



## Interactions of scope and ellipsis

The Harvard community has made this article openly available. [Please share](#) how this access benefits you. Your story matters

Citation	Stuart M. Shieber, Mary Dalrymple, and Fernando C. N. Pereira. Interactions of scope and ellipsis. <i>Linguistics and Philosophy</i> , 19(5):527-552, 1996. The original publication is available at <a href="http://www.springerlink.com">www.springerlink.com</a> .
Published Version	<a href="http://dx.doi.org/10.1007/BF00632780">http://dx.doi.org/10.1007/BF00632780</a>
Citable link	<a href="http://nrs.harvard.edu/urn-3:HUL.InstRepos:2031715">http://nrs.harvard.edu/urn-3:HUL.InstRepos:2031715</a>
Terms of Use	This article was downloaded from Harvard University's DASH repository, and is made available under the terms and conditions applicable to Other Posted Material, as set forth at <a href="http://nrs.harvard.edu/urn-3:HUL.InstRepos:dash.current.terms-of-use#LAA">http://nrs.harvard.edu/urn-3:HUL.InstRepos:dash.current.terms-of-use#LAA</a>

# Interactions of Scope and Ellipsis

Stuart M. Shieber  
Harvard University

Fernando C. N. Pereira  
AT&T Bell Laboratories

Mary Dalrymple  
Xerox PARC

Revision: 1.17 of Date: 1995/12/18 17:36:41

## **Abstract**

Systematic semantic ambiguities result from the interaction of the two operations that are involved in resolving ellipsis in the presence of scoping elements such as quantifiers and intensional operators: scope determination for the scoping elements and resolution of the elided relation. A variety of problematic examples previously noted — by Sag, Hirschbühler, Gawron and Peters, Harper, and others — all have to do with such interactions. In previous work, we showed how ellipsis resolution can be stated and solved in equational terms. Furthermore, this equational analysis of ellipsis provides a uniform framework in which interactions between ellipsis resolution and scope determination can be captured. As a consequence, an account of the problematic examples follows directly from the equational method. The goal of this paper is merely to point out this pleasant aspect of the equational analysis, through its application to these cases. No new analytical methods or associated formalism are presented, with the exception of a straightforward extension of the equational method to intensional logic.

# Contents

<b>1</b>	<b>Introduction</b>	<b>2</b>
1.1	The Equational Method . . . . .	2
1.2	Quantification . . . . .	4
<b>2</b>	<b>Interactions of Ellipsis and Quantification</b>	<b>5</b>
2.1	Wide Scope Quantification . . . . .	5
2.2	Equational Analysis of Wide Scope Quantification . . . . .	7
2.3	Missing Readings Involving Wide Scope Quantification . . . . .	8
<b>3</b>	<b>Interactions of Ellipsis and Anaphoric Dependencies</b>	<b>10</b>
3.1	Source Anaphoric Dependencies with Parallel Elements . . . . .	10
3.2	Anaphoric Dependencies Between Source and Target . . . . .	13
3.3	Source Anaphoric Dependencies with Nonparallel Elements . . . . .	16
<b>4</b>	<b>Interactions of Ellipsis and Intensional Operators</b>	<b>17</b>
4.1	Equational Analysis of the <i>De Re/De Dicto</i> Distinction . . . . .	19
4.2	Missing Readings Involving Intensional Operators . . . . .	20
<b>5</b>	<b>Conclusion</b>	<b>22</b>

# 1 Introduction

Systematic semantic ambiguities result from the interaction of the two operations that are involved in resolving ellipsis in the presence of scoping elements such as quantifiers and intensional operators: scope determination for the scoping elements and resolution of the elided relation. A variety of problematic examples previously noted in the literature all have to do with such interactions.

In a previous paper (Dalrymple, Shieber, and Pereira, 1991, henceforth DSP), we showed how ellipsis resolution can be stated and solved in equational terms. Furthermore, this equational analysis of ellipsis provides a uniform framework in which interactions between ellipsis resolution and scope determination occur. As a consequence, the previously noted phenomena follow directly from the equational method. The goal of this paper is merely to point out this pleasant aspect of the equational analysis, through its application to these cases.

No new analytical methods or associated formalism will be presented in this paper, with the exception of a straightforward extension of the equational method to intensional logic. Rather, the methods and formalism described in DSP are applied without change to a new set of phenomena involving the interaction of scope and ellipsis, in particular, interactions between ellipsis and quantifiers, anaphoric dependencies, and intensional operations.

## 1.1 The Equational Method

In DSP, we introduced a new approach to the interpretation of ellipsis in which possible interpretations arise from the solutions of certain equations involving the meanings of the two phrases (usually clauses) involved in an elliptical construction, an antecedent *source* phrase, and a *target* phrase that is missing some material. Here we will summarize the elements of our approach. For detailed arguments for the approach and further technical details the reader should refer to DSP and references therein.

Our analysis is based on the simple observation that an elliptical construction involves parallelism between the source and target. For instance, in the verb phrase (VP) ellipsis example (1), the source clause, ‘Dan likes his wife’, parallels the target ‘George does too’, with the subjects ‘Dan’ and ‘George’ being *parallel elements*.

- (1) Dan likes his wife, and George does too.

Using typed  $\lambda$ -terms to represent phrase meanings, we can specify the meaning of the source clause as  $like(\underline{dan}, wife-of(dan))$  and the meaning of the target clause as  $P(george)$  for some property  $P$ . Parallel elements in the source clause introduce so-called *primary occurrences* into the source clause meaning representation. In example (1), the single source parallel element ‘Dan’ gives rise to the primary occurrence marked above (and hereafter) with underlining.

The task of ellipsis resolution is to determine the property  $P$ . Crucially, we know more about  $P$  than the mere fact that it holds of George. We know also that it represents what George and Dan are asserted to have in common. That is,

predicating  $P$  of the parallel element in the source, Dan, gives the meaning of the source, that Dan likes his wife. We can encapsulate this observation in the simple equation (2). This equation has four solutions for  $P$  (3a-d). However, because the parallel elements in the target must play the same role in the meaning of the target as the source parallel elements play in the meaning of the source, we are only interested in those solutions that abstract over the interpretations of the parallel elements in the source, that is, over the primary occurrences. To restrict the range of solutions, we therefore require that solutions be *admissible* in that they do not contain primary occurrences, thereby eliminating solutions (3c) and (3d.) This constraint is merely a reflex of the inherent parallelism in elliptical constructions. Either of the other two remaining properties yields a possible interpretation of the target clause when applied to the interpretation *george* of the parallel element in the target clause. Solution (3a) gives rise to what has been called the *strict* reading of the second conjunct (4a), while (3b) gives rise to the *sloppy* reading (4b).

$$(2) P(\text{dan}) = \text{like}(\underline{\text{dan}}, \text{wife-of}(\text{dan}))$$

$$(3) \text{ a. } \lambda x \cdot \text{likes}(x, \text{wife-of}(\text{dan}))$$

$$\text{ b. } \lambda x \cdot \text{likes}(x, \text{wife-of}(x))$$

$$\text{ c. } \lambda x \cdot \text{likes}(\underline{\text{dan}}, \text{wife-of}(\text{dan}))$$

$$\text{ d. } \lambda x \cdot \text{likes}(\underline{\text{dan}}, \text{wife-of}(x))$$

$$(4) \text{ a. } \text{likes}(\text{george}, \text{wife-of}(\text{dan}))$$

$$\text{ b. } \text{likes}(\text{george}, \text{wife-of}(\text{george}))$$

More generally, the problem of ellipsis resolution is to recover a property of (or relation over) the interpretation of the parallel element (respectively, elements) in the target that the missing or vestigial material stands proxy for. This involves

- determination of parallelism: identifying the source, the target, and the parallelism between source and target elements; and
- finding admissible solutions for  $P$  in the equation  $P(s_1, s_2, \dots, s_n) = s$ , where  $s_1$  through  $s_n$  are the interpretations of the parallel elements of the source, and  $s$  is the interpretation of the source itself.

Once  $P$  is determined,  $P(t_1, t_2, \dots, t_n)$  serves as the interpretation of the target, where  $t_1$  through  $t_n$  are the interpretations of the corresponding parallel elements of the target.

The first step, determination of the parallelism itself, is a separate problem, which we considered in more detail (though without resolution) in DSP, but which we will not be concerned with further here. The second step, solution of equations, can be performed using Huet's *higher-order unification algorithm* (Huet, 1975).

As pointed out in DSP, our analysis does not rely on the existence of a syntactic constituent in the source (for example, a VP) whose interpretation is also the interpretation of the missing material in the target. In particular, the meaning of the implicit relation  $P$  need not be, and in general is not, the meaning of any  $VP$ , or even of  $VP$  meaning type. Therefore, the equational analysis can be applied even where no VP antecedent can be identified. For this reason, it is applicable to elliptical constructions beyond VP ellipsis as well.

## 1.2 Quantification

Many of the questions we address in this paper involve interactions between ellipsis, quantification, and bound anaphora. Here, we describe our approach to the interpretation of quantification and binding, based on the categorial semantics scheme proposed by Pereira (1990).

In general, the interpretation of a phrase will have the form  $\Gamma \vdash m$  where  $\Gamma$  is a set of *assumptions* analogous to a quantifier store in the Cooper storage method (Cooper, 1983) and  $m$  is a matrix term in which free variables introduced by the assumptions in  $\Gamma$  may occur.

The assumptions used for quantifier scoping are triples of the form  $\langle q \ x \ p \rangle$  where  $q$  is a determiner meaning,  $x$  is a free variable, and  $p$  is a proposition-typed term in which  $x$  is free. The assumption  $\langle q \ x \ p \rangle$  is said to *introduce* variable  $x$ . A quantified noun phrase is interpreted as a variable introduced by an assumption whose first component is the meaning of the noun phrase’s determiner and whose third component represents the meaning of the noun phrase’s nominal.

For a derivation to be considered complete, such assumptions must be *discharged*. We will exemplify this process with the sentence ‘Every person left.’ The quantified noun phrase ‘every person’ is given the interpretation

$$\langle \text{every } x \ \text{person}(x) \rangle \vdash x$$

That is, the meaning of the noun phrase is  $x$  under the assumption to the left of the  $\vdash$ .

The VP meaning applied to the NP meaning yields  $\text{left}(x)$  as the meaning for the sentence as a whole, still under the above assumption, of course:

$$\langle \text{every } x \ \text{person}(x) \rangle \vdash \text{left}(x)$$

Discharging the assumption involves applying the quantifier *every* to its range and scope. For instance, in the case of generalized quantifiers (Barwise and Cooper, 1981), this is done by applying the quantifier *every* of type  $(e \rightarrow t) \rightarrow (e \rightarrow t) \rightarrow t$  to the two properties  $\lambda x \cdot \text{person}(x)$  and  $\lambda x \cdot \text{left}(x)$ . In the denotationally equivalent alternative introduced for technical reasons in DSP, the quantifier *every* of type  $(e \rightarrow t \times t) \rightarrow t$  applies to the abstraction  $\lambda x \cdot \langle \text{person}(x), \text{left}(x) \rangle$ , a function from individuals to pairs of truth values. Since this distinction does not normally affect the derivations we will carry out here, we use for the result of discharging the quantifier assumption the convenient neutral notation  $\text{every}(x, \text{person}(x), \text{left}(x))$ , which is the complete interpretation of ‘Every person left.’

The equational method and related technical infrastructure having now been introduced, we turn to their unaltered application to cases of scope and ellipsis interaction.

## 2 Interactions of Ellipsis and Quantification

One widely noted source of ambiguity in elliptical constructions concerns the structure of the implicit relation in the target clause in the presence of quantification in the source. A quantifier in the source can have scope over both source and target, or over source alone. In the latter case, a similar quantificational structure is induced in the target clause. The notion of similarity is crucial; in particular, it is not merely the case that a quantifier of the same type (existential, say, or universal) appears in the target, but also that the dependencies between quantifiers and other scoping elements are preserved.

The equational analysis of ellipsis resolution predicts the similarity in dependencies between source and target clauses without further stipulation. Some simple illustrations of this were discussed in Section 3.4 of DSP. For example, in cases of antecedent-contained ellipsis, it is a consequence of the equational analysis that no reading is possible in which the quantifier containing the elliptical element quantifies separately in source and target. Similarly, if multiple quantifiers occur in the source clause, then under the reading in which the quantifiers scope separately in the source and target, they must have the same relative scope in the two clauses. Finally, cases of parallelism between quantified and nonquantified noun phrases in ellipsis are easily handled by using the natural higher-order typing of the two noun phrases when setting up the ellipsis equation. (This last point is reviewed in Section 2.3 below.)

Beyond these examples covered in DSP, the equational analysis makes predictions about so-called “wide scope quantification” examples.

### 2.1 Wide Scope Quantification

Many traditional analyses of VP ellipsis have presumed that the meaning of the missing VP in the target clause is obtained by reusing or “copying” the meaning of the VP of the source clause. Such analyses typically predict that a quantified NP contained in the source VP must have narrow scope with respect to quantifiers elsewhere in the source clause, specifically in the subject, if the quantifier is to scope separately in the two clauses. In other words, they require that parallel elements take widest scope in the source clause.

As a concrete example, Sag (1976, page 61) claims that sentence (5) has no reading paraphrasable as ‘each person was hit by a person and then Bill hit each person’, and in fact, analyses such as those of Sag (1976) and Williams (1977) do not generate such readings.

- (5) Someone hit everyone, and then Bill did.

Sag (1976, page 107) provides the following two logical forms for the two readings of the source clause ‘someone hit everyone’ of example (5):

- (6) a.  $\exists x \cdot [\lambda y \cdot \forall z \text{hit}(y, z)](x)$   
 b.  $\forall z \cdot \exists x \cdot [\lambda v \cdot \text{hit}(v, z)](x)$

Sag’s logical forms for sentences encode a division between subject meaning, represented as a quantified variable, and verb phrase meaning, represented as a lambda abstraction.<sup>1</sup> Sag requires the logical form representation of the source and target verb phrase in VP ellipsis constructions to be alphabetic variants ( $\alpha$ -interconvertible, assuming, without loss of generality, that all separately bound variables are renamed apart from free variables). If they are not, VP ellipsis is not possible.

Consider first the logical form in (6a) for the reading in which *everyone* takes narrow scope. It is possible on Sag’s analysis to provide an interpretation for the target *Bill did* if this reading is assumed, since the source verb phrase meaning is  $\lambda y \cdot \forall z \cdot \text{hit}(y, z)$ , giving the logical form  $[\lambda y \cdot \forall z \cdot \text{hit}(y, z)](\text{bill})$  for the target clause.

However, the logical form in (6b), in which *everyone* takes wide scope, does not give rise to a well-formed logical form for the target. In this case, it is not possible for the verb phrase meaning in the logical form for the target clause to be an alphabetic variant of the source VP meaning, since the source VP meaning contains a variable  $z$  that is bound outside the VP. For similar reasons, the analysis of Williams (1977) also entails the restriction that subject noun phrases must always take widest scope in VP ellipsis.

Hirschbühler (1982) was the first to note that subjects of VP ellipsis *can* have narrow scope relative to nonsubjects, and points out the difficulties that this can present. An example is the following:

- (7) A Canadian flag was hanging in front of each window, and an American one was too. (Hirschbühler’s (12))

This sentence has a reading in which each window had both an American and a Canadian flag hanging in front of it. It might be thought that the reason for the apparent availability of this reading is that ‘each window’ has scope over both the source and the target clauses, but the following sentence shows that this explanation cannot always be the right one:

- (8) A Canadian flag was hanging in front of most windows, and an American one was too.

This sentence has a reading on which the set of windows with a Canadian flag is different from the set of windows with an American flag; on this reading, the quantifier ‘most windows’ must scope separately in the source and target.

Just as Sag’s and Williams’s analyses derive no wide-scope reading for (5), they are incapable of accounting for the available reading for the Hirschbühler example

---

<sup>1</sup>From a strictly semantic point of view, this distinction is meaningless, since the denotations of a lambda redex and its reduced form are the same. Instead, the distinction makes sense as pertaining to the syntax-semantics interface; a similar but less restrictive role is played in our work by the notion of primary occurrence.



(7). It is, however, not impossible to maintain an identity-of-relations analysis of VP ellipsis while accounting for Hirschbühler’s examples; Kempson and Cormack (1983) present an identity-of-relations analysis involving a complex type-raising of the verb to invert subject and object meanings.

More recent analyses predict a larger range of readings for examples like (5), but still fail to provide the correct range of readings for examples like (7). Fiengo and May (1994) provide an analysis in which VP ellipsis must be resolved by reconstruction of the logical form of the source VP. Anaphors and traces in the source may be either ‘ $\alpha$  occurrences’ or ‘ $\beta$  occurrences’. The latter are those that involve a structural dependency on another element, and those occurrences give rise to sloppy readings in ellipsis. The former can give rise to a strict reading. Most importantly for the case at hand, an  $\alpha$ -type trace that appears outside of the scope of its quantifier is, according to Fiengo and May, analogous to an E-type pronoun.

Thus, on Fiengo and May’s analysis, the wide-scope reading for (7) is available, as it is for the variant (9) with an explicit E-type pronoun.

- (9) A Canadian flag was hanging in front of every window, and an American one was hanging in front of them too.

This approach would seem to predict that an analogous reading is available for Sag’s original example (5). Fiengo and May assert that “for whatever reason” [page 232] this reading is unavailable, just as (they claim) it is unavailable in the nonelliptical version:

- (10) Someone hit everyone, and then Bill hit them.

Below, we propose an explanation of why certain characteristics of the source sentences in these examples make these readings unavailable. Note, however, that their analysis fails to predict the correct set of readings for example (8). The unavailable reading under Fiengo and May’s analysis is the one in which ‘most windows’ takes wide scope separately in the source and target, allowing the set of windows with an American flag to be different from the set of windows with a Canadian flag. Fiengo and May’s analysis predicts only a reading in which the two sets of windows are the same, as in the paraphrase involving an E-type pronoun:

- (11) A Canadian flag was hanging in front of most windows, and an American one was hanging in front of them too.

In short, the analysis of Fiengo and May fails to provide the correct range of meanings whenever the version with ellipsis does not have the same range of meanings as the corresponding version with an E-type pronoun.

## 2.2 Equational Analysis of Wide Scope Quantification

The required scopings for Hirschbühler’s examples follow from the equational analysis of ellipsis. Recall (from DSP, Section 3.4.3) that when a target NP is parallel to a quantified source NP, both NPs are taken to have generalized quantifier types.

<sup>2</sup> For sentence (7), the categorial semantic derivation provides for the meaning of the source sentence given in (12a). The ellipsis equation (12b), using the generalized quantifier reading of ‘a Canadian flag’, has the admissible solution (12c). The meaning of the target clause is derived by applying this relation  $P$  to the meaning of the quantifier ‘an American one’, which we take to be  $\lambda S \cdot \text{some}(f, \text{amflag}(f), S(f))$  (assuming here that the ‘one’ anaphora is resolved separately), yielding the target meaning in (12d).

$$\begin{aligned}
(12) \quad & \text{a. } \text{every}(w, \text{window}(w), \text{some}(f, \text{canflag}(f), \text{hang}(f, w))) \\
& \text{b. } P(\lambda S \cdot \text{some}(f, \text{canflag}(f), S(f))) \\
& \quad = \text{every}(w, \text{window}(w), \underline{\text{some}}(f, \underline{\text{canflag}}(f), \text{hang}(f, w))) \\
& \text{c. } P \mapsto \lambda Q \cdot \text{every}(w, \text{window}(w), Q(\lambda x \cdot \text{hang}(x, w))) \\
& \text{d. } (\lambda Q \cdot (\text{every}(w, \text{window}(w), Q(\lambda x \cdot \text{hang}(x, w)))) \\
& \quad (\lambda S \cdot \text{some}(f, \text{amflag}(f), S(f)))) \\
& \quad = \text{every}(w, \text{window}(w), \text{some}(f, \text{amflag}(f), \text{hang}(f, w)))
\end{aligned}$$

This is exactly the wide scope universal reading of the sentence that is problematic for most identity-of-relations ellipsis analyses. Note that no special provision was made for deriving this reading. In fact, the derivation is virtually identical to that described in DSP in Section 3.4.3, where the motivation is not the ability to generate a wide scope reading for an object NP, but simply to allow for quantified subjects in ellipsis constructions in general.

It is also worth remarking on the similarity between the type-raised source VP meaning, allowing quantifying in, in the Kempson and Cormack analysis and solution (12c) to the ellipsis equation. In effect, equation solving by higher-order unification automatically computes the required type raising, which thus needs no separate stipulation.

### 2.3 Missing Readings Involving Wide Scope Quantification

Given that the equational analysis can generate wide scope readings of quantifiers in elided material, as in the Hirschbühler examples, the question remains as to whether such readings are possible in Sag’s example (5) and sentences of similar structure.

The equational analysis readily accounts for wide-scope readings not only for Hirschbühler’s (8) but also for Sag’s example (5). Taking the source meaning to be as in (13a), the ellipsis equation (13b) yields the solution (13c). This is applied to the meaning  $\lambda R \cdot R(b)$  of the target parallel element (suitably type-raised for consistency with the source parallel element meaning as per DSP, Section 3.4.3), to give the target meaning (13d).

$$\begin{aligned}
(13) \quad & \text{a. } \text{every}(y, \text{one}(y, \underline{\text{some}}(x, \underline{\text{one}}(x), \text{hit}(x, y))) \\
& \text{b. } P(\lambda S \cdot \text{some}(x, \text{one}(x), S(x))) = \text{every}(y, \text{one}(y, \underline{\text{some}}(x, \underline{\text{one}}(x), \text{hit}(x, y)))
\end{aligned}$$

---

<sup>2</sup>In schemes such as Montague’s, this would follow trivially, since all NP meanings are taken to be of the higher type.

- c.  $P \mapsto \lambda Q \cdot \text{every}(y, \text{one}(y), Q(\lambda x \cdot \text{hit}(x, y)))$   
d.  $P(\lambda R \cdot R(b)) = (\lambda Q \cdot \text{every}(y, \text{one}(y), Q(\lambda x \cdot \text{hit}(x, y))))(\lambda R \cdot R(b))$   
 $= \text{every}(y, \text{one}(y), \text{hit}(b, y))$

Admittedly, this reading is problematic. We, like Fiengo and May, have no explanation for this difficulty. However, as we will show, other structurally similar sentences do exhibit wide-scope readings.

Note first that interpretation of the Sag sentence is confounded by the choice of source sentence. The source clause ‘someone hit everyone’ is by itself very difficult to interpret with a wide-scope universal. Furthermore, the addition of the target clause ‘and then Bill did’, although not strictly redundant, is pragmatically unmotivated, especially in its change in perspective from hittee to hitter. We can easily correct for these confounding influences. First, we choose a universal quantifier that tends to scope wide; ‘each’ is a logical choice. Then we construct a sentence that is pragmatically quite natural on the wide-scope universal reading.

- (14) An intern must see each patient before Dr. Krankheit will.

This sentence clearly has a preferred reading where the universal takes wide scope in both clauses.

Nonetheless, there are two remaining debatable aspects to this example. First, the sentence is generic in tone, which might be thought to affect the quantifier behavior. Second, the relation between the two clauses is one of subordination. This might be thought to allow for a different way of generating the reading in question:<sup>3</sup> Rather than having two universals separately scoping wide in the two clauses, a single universal might scope over both clauses. It is more difficult to entertain such an explanation for coordinate structures, as quantifier raising out of a coordinate is more difficult than out of a subordinate.

To remedy the first problem, we can restate the sentence in a less generic fashion, and for the second problem, the subordination can be changed to coordination. In fact, to completely eliminate the possibility that a single quantifier is scoping over both clauses, we split the ellipsis across two sentences and force quantification over separate sets of patients in the two clauses.

- (15) Last fall the hospital was so overstaffed that at least three members of the house staff saw each patient. This spring because of budget cutbacks, only Dr. Krankheit did.

Here, the set of patients seen by the house staff last fall is distinct from the set seen this spring, so separate quantification is required. Still, the wide-scope universal reading is available, and quite natural.

As another example (free of the priming of previous examples), consider

- (16) At Gargantuan Press, at least three outside reviewers read each book proposal. At Pocket Press, only Fred Pocket, the editor-in-chief, does.

Such examples demonstrate that a structural explanation for the oddity of the wide-scope universal reading of the Sag sentence is misplaced.

<sup>3</sup>Hestvik (1992) and Kehler (1993) discuss the influences of subordination on ellipsis interpretation.

### 3 Interactions of Ellipsis and Anaphoric Dependencies

The prototypical elliptical interpretation phenomenon is the strict/sloppy alternation, which stems from an anaphoric dependency between a pronoun in the source clause and its source clause antecedent, where the latter is a parallel element. Other types of anaphoric dependency generate meaning alternations as well, and we examine these in this section. First, we look at alternations beyond strict/sloppy ones engendered by anaphoric dependencies between a pronoun and its parallel element antecedent within a source clause. Then we turn to anaphoric dependencies between target and source, and dependencies in the source clause between a pronoun and an antecedent that is not a parallel element. Each of these dependencies has its own characteristic reading alternations. We show that all of these cases are appropriately handled by the equational method, given a quantificational analysis of indefinite and definite NPs.

#### 3.1 Source Anaphoric Dependencies with Parallel Elements

When the source clause of an elliptical construction contains a pronoun and a parallel element antecedent, the sentence exhibits the classical strict/sloppy alternation. When the pronoun occurs within an indefinite NP, further ambiguities also arise as to the proper disposition of the indefinite. For instance, sentence (17), discussed by Gawron and Peters (1990, page 82), is three ways ambiguous, exhibiting the readings in (18a-c). They specifically discuss, and dismiss as irretrievable, a fourth reading (18d).

(17) Alice recommended a book she hated before Mary did.

- (18) a.  $some(x, book(x) \wedge hate(alice, x),$   
 $before(recommend(alice, x), recommend(mary, x)))$   
 a reading in which Alice and Mary recommend the same book, which Alice hates;
- b.  $before(some(x, book(x) \wedge hate(alice, x), recommend(alice, x)),$   
 $some(x, book(x) \wedge hate(alice, x), recommend(mary, x)))$   
 a strict reading in which different books that Alice hates are involved;
- c.  $before(some(x, book(x) \wedge hate(alice, x), recommend(alice, x)),$   
 $some(x, book(x) \wedge hate(mary, x), recommend(mary, x)))$   
 a sloppy reading in which there are two possibly distinct books one of which is hated and recommended by Alice and the other hated and recommended by Mary;
- d. \*  $some(x, book(x) \wedge hate(alice, x),$   
 $before(recommend(alice, x),$   
 $book(x) \wedge hate(mary, x) \wedge recommend(mary, x)))$

a sloppy reading in which a single book, hated by both Alice and Mary, is recommended by both.

Gawron and Peters account for the infelicity of this reading and the felicity of the other readings for this sentence using the Absorption Principle (Gawron and Peters, 1990, page 93). Our analysis also predicts the impossibility of the sloppy reading in (18d), though for reasons having to do with our treatment of indefinites such as ‘a book she hated’.

In order to allow for apparent scope ambiguities in non-elliptical sentences, a scoping analysis of indefinites (as proposed, for example, by Neale (1990)) fits naturally into the framework. We will assume such an analysis, as we have done implicitly in Section 2.2. For elliptical sentences, such an analysis seems to make similar predictions about the range of possible readings as the Absorption Principle.<sup>4</sup>

In the derivation of the meaning of (17), the source clause is interpreted with an undischarged assumption as (19a). The ellipsis may be resolved either before or after discharging the assumption. Taking the former option, the ellipsis equation (19b) has solution (19c), yielding the target interpretation (19d) and the interpretation (19e) for the for the conjoined sentence, still under the undischarged assumption. Discharging the quantifier then yields the reading (18a).

- (19) a.  $\langle \text{some } x \text{ book}(x) \wedge \text{hate}(\text{alice}, x) \rangle \vdash \text{recommend}(\text{alice}, x)$   
 b.  $P(\text{alice}) = \text{recommend}(\underline{\text{alice}}, x)$   
 c.  $P \mapsto \lambda y \cdot \text{recommend}(y, x)$   
 d.  $P(\text{mary}) = \text{recommend}(\text{mary}, x)$   
 e.  $\langle \text{some } x \text{ book}(x) \wedge \text{hate}(\text{alice}, x) \rangle \vdash$   
      $\text{before}(\text{recommend}(\text{alice}, x), \text{recommend}(\text{mary}, x))$

Discharging the assumption before resolution of ellipsis leads to different readings. The discharged source interpretation is (20a), leading to the ellipsis equation (20b). Here, because of the secondary occurrence of the argument to  $P$ , *alice*, a strict/sloppy distinction is manifested in the two available solutions (20c) and (20d) for  $P$ . These yield, respectively, readings (20e) and (20f) for the target clause and readings (18b) and (18c) for the conjoined sentence.

- (20) a.  $\text{some}(x, \text{book}(x) \wedge \text{hate}(\text{alice}, x), \text{recommend}(\text{alice}, x))$   
 b.  $P(\text{alice}) = \text{some}(x, \text{book}(x) \wedge \text{hate}(\text{alice}, x), \text{recommend}(\underline{\text{alice}}, x))$   
 c. (strict)  $P \mapsto \lambda y \cdot \text{some}(x, \text{book}(x) \wedge \text{hate}(\text{alice}, x), \text{recommend}(y, x))$

---

<sup>4</sup>Indeed, as Gawron and Peters point out (1990, pages 98–99):

One way of looking at the Absorption Principle is that it states a property of referential NPs that is also a property of quantifiers . . . if all our referential NPs were treated as quantifiers, the predictions of the Absorption Principle would automatically follow.

- d. (sloppy)  $P \mapsto \lambda y . some(x, book(x) \wedge hate(y, x), recommend(y, x))$
- e. (strict)  $P(mary) = some(x, book(x) \wedge hate(alice, x), recommend(mary, x))$
- f. (sloppy)  $P(mary) = some(x, book(x) \wedge hate(mary, x), recommend(mary, x))$

This exhausts the possible analyses of the sentence generable under the equational theory. Note that no interpretation akin to that given in (18d) is available; the lack of this fourth reading follows under the present analysis because the sloppy reading is always associated with narrow scope quantification. In order to get a wide scope reading for the indefinite, the ellipsis must be resolved while the quantifier is still in store. But in that case, there is no option of abstracting on the position of the pronoun interpretation, as it occurs in the assumptions rather than the matrix of the sequent. No additional constraint similar to Gawron and Peters’s Absorption Principle is required to eliminate it.

The behavior of definites in examples like (17) parallels that of indefinites to a great extent. Gawron and Peters discuss sentence (21), similar in structure to (17) but for the use of a definite, in the context of the Absorption Principle (Gawron and Peters, 1990, page 83). They claim that on the sloppy reading, the NP ‘the paper’ is not referential—that is, Alice and Mary may have read different papers. This follows under the equational analysis for the reason discussed earlier in this section: to get a sloppy reading the quantifier corresponding to ‘the paper about anaphora that she read’ must already be discharged, but in that case, separate quantification occurs in both source and target. Thus, as for example (17), the equational analysis predicts that there should be three readings, (22a-c), for the sentence (21).

(21) Alice liked the paper about anaphora that she read, and Mary did too.

- (22) a.  $the(x, anaphora-paper(x) \wedge read(alice, x), like(alice, x) \wedge like(mary, x))$
- b.  $the(x, anaphora-paper(x) \wedge read(alice, x), like(alice, x)) \wedge$   
 $the(x, anaphora-paper(x) \wedge read(alice, x), like(mary, x))$
- c.  $the(x, anaphora-paper(x) \wedge read(alice, x), like(alice, x)) \wedge$   
 $the(x, anaphora-paper(x) \wedge read(mary, x), like(mary, x))$

However, Gawron and Peters note only two readings for (21). The difference between the two strict readings (22a) and (22b) that we saw for indefinites does not appear. If we assume that there are uniqueness presuppositions associated with these definite NPs, following perhaps from pragmatic considerations, then the two readings collapse. Although the quantifier scopes separately over the source and target in (22b), there is only one ‘paper about anaphora that Alice read’, so the same paper is specified in both clauses.

As evidence for this view, consider example (23) in which a uniqueness presupposition is clearly not called for. Since the NP ‘his finger’ does not presuppose

uniqueness, all three readings are achieved, including both strict readings, one in which Bill hits the same one of John’s fingers that John hit, and one in which he hits a possibly different one of John’s fingers.

(23) John hit his finger with a hammer and so did Bill.

### 3.2 Anaphoric Dependencies Between Source and Target

Gawron and Peters also apply their Absorption Principle to limit the possible readings of sentences with ellipsis involving pronominal target subjects. They discuss sentence (24a), with interpretation of ‘her’ as a variable bound by ‘Madeline’ and ‘she’ as a variable bound by ‘her mother’, that is, as in (24b).

- (24) a. Madeline revised her mother’s paper before she did.  
 b. Madeline<sub>i</sub> revised [her<sub>i</sub> mother]<sub>j</sub>’s paper before she<sub>j</sub> did.

They claim that the sentence has a strict reading, under which Madeline’s mother revised her own paper, but no sloppy reading, under which Madeline’s mother revised her own mother’s (that is, Madeline’s grandmother’s) paper.

In order to analyze this example within the framework we propose, we must provide a detailed account of the semantics of possessive noun phrases. For simplicity, in DSP and above we interpreted noun phrases such as ‘Dan’s wife’ by a term such as *wife-of(dan)*, in which any scoping properties of the possessive determiner are ignored. This abbreviated representation was, as we pointed out in that work, adequate for the situations analyzed there, but here the readings to be accounted for demand a quantificational analysis parallel to that for indefinites used above. Once this has been done, there is still the issue as to whether to interpret the possessive pronouns as bound variables or pronouns of laziness. For the moment, we will take the former approach, returning later to the ramifications of the other alternative.

Given these assumptions, the equational analysis again predicts just this range of meanings for (24a). In the derivation of these meanings, the sentence as a whole is interpreted as in (25), which includes two quantifier assumptions corresponding to the definites ‘her mother’ (represented by *m*) and ‘her mother’s paper’ (represented by *p*).

$$(25) \langle \textit{the } m \textit{ mother-of}(m, \textit{madeline}) \rangle, \\ \langle \textit{the } p \textit{ paper-of}(p, m) \rangle \vdash \textit{before}(\textit{revise}(\textit{madeline}, p), \\ P(m))$$

Again, the ellipsis may be resolved either before or after discharging the assumptions.<sup>5</sup> If ellipsis is resolved before any of the quantifiers are discharged, we have the ellipsis equation (26a), whose single solution (26b) yields interpretation (26c) for the full sentence, which, upon discharging the assumptions, reduces to the strict reading (26d).

<sup>5</sup>The quantifiers must be discharged in the order presented, since the range of the quantifier for *p* depends on the quantified variable *m*. The categorial semantics justification for such constraints is presented in detail by Pereira (1990); see also Dalrymple, Lamping, Pereira, and Saraswat (1993).

- (26) a.  $P(\text{madeline}) = \text{revise}(\underline{\text{madeline}}, p)$   
 b.  $P \mapsto \lambda x \cdot \text{revise}(x, p)$   
 c.  $\langle \text{the } m \text{ mother-of}(m, \text{madeline}) \rangle,$   
 $\langle \text{the } p \text{ paper-of}(p, m) \rangle \vdash \text{before}(\text{revise}(\text{madeline}, p),$   
 $\text{revise}(m, p))$   
 d.  $\text{the}(m, \text{mother-of}(m, \text{madeline}),$   
 $\text{the}(p, \text{paper-of}(p, m),$   
 $\text{before}(\text{revise}(\text{madeline}, p), \text{revise}(m, p))))$

The quantifier for  $p$  can be discharged before ellipsis resolution, to yield interpretation (27a) and ellipsis equation (27b). The unique admissible solution (27c) leads to the interpretation (27d), which after discharging the final quantifier assumption yields interpretation (27e). If we assume, again based on pragmatic considerations, that the noun phrase ‘her paper’ presupposes uniqueness this reading is equivalent to interpretation 26d.

- (27) a.  $\langle \text{the } m \text{ mother-of}(m, \text{madeline}) \rangle \vdash$   
 $\text{before}(\text{the}(p, \text{paper-of}(p, m),$   
 $\text{revise}(\text{madeline}, p)), P(m))$   
 b.  $P(\text{madeline}) = \text{the}(p, \text{paper-of}(p, m), \text{revise}(\underline{\text{madeline}}, p))$   
 c.  $P \mapsto \lambda x \cdot \text{the}(p, \text{paper-of}(p, m), \text{revise}(x, p))$   
 d.  $\langle \text{the } m \text{ mother-of}(m, \text{madeline}) \rangle \vdash$   
 $\text{before}(\text{the}(p, \text{paper-of}(p, m), \text{revise}(\text{madeline}, p)),$   
 $\text{the}(p, \text{paper-of}(p, m), \text{revise}(m, p)))$   
 e.  $\text{the}(m, \text{mother-of}(m, \text{madeline}),$   
 $\text{before}(\text{the}(p, \text{paper-of}(p, m), \text{revise}(\text{madeline}, p)),$   
 $\text{the}(p, \text{paper-of}(p, m), \text{revise}(m, p))))$

In order to derive a sloppy interpretation, then, both quantifiers will have to be discharged before resolving the ellipsis. But this disallows use of a bound variable as the interpretation for the pronoun ‘she’. Note that under the discharged source clause meaning (28a), a bound variable interpretation for ‘she<sub>j</sub>’ is no longer available, because the binding assumption for ‘[her mother]<sub>j</sub>’ has been discharged and the corresponding variable has been abstracted over. In perhaps more intuitive but technically less precise terms, the conjoined source and target meanings (28b) contain an illicit free occurrence of  $m$  as argument of the ellipsis property  $P$ . Thus, no sloppy reading is generable.

- (28) a.  $\text{the}(m, \text{mother-of}(m, \text{madeline}),$   
 $\text{the}(p, \text{paper-of}(p, m), \text{revise}(\text{madeline}, p)))$



- b.  $before(the(m, mother-of(m, madeline),$   
 $the(p, paper-of(p, m), revise(madeline, p))),$   
 $P(m))$

We digress to note that, although, as Gawron and Peters say, it is difficult to interpret (24a) with a sloppy interpretation, sentences of similar structure can apparently be so interpreted. Consider, for example, sentences (29a) and (29c), under the pronominal antecedency relations marked in (29b) and (29d). These examples seem to allow for sloppy readings, if not perfectly felicitously, at least more easily than does (24a).

- (29) a. Ronnie criticized his predecessor's policies just as he did when he assumed office.  
 b.  $Ronnie_i$  criticized [ $his_i$  predecessor] $_j$ 's policies just as  $he_j$  did when  $he_j$  assumed office.  
 c. Mary heard about the layoffs from her manager shortly after he did.  
 d.  $Mary_i$  heard about the layoffs from [ $her_i$  manager] $_j$  shortly after  $he_j$  did.

These examples are problematic for both Gawron and Peters analysis and the equational one. As one possible alternative that would allow the equational analysis to handle such extended meanings, we might entertain interpreting the pronoun 'she' in (24a) as a pronoun of laziness, that is, with the same interpretation as that of the phrase 'her mother' (where 'her' refers to Madeline). In this case, the sentence is interpreted as in (30a), with an undischarged assumption corresponding to the pronoun of laziness 'she'. The resulting ellipsis equation (30b) has a solution (30c), which generates the interpretation (30d) for the full sentence, which reduces to the sloppy reading (30e) upon discharging the assumption. (A logical equivalent is given as (30f), demonstrating that the sloppy reading has been derived.)

- (30) a.  $\langle the\ n\ mother-of(n, madeline) \rangle \vdash$   
 $before(the(m, mother-of(m, madeline),$   
 $the(p, paper-of(p, m), revise(madeline, p))),$   
 $P(n))$   
 b.  $P(madeline) = the(m, mother-of(m, madeline),$   
 $the(p, paper-of(p, m), revise(\underline{madeline}, p)))$   
 c.  $P \mapsto \lambda x \cdot the(m, mother-of(m, x), the(p, paper-of(p, m), revise(x, p)))$   
 d.  $\langle the\ n\ mother-of(n, madeline) \rangle \vdash$   
 $before(the(m, mother-of(m, madeline),$   
 $the(p, paper-of(p, m), revise(madeline, p))),$   
 $the(m, mother-of(m, n),$   
 $the(p, paper-of(p, m), revise(n, p)))$

- e. *the(n, mother-of(n, madeline),*  
*before(the(m, mother-of(m, madeline),*  
*the(p, paper-of(p, m), revise(madeline, p))),*  
*the(m, mother-of(m, n),*  
*the(p, paper-of(p, m), revise(n, p))))*
- f. *the(m, mother-of(m, madeline),*  
*the(g, mother-of(g, m),*  
*before(the(p, paper-of(p, m), revise(madeline, p)),*  
*the(p, paper-of(p, g), revise(m, p))))*

The “pronoun of laziness” augmentation to the equational analysis allows for the extra reading — both for (24a) and for (29a) and (29c) — but has its own problems. For instance, in a sentence such as (31a), interpreting ‘she’ as a pronoun of laziness with the same meaning as ‘a friend of hers’ would allow at least the extraneous reading given in (31b), involving meetings among Mary and three separate friends.<sup>6</sup> Thus, it would be important to restrict somehow the cases in which pronoun of laziness interpretations are available.

- (31) a. Mary bumped into a friend of hers before she did.  
 b. Mary<sub>i</sub> bumped into [a friend of hers<sub>i</sub>]<sub>j</sub> before [a friend of hers<sub>i</sub>]<sub>k</sub> bumped into [a friend of hers<sub>i</sub>]<sub>l</sub>.

In summary, the equational analysis embodies the predictions of the Absorption Principle without such a principle being explicitly postulated. Cases that appear to violate the Absorption Principle can be modeled as actually involving pronouns of laziness, rather than bound anaphora, but at the risk of greatly expanding the range of possible readings.

### 3.3 Source Anaphoric Dependencies with Nonparallel Elements

In Section 3.1, we discussed the reading alternations from antecedents of pronouns in the source clause, where the antecedent NP is a parallel element of the ellipsis. We turn now to the final configuration, in which a source pronoun takes as antecedent a source NP that is *not* a parallel element. Harper (1988) notes, for instance, sentence (32), which has two readings (33a) and (33b), rather than the four (33a-d) that might be predicted by a naive analysis of strict and sloppy pronouns.

- (32) Fred showed his mother her dog, and George did too.

- (33) a. George showed Fred’s mother Fred’s mother’s dog.  
 b. George showed George’s mother George’s mother’s dog.

---

<sup>6</sup>We are indebted to one of the reviewers for bringing up this issue.

c. \*George showed George’s mother Fred’s mother’s dog.

d. \*George showed Fred’s mother George’s mother’s dog.

Again, the equational analysis makes exactly this prediction. The source clause is interpreted under two quantifier assumptions as in (34).

$$(34) \langle \textit{the } m \textit{ mother-of}(m, fred), \langle \textit{the } d \textit{ dog-of}(d, m) \rangle \vdash \textit{show}(fred, m, d)$$

The dependencies among the quantifiers require that the second assumption be discharged before the first, as discussed in footnote 5. There are three points, then, at which the ellipsis can be resolved: before any assumptions are discharged, after the second is discharged, or after both are discharged. If we assume that the phrases ‘his mother’ and ‘her dog’ introduce quantifiers that presuppose uniqueness, then it makes no difference whether the quantifiers are discharged early (getting narrow scope) or late (getting wider scope), in the sense that any wide scope reading is equivalent to some narrow scope reading. This collapsing of readings, discussed also in Section 3.1, allows us to simplify the discussion, as we need only look at the possible narrow scope readings, that is, those for which the quantifiers are discharged before ellipsis is resolved.

Discharging the quantifiers yields the source clause meaning (35a). The ellipsis equation (35b) has the two solutions (35c) and (35d). These correspond to the readings (33a) and (33b), respectively.

$$(35) \begin{aligned} \text{a. } & \textit{the}(m, \textit{mother-of}(m, fred), \textit{the}(d, \textit{dog-of}(d, m), \textit{show}(fred, m, d))) \\ \text{b. } & P(fred) = \textit{the}(m, \textit{mother-of}(m, fred), \textit{the}(d, \textit{dog-of}(d, m), \textit{show}(\underline{fred}, m, d))) \\ \text{c. } & P \mapsto \lambda x \cdot \textit{the}(m, \textit{mother-of}(m, fred), \textit{the}(d, \textit{dog-of}(d, m), \textit{show}(x, m, d))) \\ \text{d. } & P \mapsto \lambda x \cdot \textit{the}(m, \textit{mother-of}(m, x), \textit{the}(d, \textit{dog-of}(d, m), \textit{show}(x, m, d))) \end{aligned}$$

The reason that the equational analysis does not predict the ‘mixed’ readings (33c) and (33d) is that there is a referential dependence between ‘his mother’ and ‘her’ in the source. The pronoun ‘her’, since it is interpreted as a bound anaphor, gets resolved to whoever fits the description ‘his mother’.

## 4 Interactions of Ellipsis and Intensional Operators

We turn now to a discussion of the interaction of ellipsis and the scope of intensional operators, so-called *de re/de dicto* alternations. Given that we have been using typed  $\lambda$ -terms to represent the meanings of extensional clauses, it will be natural for us to use a variant of Montague’s intensional logic IL (Montague, 1973) for the meanings of intensional clauses. In order to distinguish intensional logic constants and quantifiers from their extensional counterparts, the former will be written in boldface.

Using the equational method to determine the meaning of elliptical constructions in the face of intensionality requires extending it to intensional formulas. Recall the fundamentals of the equational method: Given a source clause with meaning  $s$  and meanings of the parallel elements given by  $s_1, \dots, s_n$ , we want to find a relation  $P$  such that predicating it of  $s_1, \dots, s_n$  gives the meaning  $s$ . Since we want  $P$  to be invariant over possible worlds, it should be an intensional relation. Thus, with respect to a given world, we want  $(\forall P)(s_1, \dots, s_n) = s$ . However, since this should hold in all possible worlds, we generalize to

$$(36) \quad \wedge((\forall P)(s_1, \dots, s_n)) = \wedge s$$

This equation needs to be solved for  $P$  as before. The target clause is then interpreted by  $(\forall P)(t_1, \dots, t_n)$  where  $t_1, \dots, t_n$  are the meanings of the parallel elements in the target.

In order to solve intensional logic equations such as (36), we could specify a method for performing unification directly over higher-order intensional formulas. Alternatively, we can translate the intensional logic to an extensional logic, so that the normal higher-order unification algorithm can be used directly. We follow the latter approach here.<sup>7</sup>

The translation that we use, as described by Gallin (1975, Section 8), converts intensional formulas to *two-sorted type theory* formulas, in which possible worlds are made explicit. Two-sorted type theory is just a version of the simple theory of types that we have been using elsewhere in this work with a new primitive type  $s$  for world indices. The translation into two-sorted type theory of an intensional formula  $F$  relative to a possible world  $a$ , notated  $T_a(F)$ , is defined inductively as follows:

$$\begin{aligned} T_a(x) &= x \\ T_a(c) &= \begin{cases} c & \text{if } c \text{ corresponds to a proper name} \\ c(a) & \text{otherwise} \end{cases} \\ T_a(P(Q_1, \dots, Q_n)) &= T_a(P)(T_a(Q_1), \dots, T_a(Q_n)) \\ T_a(\neg(P)) &= \neg(T_a(P)) \\ T_a(P \wedge Q) &= T_a(P) \wedge T_a(Q) \\ T_a(\mathbf{some}(x, P, Q)) &= \mathbf{some}(x, T_a(P), T_a(Q)) \\ T_a(\lambda x \cdot P) &= \lambda x \cdot T_a(P) \\ T_a(\wedge P) &= \lambda a \cdot T_a(P) \\ T_a(\forall P) &= T_a(P)(a) \end{aligned}$$

The rule for constants corresponding to proper names follows from the fact that proper names are to be interpreted as rigid designators, that is, as denoting the same individual in all worlds (Gamut, 1991, Section 6.3.7). (Without this special rule, proper names would be subject to *de re/de dicto* alternations.) The rules for other quantifiers follow the rule for **some**, and other connectives follow  $\neg$  and  $\wedge$ .

By way of a simple example, we consider the trivial extensional sentence

$$(37) \quad \text{John left, and Bill did too.}$$

---

<sup>7</sup>Of course, one could also generate the extensional translations directly, for example, as described by Janssen (1986) or Muskens (1989).

The meaning of the source clause is taken to be  $\mathit{left}(\mathit{john})$ , and the ellipsis equation is  $\wedge((\forall P)(\mathit{john}) = \wedge(\mathit{left}(\mathit{john}))$ . Translating both sides to two-sorted logic, we get the equation  $\lambda a \cdot P(a)(\mathit{john}) = \lambda a \cdot \mathit{left}(a)(\mathit{john})$ , with solution  $P \mapsto \mathit{left}$ . The two-sorted logic target meaning is then given by

$$\begin{aligned} T_a((\forall P)(\mathit{bill})) &= P(a)(T_a(\mathit{bill})) \\ &= \mathit{left}(a)(T_a(\mathit{bill})) \\ &= \mathit{left}(a)(\mathit{bill}) \end{aligned}$$

which is the two-sorted translation of the intensional logic  $\mathit{left}(\mathit{bill})$  as desired.

#### 4.1 Equational Analysis of the *De Re/De Dicto* Distinction

We use sentence (38) to demonstrate the range of meanings generable by the equational analysis in the presence of intensional operators. The relative ordering between discharging the quantifier assumption for ‘a unicorn’ and solving the ellipsis equation generates the three possible readings of (38): a *de dicto* reading in which both seek unicorns nonspecifically, and two *de re* readings, one in which both John and Bill want to find the same specific unicorn and one in which each may be looking for a different specific unicorn.

The source clause ‘Bill wants to find a unicorn’ itself has the *de re* and *de dicto* readings given in (39a) and (39b), respectively.<sup>8</sup>

(38) Bill wants to find a unicorn, and John does too.

- (39) a.  $\mathit{some}(u, \mathit{unicorn}(u), \mathit{want}(\mathit{bill}, \wedge \mathit{find}(\mathit{bill}, u)))$   
 b.  $\mathit{want}(\mathit{bill}, \wedge \mathit{some}(u, \mathit{unicorn}(u), \mathit{find}(\mathit{bill}, u)))$

Starting with the *de dicto* reading of the source (39b), we obtain the intensional logic ellipsis equation (40a). The corresponding two-sorted equation (40b) has the single admissible solution (40c), the translation of the intensional logic (40d). The target clause meaning is therefore (40e), which is the *de dicto* meaning of ‘John wants to find a unicorn.’ The single *de dicto* interpretation of (38) is thus (40f).

- (40) a.  $\wedge((\forall P)(\mathit{bill}) = \wedge(\mathit{want}(\mathit{bill}, \wedge \mathit{some}(u, \mathit{unicorn}(u), \mathit{find}(\mathit{bill}, u))))$   
 b.  $\lambda a \cdot P(a)(b) = \lambda a \cdot \mathit{want}(a)(\mathit{bill}, \lambda a \cdot \mathit{some}(u, \mathit{unicorn}(a)(u), \mathit{find}(a)(\mathit{bill}, u)))$   
 c.  $P \mapsto \lambda a \cdot \lambda x \cdot \mathit{want}(a)(x, \lambda a \cdot \mathit{some}(u, \mathit{unicorn}(a)(u), \mathit{find}(a)(x, u)))$   
 d.  $\wedge \lambda x \cdot \mathit{want}(x, \wedge \mathit{some}(u, \mathit{unicorn}(u), \mathit{find}(x, u)))$   
 e.  $(\forall P)(\mathit{john}) = \mathit{want}(\mathit{john}, \wedge \mathit{some}(u, \mathit{unicorn}(u), \mathit{find}(\mathit{john}, u)))$

---

<sup>8</sup>Following the analysis of infinitival complements in DSP (Section 5.2.1), we take both occurrences of  $\mathit{bill}$  to be primary, as they arise together from the interpretation of a single syntactic element in the source clause. Since we will be using our categorial semantics setup for quantifier scoping, we will not need quantifying-in, and transitive verb meanings can be simply relations between individuals, and not relations between individuals and individual sublimations as in Montague’s system.

$$\text{f. } \mathit{want}(\mathit{bill}, \wedge \mathit{some}(u, \mathit{unicorn}(u), \mathit{find}(\mathit{bill}, u))) \wedge \\ \mathit{want}(\mathit{john}, \wedge \mathit{some}(u, \mathit{unicorn}(u), \mathit{find}(\mathit{john}, u)))$$

The remaining derivations in this section can be calculated similarly, using the translation between intensional logic and two-sorted type theory for ellipsis equations. However, for simplicity we will just show the intensional logic inputs and outputs of the resolution process and not the intermediate steps in two-sorted type theory.

Starting with the *de re* reading of the source (39a), we obtain the ellipsis equation (41a) with solution (41b), leading to the target clause meaning (41c), in which both John and Bill are looking for separate *de re* unicorns.

$$(41) \text{ a. } \wedge (\forall P)(\mathit{bill}) = \wedge \mathit{some}(u, \mathit{unicorn}(u), \mathit{want}(\mathit{bill}, \wedge \mathit{find}(\mathit{bill}, u))) \\ \text{b. } P \mapsto \wedge \lambda x \cdot \mathit{some}(u, \mathit{unicorn}(u), \mathit{want}(x, \wedge \mathit{find}(x, u))) \\ \text{c. } \mathit{some}(u, \mathit{unicorn}(u), \mathit{want}(\mathit{bill}, \wedge \mathit{find}(\mathit{bill}, u))) \wedge \\ \mathit{some}(u, \mathit{unicorn}(u), \mathit{want}(\mathit{john}, \wedge \mathit{find}(\mathit{john}, u)))$$

Finally, if the ellipsis is resolved before discharging the quantifier assumption in the source clause interpretation (42a), we have ellipsis equation (42b) with solution (42c), which leads to the interpretation (42d). After discharging the quantifier, the second *de re* reading (42e) is obtained, in which John and Bill pursue a single specific unicorn.

$$(42) \text{ a. } \langle \mathit{some } u \mathit{ unicorn}(u) \rangle \vdash \mathit{want}(\mathit{bill}, \wedge \mathit{find}(\mathit{bill}, u)) \\ \text{b. } \wedge (\forall P)(\mathit{bill}) = \wedge (\mathit{want}(\mathit{bill}, \wedge \mathit{find}(\mathit{bill}, u))) \\ \text{c. } P \mapsto \wedge \lambda x \cdot \mathit{want}(x, \wedge \mathit{find}(x, u)) \\ \text{d. } \langle \mathit{some } u \mathit{ unicorn}(u) \rangle \vdash \mathit{want}(\mathit{bill}, \wedge \mathit{find}(\mathit{bill}, u)) \wedge \\ \mathit{want}(\mathit{john}, \wedge \mathit{find}(\mathit{john}, u)) \\ \text{e. } \mathit{some}(u, \mathit{unicorn}(u), \mathit{want}(\mathit{bill}, \wedge \mathit{find}(\mathit{bill}, u))) \wedge \\ \mathit{want}(\mathit{john}, \wedge \mathit{find}(\mathit{john}, u))$$

## 4.2 Missing Readings Involving Intensional Operators

The previous example demonstrates that the range of readings for noun phrases made available by the equational analysis in the context of intensional operators is wide enough. But it is also important that the range generated is not too wide. Sag (1976, page 72) notes that sentences with ellipsis can sometimes display only a subset of the readings for included definites as compared to nonelliptical variants. For instance, he notes that sentence (43a) is ambiguous between readings (44a) and (44b), whereas its elliptical variant (43b) has only the reading (44a).

$$(43) \text{ a. } \text{Betsy's father wants her to read everything her boss wants her to read.} \\ \text{b. } \text{Betsy's father wants her to read everything her boss does.}$$

- (44) a.  $every(x, want(boss(betsy), \wedge read(betsy, x)),$   
 $want(father(betsy), \wedge read(betsy, x)))$
- b.  $want(father(betsy),$   
 $\wedge every(x, want(boss(betsy), \wedge read(betsy, x)),$   
 $read(betsy, x)))$

Again these facts follow from the equational analysis. Examining first the nonelliptical case, the infinitival complement ‘her to read everything...’ in (43a), prior to quantifier discharge, is interpreted as in (45a). If the quantifier is discharged here, the entire sentence is interpreted as in (44b). If, as in (45b), the quantifier is not discharged until the full sentence meaning is constructed, the reading (44a) is generated.

- (45) a.  $\langle every\ x\ want(boss(betsy), \wedge read(betsy, x)) \rangle \vdash read(betsy, x)$
- b.  $\langle every\ x\ want(boss(betsy), \wedge read(betsy, x)) \rangle$   
 $\vdash want(father(betsy), \wedge read(betsy, x))$

In the elliptical version of the sentence (43b), the meaning of ‘her to read everything...’ is (46a). Without discharging the assumption, this leads to unresolved sentence meaning (46b), ellipsis equation (46c) with solution (46d), and full sentence interpretation (46e). Discharging the assumption then yields reading (44a).

- (46) a.  $\langle every\ x\ (\forall P)(boss(betsy)) \rangle \vdash read(betsy, x)$
- b.  $\langle every\ x\ (\forall P)(boss(betsy)) \rangle$   
 $\vdash want(father(betsy), \wedge read(betsy, x))$
- c.  $\wedge((\forall P)(father(betsy))) = \wedge want(\underline{father(betsy)}, \wedge read(betsy, x))$
- d.  $P \mapsto \wedge \lambda y \cdot want(y, \wedge read(betsy, x))$
- e.  $\langle every\ x\ want(boss(betsy), \wedge read(betsy, x)) \rangle$   
 $\vdash want(father(betsy), \wedge read(betsy, x))$

If alternatively, the quantifier assumption in (46b) is discharged, we obtain (47a), which gives rise to ellipsis equation (47b).

- (47) a.  $every(x, (\forall P)(boss(betsy)), want(father(betsy), \wedge read(betsy, x)))$
- b.  $\wedge((\forall P)(father(betsy)))$   
 $= \wedge every(x, (\forall P)(boss(betsy)),$   
 $want(\underline{father(betsy)}, \wedge read(betsy, x)))$

Equation (47b) has no solutions for  $P$ . Accordingly, the higher-order unification algorithm produces no solutions, due to a constraint analogous to the so-called occurs-check in the first-order unification algorithm (Huet, 1975, Section 5.3).

## 5 Conclusion

In this paper, we have discussed a range of phenomena involving the interaction of ellipsis and quantification previously noted in the literature by Sag, Hirschbühler, Gawron and Peters, Harper, and others. All of them were seen to admit of categorial-semantic analyses within the equational analysis of ellipsis previously proposed by the authors. The only extension that is required is the ability to apply the equational analysis within an intensional logic. This is achieved by reducing the problem to the extensional case through Gallin's encoding of intensional logic in two-sorted type theory.

## Acknowledgments

This material is based upon work supported in part by the National Science Foundation under Grant No. IRI-9350192 and by a grant from Xerox Corporation. We are indebted to the following people for helpful discussions: Kazuhiko Fukushima, Mark Gawron, Andrew Kehler, Chris Kennedy, Shalom Lappin, Hiroshi Nakagawa, Stanley Peters, and Ivan Sag. In addition, we profited from interaction with audiences at various institutions at which this material was presented, including Waseda University, University of Stuttgart, the European Summer School on Logic, Language, and Information in Barcelona, Spain, University of Oslo, and IBM, Yorktown Heights. Finally, we wish to thank the anonymous reviewers for the exemplary care and thoroughness of their efforts, which contributed greatly to the paper.

## References

- Barwise, Jon and Robin Cooper. 1981. Generalized quantifiers and natural language. *Linguistics and Philosophy*, 4:159–219.
- Cooper, Robin. 1983. *Quantification and Syntactic Theory*, volume 21 of *Synthese Language Library*. D. Reidel, Dordrecht, Netherlands.
- Dalrymple, Mary, John Lamping, Fernando Pereira, and Vijay Saraswat. 1993. A deductive account of quantification in LFG. In preparation. Available from the Computation and Language E-Print Archive as cmp-lg/9404009.
- Dalrymple, Mary, Stuart M. Shieber, and Fernando C. N. Pereira. 1991. Ellipsis and higher-order unification. *Linguistics and Philosophy*, 14:399–452.
- Fiengo, Robert and Robert May. 1994. *Indices and Identity*, volume 24 of *Linguistic Inquiry Monographs*. MIT Press, Cambridge, Massachusetts.
- Gallin, Daniel. 1975. *Intensional and Higher-Order Modal Logic*, volume 19 of *North-Holland Mathematics Studies*. North-Holland, Amsterdam.
- Gamut, L. T. F. [pseud.]. 1991. *Logic, Language, and Meaning*, volume 2. University of Chicago Press, Chicago, Illinois.



- Gawron, Mark and Stanley Peters. 1990. *Anaphora and Quantification in Situation Theory*. Number 19 in CSLI Lecture Notes. Center for the Study of Language and Information, Stanford, California. Distributed by Chicago University Press.
- Harper, Mary. 1988. Representing pronouns in logical form: Computational constraints and linguistic evidence. Department of Computer Science, Brown University.
- Hestvik, Arild. 1992. Subordination and strict identity of reflexives. In *Proceedings of the Stuttgart Ellipsis Workshop*, Stuttgart. University of Stuttgart.
- Hirshbühler, Paul. 1982. VP deletion and across-the-board quantifier scope. In James Pustejovsky and Peter Sells, editors, *Proceedings of NELS 12*. GLSA, University of Massachusetts-Amherst.
- Huet, Gérard. 1975. A unification algorithm for typed  $\bar{\lambda}$ -calculus. *Theoretical Computer Science*, 1:27–57.
- Janssen, Theo M. V. 1986. *Foundations and Applications of Montague Grammar — Part 2: Applications to Natural Language*, volume 28 of *CWI Tract*. Centrum voor Wiskunde en Informatica, Amsterdam, The Netherlands.
- Kehler, Andrew. 1993. The effect of establishing coherence in ellipsis and anaphora resolution. In *Proceedings of the 31st Conference of the Association for Computational Linguistics (ACL-93)*, Columbus, Ohio, June.
- Kempson, Ruth M. and Annabel Cormack. 1983. Type lifting rules and VP anaphora. In Michael Barlow, Daniel P. Flickinger, and Michael T. Wescoat, editors, *Proceedings of West Coast Conference on Formal Linguistics 2*, pages 140–152.
- Montague, Richard. 1973. The proper treatment of quantification in ordinary English. In J. Hintikka, J. Moravcsik, and P. Suppes, editors, *Approaches to Natural Language*. Reidel, Dordrecht.
- Muskens, R. 1989. *Meaning and Partiality*. Ph.D. thesis, University of Amsterdam.
- Neale, Stephen. 1990. *Descriptions*. MIT Press, Cambridge, Massachusetts.
- Pereira, Fernando C. N. 1990. Categorical semantics and scoping. *Computational Linguistics*, 16(1):1–10, March.
- Sag, Ivan A. 1976. *Deletion and Logical Form*. Ph.D. thesis, MIT.
- Williams, Edwin. 1977. Discourse and logical form. *Linguistic Inquiry*, 8(1):101–139.