undermine our analysis.

HPSG literature goes wrong for this very reason. Specifically, in this type of approach, if the surface form of the sentence demands an analysis in which the scopal operator is part of the material that undergoes surface ellipsis, the default prediction is that the scopal operator takes scope *inside* each conjunct, but such readings are systematically lacking in all of the three cases considered above. For a similar discrepancy between the underlying combinatoric structure and the actual interpretation observed with generalized quantifiers, Beavers & Sag (2004) propose a mechanism called Optional Quantifier Merger, which specifically does away with the duplication of quantifier meanings from the final interpretation of the sentence on the condition that surface ellipsis takes place—effectively stipulating by fiat the effect that one would automatically get if the surface form of the sentence was directly assigned semantic interpretation without the ellipsis mechanism. Beavers & Sag's (2004) approach covers only the case of generalized quantifiers and it is not clear if it is extendable to other cases like those discussed in the present paper—in particular those involving symmetrical predicates, whose semantics is known to be more complex than that of ordinary generalized quantifiers (Keenan 1992; Barker 2007).

As we have discussed, CG offers a potentially very promising framework for analyzing these complex interactions between coordination and scopal expressions, given its transparent syntax-semantics interface and given its renowned 'direct coordination' analysis of non-standard coordination. However, the standard directional variants of CG is less than optimal for the treatment of scopal expressions due to the fact that the basic mode of implication dealing with syntactic combinatorics is inherently sensitive to word order. Thus, in order to analyze the interactions between scopal expressions and coordination in a fully general manner, we have chosen to extend a directional fragment, which is essentially a labelled deduction (re)formulation of the Lambek calculus, with a mechanism that deals with directionality-insensitive reasoning, incorporating the insight of Oehrle's (1994) term-labelled calculus for quantification. The resultant system recognizes both directional and non-directional modes of implication within a single calculus, and the two types of inference feed into one another freely. As we have shown above, this hybrid architecture of the present framework plays a crucial role in capturing the the empirical interactions between coordination (whose analysis involves inferences with the directional mode of implication) and scope-taking expressions (whose analysis involves the non-directional mode of implication). We thus conclude that the direct coordination analysis of non-standard coordination in CG is truly superior to an alternative that extensively relies on surface ellipsis like the LBE approach in the recent HPSG literature, but that the real empirical payoff of the direct coordination analysis becomes fully apparent only when it is embedded in a framework—like the one we have proposed in this paper—which can deal with complex yet systematic interactions between directional and non-directional modes of inference, each modelling the behaviors of different types of linguistic phenomena in a fully general manner.

References

ABBOTT, BARBARA. 1976. Right node raising as a test for constituenthood. *Linguistic Inquiry* 7.639–642.

BARKER, CHRIS. 2007. Parasitic scope. *Linguistics and Philosophy* 30.407–444.

BAYER, SAMUEL. 1996. The coordination of unlike categories. *Language* 72.579–616.

BEAVERS, JOHN, & IVAN A. SAG. 2004. Coordinate ellipsis and apparent non-constituent coordination. In *The Proceedings of the 11th International Conference on Head-Driven Phrase Structure Grammar*, ed. by Stefan Müller, 48–69, Stanford. CSLI.

BERNARDI, RAFFAELLA. 2002. *Reasoning with Polarity in Categorial Type Logic*. University of Utrecht dissertation. [Available at `http://www.inf.unibz.it/~bernardi/finalthesis.html`].

CARLSON, GREG N. 1987. Same and different: Some consequences for syntax and semantics. *Linguistics and Philosophy* 10.531–565.

CHAVES, RUI PEDRO. 2006. Coordination of unlikes without unlike categories. In *The Proceedings of the 13th International Conference on Head-Driven Phrase Structure Grammar*, ed. by Stefan Müller, 102–122, Stanford. CSLI Publications.

——. 2007. *Coordinate Structures - Constraint-based Syntax-Semantics Processing*. Portugal: University of Lisbon dissertation.

——. 2012. Conjunction, cumulation and respectively readings. *Journal of Linguistics* 48.297–344.

CRYSMANN, BERTHOLD. 2003. An asymmetric theory of peripheral sharing in HPSG: Conjunction reduction and coordination of unlikes. In *Proceedings of Formal Grammar 2003*, ed. by Gerhard Jäger, Paola Monachesi, Gerald Penn, & Shuly Wintner, 47–62. Available at http://cs.haifa.ac.il/˜shuly/fg03/.

DE GROOTE, PHILIPPE. 2001. Towards abstract categorial grammars. In *Association for Computational Linguistics, 39th Annual Meeting and 10th Conference of the European Chapter, Proceedings of the Conference*, 148–155.

DOWTY, DAVID. 1988. Type raising, functional composition, and non-constituent conjunction. In *Categorial Grammars and Natural Language Structures*, ed. by Richard T. Oehrle, Emmon Bach, & Deirdre Wheeler, 153–198. Dordrecht: D. Reidel Publishing Company.

GAWRON, JEAN MARK, & ANDREW KEHLER. 2004. The semantics of respective readings, conjunction, and filler-gap dependencies. *Linguistics and Philosophy* 27.169–207.

GAZDAR, GERALD. 1981. Unbounded dependencies and coordinate structure. *Linguistic Inquiry* 12.155–184.

HEYCOCK, CAROLINE, & ROBERTO ZAMPARELLI. 2005. Friends and colleagues: Plurality, coordination, and the structure of dp. *Natural Language Semantics* 13.201–270.

JACKENDOFF, RAY. 1977. *X-bar Syntax: A Study of Phrase Structure*. Cambridge, MA, USA: MIT Press.

KATHOL, ANDREAS. 1995. *Linearization-Based German Syntax*. Columbus: Ohio State University dissertation.

KEENAN, EDWARD L. 1992. Beyond the Frege boundary. *Linguistics and Philosophy* 15.199–221.

KUBOTA, YUSUKE. 2010. *(In)flexibility of Constituency in Japanese in Multi-Modal Categorial Grammar with Structured Phonology*. The Ohio State University dissertation.

——. to appear. The logic of complex predicates: A deductive synthesis of 'argument sharing' and 'verb raising'. To appear in *Natural Language and Linguistic Theory*.

——, & ROBERT LEVINE. 2012. Gapping as like-category coordination. In *Logical Aspects of Computational Linguistics: 7th International Conference*, ed. by Denis Béchet & Alexander Dikovsky, 135–150. Springer.

——, & ROBERT LEVINE. 2013. Against ellipsis: Arguments for the direct licensing of 'non-canonical' coordinations. MS., University of Tokyo and Ohio State University.

——, & CARL POLLARD. 2010. Phonological interpretation into preordered algebras. In *The Mathematics of Language: 10th and 11th Biennial Conference*, ed. by Christian Ebert, Gerhard Jäger, & Jens Michaelis, 200–209. Springer.

LAMBEK, JOACHIM. 1958. The mathematics of sentence structure. *American Mathematical Monthly* 65.154–170.

LEVINE, ROBERT. 2011. Linerarization and its discontents. In *The Proceedings of the 18th International Conference on Head-Driven Phrase Structure Grammar*, ed. by Stefan Müller, 126–146, Stanford. CSLI Publications.

MOORTGAT, MICHAEL. 1997. Categorial Type Logics. In *Handbook of Logic and Language*, ed. by Johan van Benthem & Alice ter Meulen, 93–177. Amsterdam: Elsevier.

——, & RICHARD T. OEHRLE. 1994. Adjacency, dependence, and order. In *Proceedings of the Ninth Amsterdam Colloquium*, ed. by Paul Dekker & Martin Stokhof, 447–466, Universiteit van Amsterdam. Instituut voor Taal, Logica, en Informatica.

MORRILL, GLYN, & TERESA SOLIAS. 1993. Tuples, discontinuity, and gapping in categorial grammar. In *Proceedings of the Sixth Conference of the European Chapter of the Association for Computational Linguistics*, 287–297, Morristown, NJ. Association for Computational Linguistics.

MORRILL, GLYN V. 1994. *Type Logical Grammar: Categorial Logic of Signs*. Dordrecht: Kluwer Academic Publishers.

MUSKENS, REINHARD. 2001. Categorial Grammar and Lexical-Functional Grammar. In *The Proceedings of the LFG '01 Conference*, ed. by Miriam Butt & Tracy Holloway King, University of Hong Kong.

——. 2003. Language, lambdas, and logic. In *Resource Sensitivity in Binding and Anaphora*, ed. by Geert-Jan Kruijff & Richard Oehrle, Studies in Linguistics and Philosophy, 23–54. Kluwer.

——. 2007. Separating syntax and combinatorics in categorial grammar. *Research on Language and Computation* 5.267–285.

OEHRLE, RICHARD T. 1994. Term-labeled categorial type systems. *Linguistics and Philosophy* 17.633–678.

PARTEE, BARBARA, & MATS ROOTH. 1983. Generalized quantifiers and type ambiguity. In *Meaning, Use, and Interpretation of Language*, ed. by Rainer Bäuerle, Christoph Schwarze, & Arnim von Stechow, 361–383. Berlin: Walter de Gruyter.

POLLARD, CARL. 2009. Parasitic scope in categorial grammar with φ-labelling. Presentation at the Synners meeting, May 27, 2009.

——. 2011. Proof theoretic background for linear grammar. MS., Ohio State University.

——, & E. ALLYN SMITH. to appear. A unified analysis of *the same*, phrasal comparatives and superlatives. In *Proceedings of SALT 2012*, volume ??, ??–??

REAPE, MIKE. 1996. Getting things in order. In *Discontinuous Constituency*, ed. by Harry Bunt & Arthur van Horck, volume 6 of *Natural Language Processing*, 209–253. Berlin, Germany and New York, NY, USA: Mouton de Gruyter. Published version of a Ms. from 1990.

SAG, IVAN, & RUI CHAVES. 2008. Left- and right-periphery ellipsis in coordinate and non-coordinate structures. MS., Stanford University and University at Buffalo, The State University of New York.

STEEDMAN, MARK. 1985. Dependency and coordination in the grammar of Dutch and English. *Language* 61.523–568.

YATABE, SHÛICHI. 2001. The syntax and semantics of left-node raising in Japanese. In *Proceedings of the 7th International Conference on Head-Driven Phrase Structure Grammar*, ed. by Dan Flickinger & Andreas Kathol, 325–344, Stanford. CSLI. http://cslipublications.stanford.edu/HPSG/.

YATABE, SHÛICHI. 2012. Comparison of the ellipsis-based theory of non-constituent coordination with its alternatives. In *Proceedings of the 19th International Conference on Head-Driven Phrase Structure Grammar, Chungnam National University Daejeon*, ed. by Stefan Müller, 453–473.

ZAENEN, ANNIE, & LAURI KARTTUNEN. 1984. Morphological non-distinctiveness and coordination. In *Proceedings of the First Eastern States Conference on Linguistics*, ed. by Gloria Alvarez, Belinda Brodie, & Terry McCoy, 309–320.

A Coordination of unlikes with different subcategorization frames

In this appendix, we show that, by adopting the 'semantically potent' variant of the meet connective (in Bayer's (1996) terminology), examples such as (51) receives a straightforward analysis in the direct coordination analysis in CG, thereby refuting the claim occasionally raised in the literature by proponents of the LBE approach coordination that such examples undermine the CG analysis of NCC.

(51) John gave Mary a book and to Peter a record.

We assume that (51) is a variant of (52) which has undergone a surface-oriented reordering operation. For expository convenience, we provide the derivation for (52), and gloss over the details of the reordering operation.

(52) ?John gave Mary a book and a record to Peter.

The semantically potent variant of the meet connective assigns pairs of meanings as the denotations of the linguistic expressions that are assigned such categories. Thus, on this analysis, the different subcategorization frames of *give* can be compiled into one lexical entry in the following form:

(53) gave; $\langle \lambda x \lambda y \lambda z.\mathbf{give}(x)(y)(z), \lambda x \lambda y \lambda z.\mathbf{give}(y)(x)(z)\rangle$; (VP/PP/NP)∧(VP/NP/NP)

Note that, corresponding to the two subcategorization frames enocded in the syntactic category $\mathrm{VP/PP/NP}$ and $\mathrm{VP/NP/NP}$, we have two distinct semantic translations involving the same constant **give** but which take the first two arguments in different orders.

In actual derivations, one of these subcategorization frames is chosen via Meet Elimination:

(54)

$$\dfrac{\text{john}; \mathbf{j}; \mathrm{NP} \qquad \dfrac{\dfrac{\dfrac{\dfrac{\begin{array}{l}\text{gave};\\ \langle \lambda x \lambda y \lambda z.\mathbf{give}(x)(y)(z), \lambda x \lambda y \lambda z.\mathbf{give}(y)(x)(z)\rangle;\\ (\mathrm{VP/PP/NP}) \wedge (\mathrm{VP/NP/NP})\end{array}}{\text{gave}; \lambda x \lambda y \lambda z.\mathbf{give}(y)(x)(z); \mathrm{VP/NP/NP}}{\wedge}\mathrm{E} \qquad \text{mary}; \mathbf{m}; \mathrm{NP}}{\text{gave} \circ \text{mary}; \lambda y \lambda z.\mathbf{give}(y)(\mathbf{m})(z); \mathrm{VP/NP}}/\mathrm{E} \qquad \text{the} \circ \text{book}; \mathbf{b}; \mathrm{NP}}{\text{gave} \circ \text{mary} \circ \text{the} \circ \text{book}; \lambda z.\mathbf{give}(\mathbf{b})(\mathbf{m})(z); \mathrm{VP}}/\mathrm{E}}{\text{john} \circ \text{gave} \circ \text{mary} \circ \text{the} \circ \text{book}; \mathbf{give}(\mathbf{b})(\mathbf{m})(\mathbf{j}); \mathrm{S}}\backslash\mathrm{E}$$

With these assumptions, the derivation for (52) is now straightforward. It just involves an interaction of the usual hypothetical reasoning analysis of NCC and the meet elimination analysis of the 'disambiguation' of two subcategorization frames assigned to *give* in (53). (Here, DTV abbreviates $\mathrm{VP/NP/NP}$ and PDTV abbreviates $\mathrm{VP/PP/NP}$; π_1 and π_2 are the first and second projection functions.)

(55)

$$[\varphi; f; \mathrm{PDTV} \wedge \mathrm{DTV}]^1$$
$$\wedge\mathrm{E}:\ \varphi; \pi_2(f); \mathrm{DTV}$$
$$\text{mary}; \mathbf{m}; \mathrm{NP}$$
$$/\mathrm{E}:\ \varphi \circ \text{mary}; \pi_2(f)(\mathbf{m}); \mathrm{VP/NP}$$
$$\text{the} \circ \text{book}; \mathbf{b}; \mathrm{NP}$$
$$/\mathrm{E}:\ \varphi \circ \text{mary} \circ \text{the} \circ \text{book}; \pi_2(f)(\mathbf{m})(\mathbf{b}); \mathrm{VP}$$
$$|\mathrm{I}^1:\ \text{mary} \circ \text{the} \circ \text{book}; \lambda f.\pi_2(f)(\mathbf{m})(\mathbf{b}); (\mathrm{PDTV} \wedge \mathrm{DTV})\backslash\mathrm{VP}$$

$$\text{and}; \lambda g \lambda h. g \sqcap h; (X\backslash X)/X$$
$$\vdots \quad \vdots$$
$$\text{the} \circ \text{record} \circ \text{to} \circ \text{peter}; \lambda f.\pi_1(f)(\mathbf{r})(\mathbf{p}); (\mathrm{PDTV} \wedge \mathrm{DTV})\backslash\mathrm{VP}$$
$$/\mathrm{E}:\ \text{and} \circ \text{the} \circ \text{record} \circ \text{to} \circ \text{peter}; \lambda h.[\lambda f.\pi_1(f)(\mathbf{r})(\mathbf{p})] \sqcap h; ((\mathrm{PDTV} \wedge \mathrm{DTV})\backslash\mathrm{VP})\backslash((\mathrm{PDTV} \wedge \mathrm{DTV})\backslash\mathrm{VP})$$

$$\backslash\mathrm{E}:\ \text{mary} \circ \text{the} \circ \text{book} \circ \text{and} \circ \text{the} \circ \text{record} \circ \text{to} \circ \text{peter}; \lambda f.\pi_1(f)(\mathbf{r})(\mathbf{p}) \wedge \pi_2(f)(\mathbf{m})(\mathbf{b}); (\mathrm{PDTV} \wedge \mathrm{DTV})\backslash\mathrm{VP}$$

$$\text{gave}; \langle \lambda x \lambda y \lambda z.\mathbf{give}(x)(y)(z), \lambda x \lambda y \lambda z.\mathbf{give}(y)(x)(z)\rangle; \mathrm{PDTV} \wedge \mathrm{DTV}$$
$$\vdots \quad \vdots$$
$$\text{mary} \circ \text{the} \circ \text{book} \circ \text{and} \circ \text{the} \circ \text{record} \circ \text{to} \circ \text{peter}; \lambda f.\pi_1(f)(\mathbf{r})(\mathbf{p}) \wedge \pi_2(f)(\mathbf{m})(\mathbf{b}); (\mathrm{PDTV} \wedge \mathrm{DTV})\backslash\mathrm{VP}$$
$$\backslash\mathrm{E}:\ \text{gave} \circ \text{mary} \circ \text{the} \circ \text{book} \circ \text{and} \circ \text{the} \circ \text{record} \circ \text{to} \circ \text{peter}; \lambda x.\mathbf{give}(\mathbf{r})(\mathbf{p})(x) \wedge \mathbf{give}(\mathbf{b})(\mathbf{m})(x); \mathrm{VP}$$

Now, we should recall that, in defining the semantics of the meet connective, Bayer (1996) (section 7.1) opts for an impoverished, semantically nonpotent definition. The alleged motivation for this choice, according to Bayer (1996), comes from the fact that examples like the following (constituting a violation of Zaenen & Karttunen's (1984) well-known Anti-Pun Ordinance) can be derived once we admit the semantically potent variant of the meet connective and assign to *can* a syntactic category $(\mathrm{VP/NP}) \wedge (\mathrm{VP/VP[BASE]})$ with the corresponding semantic interpretation which pairs the main verb meaning and the auxiliary meaning as one entry.

(56) *I can tuna for a living and get a job if I want.

We take it that Bayer's (1996) argument here is somewhat misguided. In particular, Bayer (1996) seems to overlook the point that the availability of the semantically potent variant of the meet connective in the theory does not necessitate an analysis of the ambiguity of *can* in terms of it. The auxiliary *can* and the main verb *can* can just be entered in the lexicon as two separate entries, and then the overgeneration of (56) does not arise.

This of course begs the question of how to restrict the use of the semantically potent variant of the meet connective. In order to provide a complete answer to this question, we need to study examples of the sort exemplified by (52) more closely, but a conceptually plausible hypothesis which gives us a starting point is readily available: what distinguishes the ungrammatical cases like (56) and the grammatical cases like (52) seems to be that, while the two uses of the same phonological form are totally unrelated in the former, the two subcategorization frames of *give* in the latter are clearly related semantically. By assuming that a semantically potent variant of the meet connective is invoked only in cases like the latter, we have a principled explanation for the Anti-Pun Ordinance while at the same time recognizing semantically potent meet. In other words, Anti-Pun Ordinance is a reflection of some substantive generalization governing the lexicon (whose exact nature we still don't understand), and not a consequence of a formal property of the underlying logic.