

Quantification, Pronouns, and VP Anaphora

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1. STARTING POINTS

The central concern of this paper is the nature of semantic interpretation, in particular the issue of whether an intermediate level of "logical form" (e.g. a translation into intensional logic as in Montague 1973), mediating between natural language syntax and its model-theoretical interpretation, is dispensable. Such questions cannot, of course, be examined in isolation; in this section we will lay out a number of hypotheses that we will initially assume, the dispensability of translation into IL being just one of them. In Section 2 we state the central problems to be dealt with. In Section 3 we present a fragment of English which embodies our initial hypotheses and offers solutions to certain problems about pronouns and quantifiers. In Section 4 we attempt to extend the fragment to account for "VP deletion" phenomena (though not by deletion), and then show that our original hypotheses appear not to be cotenable. We end up with an apparent need for accepting a level of "logical form" as indispensable, even if we were to give up the uniform treatment of bound-variable pronouns and "free variable" pronouns described in Section 1.1 below. There is an additional technical problem which arises in our fragment even without the extension to VP deletion, which we discuss in an appendix and which may also signal the need for a level of logical form. Our particular conclusions are necessarily relative to our initial assumptions; our only general conclusion is that the nature of free and bound variables in semantic interpretation is very much in need of further elucidation before we can hope to settle the issue of the need for or desirability of a level of logical form in explaining the relation between syntax and semantics in natural languages.

1.1. Pronouns as variables

As one initial hypothesis we adopt the proposal of Cooper (1979) that each of the third-person singular non-reflexive pronouns *he*, *she*, *it* has the set of possible meanings represented by the following translation schema:

- (1) $\{ \lambda P^V P(x_i): i \text{ a natural number} \} \cup$
 $\{ \lambda P \exists x [\forall y [[^V \pi] (y) \leftrightarrow y = x] \wedge ^V P(x)]; \pi \text{ a property-denoting}$
 $\text{expression containing only free variables and parentheses} \} .$

Under this proposal the difference between “bound variable pronouns” and other pronouns (e.g. “discourse” pronouns) is not in the meanings of the pronouns themselves, but only in whether their initially free variables (x_i in the simple case, any variables free in the π -expression in the complex case) eventually get bound within the sentence or not. For example, *him* in both (2a) and (2b) below

- (2) (a) Mary loves *him*.
 (b) *Every man* loves a woman who loves *him*.

has as one of its interpretations¹ $\lambda P^V P(x_0)$; the difference is that in (2a) an appropriate value for the free x_0 must be determinable from the linguistic or non-linguistic context for an occurrence of the sentence to receive a determinate interpretation, whereas in (2b) x_0 may be bound by interpreting *every man* as “quantified in” with respect to x_0 . (The complex part of Cooper’s translation schema covers cases like the *it* of (3a) and (3b) below:

- (3) (a) The man who gave his paycheck to his wife was wiser than the man who gave *it* to his mistress.
 (b) Every man who owns a donkey beats *it*.

But we will not be much concerned with these cases here, and will ignore them for the most part in what follows.)

Cooper’s proposal contrasts with the alternative urged by Janssen (1980) in which the bound variable *him* in (2b) is translated as $\lambda P^V P(x_0)$, as above, but the “free” *him* in (2a) is interpreted as something like $\lambda P^V P(c_0)$, where c_0 is a context-dependent constant or what is sometimes called a context variable: semantically a constant, but dependent for its interpretation on the context. The recent literature in formal semantics contains examples of both types of treatments of pronouns², but relatively few arguments for choosing between them besides those in Cooper (1979) and Janssen (1980). We return to this issue in Section 4.6 below.

1.2. General framework

Among our other initial assumptions are the following constraints on the overall theory of syntax and semantics:

- (i) We assume Montague's general theory (Montague 1970b: UG), especially with respect to compositionality, except as modified by Cooper (1975) to permit the direct assignment of sets of interpretations to ambiguous sentences without a level of a disambiguated language, including Cooper's "storage" device (which amounts to a limited relaxation of the compositionality requirement).
- (ii) We assume the well-formedness constraint of Partee (1979) strengthened to exclude indexed forms like he_0 , he_1 ... from the syntax.
- (iii) The syntax is limited to a (rich) context-free grammar³ along the lines of recent proposals by Gazdar (1982), Gazdar & Sag (1981), Saenz (see Saenz (forthcoming)), and Peters and Karttunen (see Karttunen (1981)).
- (iv) The semantics is a direct model-theoretic interpretation of the syntax; an intermediate level of translation into intensional logic is dispensable (Cooper (1975)).⁴ This last hypothesis accords with Montague's assertions but runs counter to most earlier and much current work in semantics by linguists, where the usual assumption is that the output of semantic interpretation is a "semantic representation", an assumption which is compatible with the rest of Montague's program provided that the "semantic representation" is capable of being interpreted model-theoretically.

1.3. VP-deletion

Our final starting point is the recent work on VP-deletion by Williams (1977) and Sag (1976). Sag and Williams both provide treatments which involve the basic principle that VP-deletion depends on "semantic identity" (McCawley 1967, Morgan 1970, Keenan 1971, Verkuyl 1972, Dahl 1972, Koster 1979), Sag with a deletion rule, and Williams with an interpretive principle. Both interpret semantic identity as identity of "logical form" up to within alphabetic change of bound variables. Ladusaw (1979) suggests that the appropriate sense of "semantic identity" should be model-theoretically definable; if it is not, that would be evidence for the need for an intermediate level of logical form. This issue is taken up in Section 4 below.

2. THE PROBLEMS

2.1. *Reflexive and non-reflexive pronouns*

Montague's PTQ did not include reflexive pronouns; an adequate treatment must give the correct distribution of reflexive pronouns and correspondingly restrict the possible interpretations of non-reflexive pronouns. All of the approximately adequate treatments so far proposed seem to violate one or more of the constraints given in Section 1.2 above (e.g. Bennett 1976, Thomason 1976, Chomsky 1973). One of our aims here is to try to provide a descriptively adequate account of pronoun distribution and interpretation within the bounds of those constraints; this is the primary goal of the fragment presented in Section 3.

2.2. *Semantic identity, pronouns, and variables*

The chief difficulty we find in providing a model-theoretic version of "semantic identity" appropriate for the VP-deletion phenomena arises in trying to give a suitable interpretation to variables free within the "antecedent" VP. Details and examples will be found in Section 4; here we just sketch the problem very briefly. Stated in terms of "logical form", VP-deletion may involve a VP translation containing a free variable iff either (a) that variable remains free (i.e. gets its interpretation from the context) in the sentence containing the antecedent VP and the (possibly same) sentence containing the missing VP, or (b) the variable is bound in both VP's by the same (token) variable-binder. From this condition it appears that the relevant sameness of interpretation of two VP's cannot be determined independently of the larger context in which they appear, insofar as the interpretation of any variables free within them rests on whether and where they are bound in the containing sentence(s). Jansen's proposal for non-uniform pronoun interpretations would appear to have some advantages over Cooper's uniform treatment with respect to this problem; we discuss this issue in Section 4.6.

Our discussion of these problems below will not be conclusive; we hope at least to show the need for a better understanding of the interpretation of variables. The chief difficulties encountered in both Sections 3 and 4 seem to result from the "globally syncategorematic" nature of the interpretation of variables, i.e. from the fact that their interpretation in some sense depends on what binds them, which may be arbitrarily "far away" from where they occur in the semantic structure. The difficulties are resolvable in a system which includes a level of logical form and allows principles to be stated in terms of global properties of the logical form (as is apparently allowed in the work of Chomsky, Williams, Sag, Higgin-

botham, and others working in the Revised Extended Standard Theory); whether they are resolvable in a more constrained theory is an open question.

3. THE FIRST FRAGMENT: QUANTIFICATION, BOUND AND FREE PRONOUNS, REFLEXIVES, AND CONTROL

The fragment presented in this section is roughly comparable to that of PTQ in its coverage, but incorporates the distinction between reflexive and non-reflexive pronouns (including a version of the “non-coreference” restrictions of Lasnik 1976 and Reinhart 1977) and a set of constraints on when a quantifier phrase can be interpreted as binding a pronoun which we consider more adequate than the simple “leftmost constraint” of PTQ. In Section 3.1 we describe the format of the fragment with illustration of its novel features; in Section 3.2 we present the fragment; and in Section 3.3 we provide some examples and brief discussion. Fuller discussion and motivation of many features of the analysis are found in Bach & Partee (1980).

3.1. Format

Our framework is a Saenz-Ross phrase structure grammar⁵ with a Cooper store (see Cooper 1975) and two new stores. The grammar is a simultaneous recursive definition of 9-tuples:

- (i) an English expression
- (ii) a syntactic category
- (iii) syntactic features (mostly omitted here)⁶
- (iv) translation into intensional logic
- (v) QST (“quantifier store” or “Cooper store”): a set of pairs (possibly empty) $\langle \alpha, i \rangle$ where α is an NP meaning or WH, SELF1, or SELF2 and i is a natural number
- (vi) semantic type (omitted here)
- (vii) semantic features (omitted here)
- (viii) LPST (“local pronoun store”): a set of natural numbers (described below)
- (ix) SPST (“super pronoun store”): a set of natural numbers (described below)

Here is an example of a rule in this format:

$$\begin{array}{ll}
 \text{(R6)} \quad S = NP \text{ VP} & \text{LPST}(1) \cap \text{LPST}(2) = \emptyset \\
 \quad \quad \quad 0' = 2' (\wedge 1') & \text{QST}_R(2) = \emptyset \\
 \quad \quad \quad \text{QST}(0) = \text{QST}(1) \cup \text{QST}(2) & \text{LPST}(0) = \text{QST}_1(0) \\
 & \text{SPST}(0) = \text{SPST}(1) \cup \text{SPST}(2)
 \end{array}$$

Interpretation: The numbers 0, 1, 2 refer to the S, the NP, and the VP respectively (numbering mentioned categories from left to right); 0' means the translation of element 0 (the S in this case). The first two lines on the left are thus tantamount to the rules S4 and T4 of PTQ. The QST statement says that the stored part of the meaning for the whole sentence is the union of the stores of its parts (the usual case). The statements on the right put conditions on the contents of the stores of the NP and the VP and define the contents of the stores of the S; the functions of LPST and SPST are sketched briefly below and discussed with examples in Section 3.3.

The function of LPST is to recursively define the domains in which a non-reflexive pronoun cannot function as a variable bound to a potential antecedent; cf. the contrast between (4a) and (4b).

- (4) (a) #*Every man* loves *him*. [# indicates anomaly on intended reading.]
 (b) *Every man* believes that Mary loves *him*.

Our treatment of the contrast rests on the idea that two variables within the same "local context" (roughly, co-arguments of a verb or other predicate) cannot have the same index.⁷

Our QST functions basically like Cooper's storage device (Cooper 1975); all quantifier phrases are syntactically generated in their surface positions, but their meanings may be optionally stored in QST, to be "quantified in" at a higher S or VP level. We also use QST to obligatorily store special meanings for reflexive pronouns which enable them to be treated as "relation-reducers" (Geach 1962, Potts 1979) applying to VP's and TVP's (Montague's IV's and TV's), and to store a special symbol WH corresponding to a gap (an empty NP) in a relative clause, which triggers the appropriate binding by the relative pronoun, which is generated in its surface position.⁸ Following Cooper, we make use of QST to capture island constraints on both quantifier scope and WH-movement (not a movement rule here). For example, the restriction $QST(2) = \{ \langle WH, i \rangle \}$ on the relative clause rule R18 simultaneously prevents WH-extraction out of relative clauses and prevents a quantifier inside a relative clause from having scope outside that relative clause (cf. Rodman 1976).

$QST_I(x)$ and $QST_R(x)$ are defined in terms of QST as follows:

$$QST_I(x) = \{ i \mid \langle \alpha, i \rangle \in QST(x) \}$$

$$QST_R(x) = \{ i \mid \langle SELF1, i \rangle \text{ or } \langle SELF2, i \rangle \in QST(x) \}.$$

$QST_I(x)$ for any expression x contains the set of indices i of pronoun meanings $\lambda P[P\{x_i\}]$ in the translation of x which are eventually going to

be bound by quantifying in a stored NP meaning (whose surface syntactic position is within x). By always including $QST_I(x)$ in $LPST(x)$, we prevent quantifier phrases from binding pronouns "higher" in the tree (in a sense made precise by the rules.) QST_R is used in stating our analog of the "clause-mate" condition on reflexivization. Since reflexivization in our treatment involves storing special reflexive meanings and then bringing them out of store at TVP or VP level by rules which are necessarily optional (see R20, R21), we need to insure that there are no reflexives still in QST when a VP is combined with another constituent. This is accomplished by putting the condition $QST_R(\alpha) = \emptyset$ on the NP-VP rule, R6, and on the infinitival rule, R19.

The third store, SPST, simply keeps track of the indices of all variables still free in the interpretation of each constituent; it is similar to the "BAG" of Janssen (1980). Whether such a device is really necessary is an open question; it is inessential to the fragment below except if we want to implement the (controversial) "leftmost" constraint on the binding of variables by quantifier phrases (Jacobson 1977). It becomes potentially crucial in the discussion of VP-deletion in Section 4.

3.2. The fragment

<i>Syntactic category</i>	<i>Semantic type</i>
S, \bar{S} , REL, INFS	t
CN, CNP	$\langle\langle s, e \rangle, t \rangle$
N, NP, PP [to]	$\langle\langle s, f(\text{CNP}) \rangle, t \rangle$
V, VP, \bar{V}	$\langle\langle s, f(\text{NP}) \rangle, t \rangle$
TV, TVP	$\langle\langle s, f(\text{NP}) \rangle, f(\text{VP}) \rangle$
Det	$\langle\langle s, f(\text{CNP}) \rangle, f(\text{NP}) \rangle$
VP/INFS (try)	$\langle\langle s, t \rangle, f(\text{VP}) \rangle$
VP/ \bar{S} (believe)	etc.
TVP/PP (give, explain) [to]	
TVP/NP (give, envy)	
TVP/INFS (persuade, tell)	
TVP/ \bar{S} (persuade, tell)	
(VP/INFS)/NP (promise)	

- R4. PP = to NP same
 [to]
 $0' = 2'$
 $QST(0) = QST(2)$

Function-argument rules, NP and S

- R5. NP = DET CNP LPST(1) \cap LPST(2) = \emptyset
 $0' = 1' (\wedge 2')$ LPST(0) = QST_I(0)
 $QST(0) = QST(1) \cup QST(2)$ SPST(0) = SPST(1) \cup SPST(2)
- R6. S = NP VP Same as for R5, plus
 $0' = 2' (\wedge 1')$ QST_R(2) = \emptyset
 $QST(0) = QST(1) \cup QST(2)$

Function-argument rules, other than NP and S

- R7. VP = TVP NP LPST(1) \cap LPST(2) = \emptyset
 $0' = 1' (\wedge 2')$ LPST(0) = LPST(1) \cup LPST(2)
 $QST(0) = QST(1) \cup QST(2)$ SPST(0) = SPST(1) \cup SPST(2)
- R8. TVP = TVP/PP PP same conditions
 [to] [to]
 $0' = 1' (\wedge 2')$
 $QST(0) = QST(1) \cup QST(2)$
- R9. TVP = TVP/NP NP same
 $0' = 1' (\wedge 2')$
 $QST(0) = QST(1) \cup QST(2)$
- R10. TVP = TVP/ \bar{S} \bar{S} same
 $0' = 1' (\wedge 2')$
 $QST(0) = QST(1) \cup QST(2)$
- R11. VP = VP/ \bar{S} \bar{S} same
 $0' = 1' (\wedge 2')$
 $QST(0) = QST(1) \cup QST(2)$
- R12. VP/INFS = (VP/INFS)/NP NP same
 $0' = 1' (\wedge 2')$
 $QST(0) = QST(1) \cup QST(2)$

$$\begin{aligned} \text{QST}(0) = & \text{a) QST}(1) \\ & \text{b) QST}(1) \cup \{ \langle \text{SELF1}, i \rangle \} \\ & \text{c) QST}(1) \cup \{ \langle \text{SELF2}, i \rangle \} \end{aligned}$$

R20. (Reflexive 1: Subject control)

$$\begin{aligned} \text{VP} &= \text{VP} & \langle \text{SELF1}, i \rangle &\in \text{QST}(1) \\ \text{O}' &= \lambda \mathcal{P} [\mathcal{P} \wedge \text{SELF1} (\lambda x_1 1')] & \text{LPST}(0) &= \text{LPST}(1) - \{ i \} \\ \text{QST}(0) &= \text{QST}(1) - & \text{SPST}(0) &= \text{SPST}(1) - \{ i \} \\ & \{ \langle \text{SELF1}, i \rangle \} \end{aligned}$$

R21. (Reflexive 2: Object control)

$$\begin{aligned} \text{TVP} &= \text{TVP} & \langle \text{SELF2}, i \rangle &\in \text{QST}(1) \\ \lambda \mathcal{P}_2 \lambda \mathcal{P}_1 [\mathcal{P}_2 \{ \wedge \lambda y \text{SELF2} & \text{LPST}(0) &= \text{LPST}(1) - \{ i \} \\ (\lambda x_1 1') (y) (\mathcal{P}_1) \}] & & \\ \text{QST}(0) &= \text{QST}(1) - \{ \langle \text{SELF2}, i \rangle \} & \text{SPST}(0) &= \text{SPST}(1) - \{ i \}. \end{aligned}$$

Following Cooper's convention, QST must be empty in any final output for that output to count as well-formed. (The constraint of Janssen (1980) against allowing any free variables in the final output would amount here to requiring SPST also to be empty, but we do not incorporate that constraint in this fragment.)

3.3. Discussion and examples¹⁰

The grammar presented above meets a number of strong constraints on syntax, semantics, and the relation between them. The syntax is essentially context-free and meets the well-formedness constraint. Montague's compositionality requirements are almost met, except that QST provides a way for NP meanings to "escape" from their surface positions. There is no way, as far as we can see, of maintaining Montague's strong form of compositionality in conjunction with direct generation of well-formed surface structures by context-free rules, given the multiple scope ambiguities of NP's. The QST device appears to be the minimal weakening of the compositionality requirement sufficient to permit the full range of NP scope phenomena.

The main innovations in this fragment are the use of LPST and its interaction with QST, and the treatment of reflexives and control. We will limit our discussion here mainly to points relevant to VP-deletion phenomena, although much of the original motivation for this fragment was to show how a "rule-by-rule" semantics would potentially improve upon the treatments of "non-coreference" phenomena and restrictions on variable-binding originally discussed in the framework of "configurational" semantics (e.g. with Reinhart's use of c-command, Reinhart 1976); this comparison is the focus of Bach & Partee (1980).

The shortest example of the effect of LPST is the restriction it places on the interpretation of sentence (5).

(5) # *He sees him.*

By virtue of the LPST conditions in the lexicon and in R6 and R7, the italicized pronouns cannot be interpreted as coindexed variables.¹¹ As a result we achieve the blocking of bound variable readings of (6 a,b), since R16, the NP Storage rule, leaves a pronoun meaning in the place corresponding to the surface position of the stored NP.

(6) (a) # *Every man sees him*
(b) # *He sees every man.*

What the LPST conditions in effect say is that two pronoun-meanings both "locally free" in the same NP or S domain cannot have the same variable index. In terms of function-argument structure, this amounts to saying that two immediate arguments of a verb cannot be coindexed, nor can two immediate arguments of a noun.¹² While ruling out (5), these conditions permit (7):

(7) *He loves his mother.*

The difference between (5) and (7) is that the LPST of *his mother* in the derivation of (7) is empty (R5); *his* is not an immediate ("local") argument of *loves*. As (5) led us to predict (6 a,b) to be bad, (7) would lead us to predict (8 a,b) to be good. As expected, (8a) is fine; but (8b) is not, which brings us to the additional factor of interaction between LPST and QST.

(8) (a) *Every man loves his mother.*
(b) # *He loves every man's mother.*

In the rules above, LPST(x) always includes QST_I(x), for any expression x. This means that if an NP is interpreted as having higher scope than its surface position, via QST, it may bind pronouns that are higher in the surface tree, but not ones which occur as local arguments to any function expression which contains the surface position of that NP. In other words, pronoun meanings linked to QST elements stay "local" until they are bound, acting as if they were local co-arguments of any other NP up to the point in the tree where they are "quantified in" (retrieved from store). In the derivation of (8b), if $\langle \textit{every man}'_i \rangle$ is stored in QST, then *i* is in LPST of the object NP and hence of the VP, so the subject *he* cannot be interpreted as $\lambda P[P\{x_i\}]$. (For differences between our constraint

and either the “leftmost constraint” of Jacobson (1977) or the C-command constraint of Reinhart (1977), see Bach & Partee (1980); our constraint is closely related to the “functional principle” of Keenan (1974).) It may well be that all three kinds of principles – relating to function-argument structure, left-right order, and surface syntactic domination relations – have some validity, since examples ruled out by all three are most clearly bad, and those where the principles make differing predictions often seem to provoke unclear judgments of acceptability.¹³)

Our treatment of reflexives is designed to capture the fact that in English, reflexives can be controlled either by direct objects (arguments of TVP’s) or subjects (arguments of VP’s), and the fact that they always act as bound variables, never as referential NP’s.¹⁴ A reflexive pronoun is always given a two-part interpretation: an ordinary pronoun meaning as its direct translation, and a special stored meaning – either “SELF1” or “SELF2” –, corresponding to subject or object control. The rules that bring these meanings out of store serve to treat the reflexive as a “relation-reducer” (see Potts 1979). For example, in deriving sentence (9),

(9) *Every woman* told *herself* that *she* was lucky.

we might first translate *she* as $\lambda P[P\{x_3\}]$, and then translate *herself* also as $\lambda P[P\{x_3\}]$, while putting $\langle \text{SELF1,3} \rangle$ into QST; then when we bring the stored meaning out of QST at the VP level, we obtain the translation (9a), which reduces to (9b).

(9) (a) *Every woman* told *herself* that *she* was lucky.

\downarrow \downarrow
 $\lambda P[P\{x_3\}]$ ($\lambda P[P\{x_3\}]$)
 QST: { $\langle \text{SELF1,3} \rangle$ }

told herself that she was lucky:

$\lambda \mathcal{P}[\mathcal{P}\{\wedge \text{SELF1} (\lambda x_3 [\text{told}' (\wedge \text{lucky}' (\wedge \lambda P[P\{x_3\}]))$
 $(\wedge \lambda P[P\{x_3\}])])]\}]$

(b) $\equiv \lambda \mathcal{P}[\mathcal{P}\{\wedge \lambda x \text{ told}' (\wedge \lambda P[P\{x\}], \wedge \lambda P[P\{x\}], \wedge \text{lucky}'$
 $(\wedge \lambda P[P\{x\}])\}]\}]$.

On this kind of derivation, the subject *every woman* does not have to be quantified in; the meaning of the VP itself guarantees that “every woman” must be (derivatively) bound to the reflexive, and hence to the non-reflexive *she* in this case.

Our LPST restrictions account for the difference between (9) above and (10), since *him* in (10) is a local argument of *sold*.

(10) # *Every dealer* sold *himself* to *him*.

The treatment of control of infinitives in this fragment departs from previous Montague framework treatments in which infinitives are treated semantically simply as VP's. In order to capture the distribution of reflexive and non-reflexive pronouns in controlled infinitives, we are forced to posit a semantic reflex of the "missing subject".¹⁵ Consider the standard paradigm in (11),

- (11) (a) *Every unicorn* persuaded every fish to kiss *it*.
 (b) # *Every unicorn* persuaded every fish to kiss *itself*.
 (c) # Every unicorn persuaded *every fish* to kiss *it*.
 (d) Every unicorn persuaded *every fish* to kiss *itself*.

The rule R19 translates the "missing subject" as a pronoun, $\lambda P[P\{x_i\}]$, which acts as a local argument of the embedded verb with respect to LPST, while at the same time a reflexive meaning, either $\langle \text{SELF1}, i \rangle$ or $\langle \text{SELF2}, i \rangle$ is put into QST. Obligatory control is effected via R20 and R21; our fragment in effect provides an explicit semantics for a treatment like that of Helke (1971) which posited a "SELF" morpheme as the subject of controlled infinitives, reflecting the fact that both reflexives and controlled "deletions" are obligatorily interpreted as bound variables which act as relation-reducers. (In the case of "free control" the missing subject is also translated as a pronoun meaning, but nothing is added to QST, so these missing subjects are predicted to behave just like embedded pronouns.)

In sum, our first fragment gives a treatment of quantification scope and the binding of reflexive and non-reflexive pronouns and "missing subjects" within a highly constrained version of Montague grammar. With respect to the distribution of reflexive and non-reflexive pronouns, our account gives results similar to those obtained by various indexing devices proposed within the Revised Extended Standard Theory by Chomsky (1980), Higginbotham (1979, 1980), and others, and our LPST can perhaps be viewed as an "indexing device" insofar as it is not otherwise needed for the syntax or the semantics. The main difference between our approach and the REST approach, besides the general differences in the two theories, is that our "locality" principles (cf. Koster 1978) are in terms of semantic function-argument structure rather than in terms of syntactic C-command.

In the next section, we examine the result of attempting to extend the fragment to account for VP-deletion with particular attention to cases involving quantifiers and reflexive and non-reflexive pronouns.

4. VP-DELETION

4.1. General properties

The phenomenon of VP-deletion can occur with or across sentences, but not with a non-linguistic antecedent.¹⁶

- (12) (a) John left before Bill did.
 (b) John left. Bill won't.
 (c) [Scene: John leaves] *Bill won't.

As mentioned above in Section 1, it has long been observed that the identity conditions governing VP-deletion are semantic rather than syntactic; the so-called "sloppy identity" illustrated in (13) (sloppy because "himself" \neq "myself") should really be viewed as a case of strict semantic identity.

- (13) John enjoyed himself. I did too.

Sag (1976) states the condition as follows:

"With respect to a sentence S, VPD can delete any VP in S whose representation at the level of logical form is a λ -expression that is an alphabetic variant of another λ -expression present in the logical form of S or in the logical form of some other sentence S', which precedes S in discourse" (pp. 105-6)

Sag does not give explicit rules defining the level of logical form nor a full set of rules for mapping syntactic structures onto logical form, but he gives enough examples and discussion to make it clear that his "logical form" is somewhere in between English syntactic structure ("shallow") and a logical language like IL. If we try to apply Sag's formulation to IL translations of sentences as in PTQ or in our first fragment, we find that it would incorrectly predict the possibility of deleting a VP semantically equivalent to some antecedent which is not itself a syntactic VP.

Consider (14), for instance.

- (14) A paper was submitted by almost every student. *But Bill didn't.

If the first sentence of (14) is interpreted with *almost every student* having wide scope, the most natural reading, then there is a *semantic* constituent roughly paraphrasable as " λx [a paper was submitted by x]", which is semantically equivalent to "submitted a paper". But that VP-type meaning cannot serve as the antecedent for the missing VP, even though it would

yield a most plausible reading, and the explanation seems to be that it is not the meaning of any syntactic VP in that sentence. So the basic identity condition involved seems to be semantic identity between the missing VP and some antecedent syntactic VP.¹⁷

4.2. Initial hypotheses: an interpretive principle

There are three basic approaches to VP-deletion available:

- (i) "quantifying in" VP's (Bach 1977, 1979a);
- (ii) deletion of a generated full VP (e.g. Sag 1976);
- (iii) interpretation of an empty or "pro" VP (e.g. Williams 1977).

In the present framework the interpretive approach is most natural. Against quantifying in, there is the fact that VP deletion occurs across as well as within sentences¹⁸, together with the absence of independent evidence of VP scope ambiguity. Such an approach in this framework would further require relaxing the constraints on QST to allow VP meanings as well as NP meanings to be stored. The deletion approach is incompatible with the context-free syntax of the present framework.

So as our first hypothesis we will assume that the lexicon includes an empty VP, which translates as P_i , a free property variable.¹⁹ Somewhere (it is not clear where) a condition on the interpretation of the variable must be stated, to the effect that the possible values for P_i are the intensions of any of the VP's in the same or previous sentences. (This is basically like the interpretation of free pronoun meanings, except that possible salient values available in the non-linguistic context are excluded in the VP case.)

4.3. Examples

Our first fragment makes just the right VP-meaning available in the case of reflexives, as in (15).

- (15) John admires himself. Bill does too.

The translation of *admires himself* comes out as (15') via the reflexive rule R20; a simplified form with the PTQ IV-type is (15'')

$$(15') \quad \lambda \mathcal{P}[\mathcal{P}\{\lambda x[\text{admire}' (\lambda \mathcal{P}\{P\{x\}}) \lambda \mathcal{P}\{P\{x\}}]\}]]]$$

$$(15'') \quad \lambda x[\text{admire}' (\lambda \mathcal{P}\{P\{x\}})(x)].$$

But for the sentence (16), there are two non-equivalent interpretations for the verb phrase even on the assumption that *he* is John; these are given as (16a) and (16b).

- (16) *John* thinks *he* is sick. Bill does too.
 (a) bound *he*: $\lambda x_0 [\text{think}' (\wedge \text{sick}'(x_0)) (x_0)]$
 (b) free *he*: $\lambda x_1 [\text{think}' (\wedge \text{sick}'(x_0)) (x_1)]$
 $\equiv \text{think}' (\wedge \text{sick}'(x_0)).$

In our fragment so far, only one VP meaning is assigned to a VP constituent in generating the first sentence of (16), namely (17) (=16b).

- (17) $\text{think}' (\wedge \text{sick}'(x_0)).$

Whether x_0 is free or bound isn't determined until the VP is combined with the subject NP, either directly (thus leaving x_0 free), or via storing $\langle \text{John}', 0 \rangle$ in QST, leaving $\lambda P[P\{x_0\}]$ in the sentence translation, and removing *John'* from QST at the sentence level via R17 (binding x_0). Since the latter binding occurs at the S-level and not the VP-level, it does not provide a VP-constituent to serve as a possible antecedent, even though the λ -abstract formed in R17 has an appropriate meaning (i.e. 16a). (Sentence (14) above shows that we can't in general take such abstracts as antecedents for VP's.) In the next two sections we will explore two alternative extensions to the grammar that will serve to generate both (16a) and (16b) as meanings for the VP of (16). In both extensions a problem arises which requires an unpleasantly *ad hoc* restriction involving SPST. A more fundamental problem concerning meanings of variables is raised in Section 4.6.

4.4. First option: fragment plus Derived Verb Phrase rule

Both Williams and Sag employ versions of the Derived Verb Phrase rule (DVP) of Partee (1973) in their treatments of VP-deletion; the version we will add here will be one which maps VP's onto VP's, syntactically doing nothing to the VP, but semantically abstracting on some variable free in the VP. We will illustrate the effect of the rule before stating it. Suppose we have generated the VP in (18), with the translation and stores as in (18')

- (18) believe that she loves him
 (18') $\text{believe}' (\wedge \text{love}' (\wedge \lambda P[P\{x_1\}]) (\wedge \lambda P[P\{x_0\}]))$
 $\text{QST} = \emptyset \quad \text{LPST} = \emptyset \quad \text{SPST} = \{0,1\}.$

With the DVP rule added, we will have three relevant options:

- (i) If we don't apply the DVP rule at all, we will have the meaning given in (18'), with both variables free.

- (ii) If we apply DVP to x_0 , we will obtain a meaning in which *she* is bound by λ -abstraction, i.e. (simplified) (18'').

(18'') $\lambda x_0 [\text{believe}' (\wedge \text{love}' (\wedge \lambda P [P \{x_1\}]) (\wedge \lambda P [P \{x_0\}])) (x_0)]$.

- (iii) If we apply DVP to x_1 , we get a similar meaning but with *him* bound.

This gives us the right set of meanings; if we applied DVP to any variable not free in the verb phrase, the result would simply be equivalent to (18'). The rule is stated below.²⁰

R 22. (DVP Rule)

$VP = VP$

$O' = \lambda x_i [1'(x_i)]$

$QST(0) = QST(1)$

$i \in \text{SPST}(1) - \text{LPST}(1)$

$\text{LPST}(0) = \text{LPST}(1) \cup \text{SPST}(1)$

$\text{SPST}(0) = \text{SPST}(1) - \{i\}$

This rule provides appropriate translations of VP's for all the basic cases of VP-deletion and gives essentially the same results as Williams' and Sag's treatments. (But see Section 4.6 for problem cases.)

4.4.1. *The need for SPST*

The condition on LPST in the rule above is unnatural; the expected condition would be $\text{LPST}(0) = \text{LPST}(1)$: the local arguments of the verb shouldn't be affected by the rule, and SPST (the set of *all* variables free in the expression) has been completely inessential in the fragment up to this point (unless we wanted to incorporate the "leftmost" condition on quantifier-pronoun binding). (Removing SPST from the first condition on the DVP rule would simply permit some innocuous cases of vacuous λ -abstraction.) Why do we need the condition $\text{LPST}(0) = \text{LPST}(1) \cup \text{SPST}(1)$?

Consider sentence (19) with the indicated choices of variables.

(19) Every man $\underset{x_0}{\text{VP}}$ [says that he $\underset{x_0}{\text{believes}}$ that he $\underset{x_1}{\text{loves}}$ him].

Suppose that in the derivation, the DVP rule were applied to the VP with respect to x_0 , yielding (20):

(20) $\lambda x_0 [\text{say}'(x_0, \wedge \text{believe}'(x_0, \wedge \text{love}'(x_0, x_1)))]$.

If we had the expected condition, $\text{LPST}(0) = \text{LPST}(1)$, nothing would

block the use of x_1 for storing and quantifying in the subject, since $LPST(1) = \emptyset$. Such a derivation would yield (21):

$$(21) \quad \forall x_1 [\text{man}'(x_1) \rightarrow \text{say}'(x_1, \text{^A believe}'(x_1, \text{^A love}'(x_1, x_1)))] .$$

But (21) is not a possible reading of (19), since the last *him* in (19) is not reflexive. The choice of x_1 as subject of the (derived) verb phrase (20) results in overriding the distinctness of x_0 and x_1 imposed on the lowest clause by the earlier use of LPST.

Putting all of SPST into LPST in the DVP rule prevents such "overriding" of earlier LPST restrictions, but the solution is at best *ad hoc*, and it turns out that the same problem arises in another quarter, discussed in the Appendix.

4.5. Second option: pronouns as optional "distant reflexives"

One interesting feature of the DVP rule is that its translation is logically equivalent to the translation that would have been gotten by the subject-control reflexive rule (R20) if the pronoun abstracted on had been a reflexive: $\lambda \mathcal{P}[\mathcal{P}\{\text{^A SELF1}(\lambda x_1, 1')\}]$.²¹ This suggests an alternative to the DVP, in which non-reflexive pronouns are optionally given reflexive meanings which can be carried along indefinitely in QST, to be retrieved from store at any higher VP level. The new pronoun entries will be as in (22).

$$(22) \quad \langle \text{he}, N, \lambda \mathcal{P}[\mathcal{P}\{x_i\}] \rangle, \left\{ \begin{array}{c} \text{QST} \\ \emptyset \\ \langle \text{LAMB}, i \rangle \end{array} \right\}, \langle \text{LPST SPST} \rangle, \{i\}, \{i\} \rangle .$$

(Similarly for *him*, *she*, etc., and analogously for *his* etc.)

The stored meaning "LAMB" is semantically identical to SELF1; the difference is that SELF1 must be cleared from the store at the first possible VP (via the restriction $QST_R = \emptyset$ on R6, R19), while no such restriction is placed on LAMB. (The conditions on LPST will in fact prevent clearing LAMB out at the *first* VP level if it corresponds to e.g. a direct object *him*.) The DVP rule in this version will be conditioned by the presence of $\langle \text{LAMB}, i \rangle$ in QST, rather than purely optional as in the first option.

R22'. (Alternative DVP rule)²²

$$VP = VP$$

$$O' = \lambda x_i [1'(x_i)]$$

$$QST(0) = QST(1) -$$

$$- \{ \langle \text{LAMB}, i \rangle \}$$

$$\langle \text{LAMB}, i \rangle \in QST(1)$$

$$LPST(1) \cap \{i\} = \emptyset$$

$$LPST(0) = LPST(1) \cup SPST(1)$$

$$SPST(0) = SPST(1)$$

(Note that this rule requires the same SPST condition as the previous version, and for the same reason.) For English, this option is exactly equivalent to the previous. We speculate that an option like this one might be preferable for languages with a distinction between reflexive and non-reflexive possessive pronouns.

4.6. *The problem of "open properties"*

So far we have been treating bound and free pronouns alike, as discussed in Section 1.1. This leads to a situation in which the notion of semantic identity between VP-meanings must sometimes involve closed properties and sometimes open ones, both within and across sentences. Consider example (16) again.

(16) John thinks he is sick. Bill does too.

We assume that the second sentence of (16) is translated as (16') (using simplified types):

(16') Bill'(P₀).

The two available values for P₀ are the intensions of the two expressions (16a) and (16b), repeated below.

(16a) $\lambda x_0 [\text{think}' (\wedge \text{sick}'(x_0)) (x_0)]$ (closed)

(16b) $\lambda x_1 [\text{think}' (\wedge \text{sick}'(x_0)) (x_1)]$ (open).

In case (16b), we depend on the assumption that the context includes a choice of variable assignment g (call it g_c), such that the same assignment g_c applies in both sentences. In the case of discourse (16) on the interpretation we have been considering, $g_c(x_0)$ is John. We can therefore look at the semantic identity in question either as involving open properties or as involving closed properties obtained by evaluation with respect to g_c .

The only cases which *crucially* involve identity of *open* properties are those in which a pronoun within the VP is bound from outside, as in one reading of (23).

(23) *Every man* believes that Sally loves *him* and Mary doesn't.

The verb phrase *loves him* has an interpretation (23').

(23') $\text{love}'(x_0)$ (equivalent to $\lambda x_1 [\text{love}'(x_0) (x_1)]$).

cannot be bound and with an output filter that rules as ill-formed any expression with a free x_i in it. The cases of examples (24) and (25) would no longer arise, and VP-deletion *across* sentences could be simply required always to involve *closed* VP-meanings, i.e. simple identity of intensions.

But even with this modification, a global restriction like the second part of (27) would still be required for VP-deletion within sentences, since there are cases crucially involving open properties within sentences, e.g. (23), and thus the problem cases like (26) could still arise. If, as suggested in footnote 18, it should turn out that it would be best to treat within-sentence VP-deletion separately from across-sentence VP-deletion, we should reconsider the possibility of using a quantifying-in rule for the former (which would increase the similarity of types of VP-deletion to types of pronominal anaphora). It looks as though splitting the VP-deletion phenomena in this way and incorporating Janssen's treatment of pronouns might obviate the need for a global IL-level restriction like (27). But we cannot make any firm conclusions without a treatment of "antecedent-contained" VP-deletion (see footnote 17), so we leave that possibility for future exploration.

Our conclusions from this section can be summarized as follows:

- (i) if we follow Cooper in assigning uniform interpretations to free and bound pronouns, we cannot handle VP-deletion without a level of translation into IL;
- (ii) if we instead adopt Janssen's non-uniform treatment of free and bound pronouns, and if we treat VP-deletion differently within and across sentences, then it *might* be possible to continue to regard the level of IL as dispensable;
- (iii) the widely accepted view that VP-deletion involves semantic identity offers an interesting and so far unmet challenge, since it cannot be made precise without resolving the problematic issue of the semantic value of free variables.

5. SUMMARY

In this paper we have tried to provide an account within a constrained version of Montague grammar of various phenomena involving quantification and anaphora which challenge the assumption of the dispensability of any level of "logical form" or translation into IL mediating between surface syntax and model-theoretic interpretation. What REST theories do with global indexing mechanisms we have attempted to do with the addition of one limited device, LPST, to the recursive rules which simultaneously construct syntactic structures and their semantic interpretations. The interaction between LPST and our version of Cooper's storage device,

QST, permits us to provide a fairly unified account of the distribution of reflexive and non-reflexive pronouns, the conditions on permissible binding of pronouns by quantifiers, the parallels among reflexives, obligatory control, and the DVP rule, and the parallels between WH-movement and quantification. QST can be viewed as a limited weakening of the compositionality constraint which makes possible a strengthened constraint on the syntax, namely that it be context free. (But see Engdahl (1980) for a serious challenge to this claim.) LPST can be viewed as a device which is neither purely syntactic nor purely semantic, perhaps as a concession to the need for some properties of a level of "logical form" intermediate between syntax and semantics; but if LPST suffices, it is a much more limited addition than a whole level of representation.

It is not clear yet whether LPST does suffice, however; the condition on both versions of the Derived Verb Phrase rule requiring all variables free in the resulting verb phrase (i.e. all of SPST) to be added to LPST is an *ad hoc* and in some sense global device that is needed to prevent earlier (local) effects of LPST conditions to be destroyed by later lambda-abstraction on a deeply embedded variable. The Appendix shows that reflexivization creates a similar problem in the first fragment even without the DVP rule. Since SPST is itself a rather limited device (see Janssen's discussion of his analogous BAG device), this problem does not by itself show that a level of "logical form" is indispensable.

The main problem facing our attempt to constrain the theory as described above arose in the extension of our fragment to handle VP-deletion. The DVP rule (either version) provides a natural extension of the fragment which gives the right results for the most part, but we have not yet been able to account for cases in which there is a variable free within the antecedent VP without appeal to global restrictions on the level of the syntax of IL. We feel that a deeper understanding of the semantics of free and bound variables is a crucial prerequisite to further investigation of the important question of whether a linguistic theory needs a level intermediate between syntax and model-theoretic semantics.

6. APPENDIX: FURTHER CASES OF APPARENT GLOBALITY OF COINDEXING RESTRICTIONS

In Section 4.4.1 we discussed the need to prevent combining a subject interpreted as $\lambda P[P\{x_i\}]$ with a derived verb phrase interpreted as $\lambda x_j\phi$ if x_i is free in ϕ . The reason was that the net effect would be to identify x_i with x_j , overriding any earlier restriction that x_i and x_j be distinct (see examples (19), (20), (21)). The needed restriction was achieved in both versions of the DVP rule, R22 and R22', by adding all of SPST to the

LPST of the derived verb phrase. In this appendix, we present three additional places in the grammar where a similar problem arises: (i) double applications of DVP; (ii) application of DVP to a subject-controlled reflexive VP; and (iii) double application of the subject-control reflexive rule, R20. In the first two cases, the solution of adding all of SPST to LPST works all right, but in the third it does not, suggesting that a more powerful global device than SPST may be needed.

6.1. Double applications of DVP

For the same reason as above, we must prevent the DVP (either version) from applying twice in a row to the same VP. (To see that this is the same problem, note that the result would have the effect of identifying the first variable abstracted on with the second variable abstracted on, again overriding any earlier distinctness requirements.) The restriction already suggested for the original problem, adding all of SPST to LPST in the DVP rule, takes care of this problem as well. Note that in the second option, R22' of Section 4.5, both $\langle \text{LAMB}_i \rangle$ and $\langle \text{LAMB}_j \rangle$ can be in QST together; the restriction simply prevents bringing them out of store on the same VP.

6.2. DVP and subject-controlled reflexives

Similarly, we must prevent applying DVP to a subject-controlled reflexive, which on our treatment is always interpreted as a λ -abstract, as in (28).

$$(28) \quad \begin{array}{cccccc} \text{convince} & \text{himself} & \text{that} & \text{he} & \text{loves} & \text{him} \\ & x_0 & & x_0 & & x_1 \\ & \langle \text{SELF1}, 0 \rangle & & & & \\ \lambda x_0 [& \text{convince}'(x_0, x_0, \text{love}'(x_0, x_1)) &] & & & \end{array}$$

In this case as well, applying the DVP rule with respect to a variable free in the VP, here x_1 , could override the earlier restriction (via LSPT conditions on the embedded clause) that x_0 and x_1 be distinct.

And for the same reason, a reflexive VP such as the above must not be combined with a subject $\lambda P[P\{x_i\}]$ if x_i is free in the VP.

We can solve this pair of problems by adding all of SPST to LPST in the subject-control reflexive rule R20 as we did in R22. This is a modification of the original fragment which forces a retraction of the claim that SPST is inessential to that fragment.

6.3. Double application of the subject-control reflexive rule

We need to be able to apply R20 twice in a row to generate (29):

- (29) Mary talks to herself about herself.
 $\lambda P[P\{x_2\}] \quad \lambda P[P\{x_3\}]$
 $\langle \text{SELF}_{1,2} \rangle \quad \langle \text{SELF}_{1,3} \rangle$

(Why aren't the two reflexives necessarily given the same translation in the first place, if they are both subject-controlled, i.e. SELF1, and in the same clause? Because in this bottom-to-top recursive syntax, each one is generated separately and is "blind" to what it will be combined with later. We assume here that both of these pronouns are arguments of the verb *talk*, which would be categorized as (VP/PP)/PP; but the problem raised here would still arise if either or both PP's were regarded as VP or TVP modifiers.)

We need to give reflexives a basic $\lambda P[P\{x_i\}]$ translation in addition to their stored reflexive meaning in order to permit coindexing of reflexives with lower plain pronouns, as in (28) above.²⁶ But these factors together create the possibility here too of overriding earlier distinctness restrictions, as in (30) below.

- (30) #Every man talked
to himself by himself about a book that he gave to him.
 $\lambda P[P\{x_0\}] \quad \lambda P[P\{x_1\}] \quad \lambda P[P\{x_1\}] \quad \lambda P[P\{x_0\}]$
 $\langle \text{SELF}_{1,0} \rangle \quad \langle \text{SELF}_{1,1} \rangle$

This problem, unlike the previous ones, cannot be solved by requiring the reflexive rule R20 to apply only to variables not in LPST (and adding all of SPST to LPST, as we already did in 6.2 above), since the reflexivized variable itself is *always* in LPST at the time R20 applies. We see no solution to this problem using the limited mechanisms of our framework.

The problem may of course arise from some fault in our particular analyses, or from some aspect of our framework we have not considered in detail. What worries us is that it looks like a natural solution to the whole family of problems raised in 4.4.1 and this appendix is to reinstate the translation into IL as a level of "logical form" and employ a global book-keeping device on that level akin to Chomsky's "anaphoric index": a set of integers attached to each indexed pronoun meaning indicating explicitly which indices it must be distinct from. To implement such a solution appears to require having access to the entire "logical form" of the sen-

tence. (Note that there is nothing *semantically* ill-formed about $love'(x_i, x_i)$.) The apparent need for a device of such power is a serious challenge both to compositionality (even as weakened via the use of storage devices) and to the dispensability of a level of "logical form".

NOTES

We are grateful to our colleagues, students, and visitors to our department this past year for providing a most stimulating atmosphere for discussing problems in syntax and semantics from the varying perspectives of Montague grammar and current versions of the Revised Extended Standard Theory. Special thanks go to Rick Saenz and Ken Ross for their important role in developing the framework discussed here, and to Robin Cooper, Elisabet Engdahl, Irene Heim, Mats Rooth, Arnim von Stechow, Lars Hellan, and James Higginbotham for valuable discussion. Remaining inadequacies are our own.

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1. As Cooper does, we will employ expressions of Montague's intensional logic to represent the model-theoretic entities they denote; except where explicitly noted, we are using the logic as an inessential convenience and not as a genuine "linguistic level".
2. For example, a position like Cooper's is adopted in Montague (1970b) and in Groenendijk & Stokhof (1976); Hausser (1979) also argues for a uniform treatment of pronouns but with all of them involving context variables; Bartsch (1979) invokes an intermediate representational level in which pronouns are represented uniformly, but at a subsequent stage some are translated as variables and others as constants. Bennett (1978) makes a clear distinction between bound variable pronouns and demonstrative pronouns (constants) but does not discuss non-demonstrative anaphoric pronouns.
3. More precisely, to a class of grammars whose generative capacity does not exceed that of context-free grammars.
4. See footnote 1. Also see the paper by Van Benthem (1981) for some discussion of this issue. See also Ladusaw (1979).
5. The main features of our framework were originally proposed by Rick Saenz and Ken Ross (see Saenz (forthcoming), neither of whom is necessarily in agreement with the details of our use of it or the analysis of English presented. Similar proposals are mentioned in Section 1.2 (iii), above.
6. We assume a treatment of syntactic features similar to that of Gazdar (1982). The only features mentioned explicitly in the fragment below are a few non-standard ones that are essential for making sense of the rules.
7. Montague suggested approximately this principle in footnote 12 of Montague (1970a: EFL); the recursive definition of "exposed to reflexivization" in Thomason (1976) has a similar function. The problem of how best to describe such constraints has received much recent attention in the EST framework (Reinhart 1977, Chomsky 1980, Higginbotham 1980).
8. We treat only the simplest cases of relative clauses with relative pronoun "that"; serious difficulties for direct surface structure generation of WH-constructions are posed by the work of Engdahl (1980).

9. The inclusion of the "rightwrap" transformation (see Bach 1979b) makes the grammar not a strictly phrase-structure grammar; see Gazdar & Sag (1981) for a way of including TVP (which frequently appears to be a discontinuous constituent in surface structure) in a phrasestructure grammar via a metarule which has much the same effect as our rightwrap operation.

10. Our discussion here is limited mainly to issues relevant to the discussion of VP-deletion in Section 4; further discussion of this fragment is contained in Bach & Partee (1980).

11. Since there is nothing within the semantics proper that prevents assigning the same value to distinct variables, our conditions do not require that the two pronouns refer to distinct individuals when sentence (5) is used as a complete sentence. We believe that our restrictions give semantically appropriate results with respect to pronouns as bound variables, as in (6 a,b), and that a full account of the effect of the restrictions on nonbound-variable pronouns requires an explicit pragmatics, which we have not attempted to provide. See Postal (1971) and Higginbotham (1980, footnote 1) for discussion of the problems of specifying the linguistically appropriate notion of "non-coreference".

12. A major shortcoming of the present work is the absence of a full treatment of complex NP's involving various sorts of prepositional phrase adjuncts; see Higginbotham (1979) and Fiengo & Higginbotham (1981) for rich sources of relevant examples, problems, and hypotheses.

13. On the positive side, our fragment predicts correctly that (i) is all right, while the leftmost constraint would rule it out.

(i) in *its* early years, *every organization* suffers some setbacks.

And it also predicts the acceptability of (ii), which the c-command condition of Reinhart (1977) would disallow.

(ii) Every student claimed that *one of his professors* was a genius in order to influence *her*.

As apparent counterexamples, our fragment predicts that (iii) is bad and (iv) good; note that c-command would rule both bad, while the leftmost constraint would allow (iii) and disallow (iv).

(iii) *Every man's* mother loves *him*.

(iv) *His* mother loves *every man*.

In Bach & Partee (1980), we offer an explanation of the goodness of (iii) consistent with our fragment by arguing that the *him* is not a bound variable but a "Geach's donkey"-pronoun, to be treated by Cooper's complex pronoun translation schema as in (3) above. See also Higginbotham (1979, 1980) for discussion of the problem status of these cases.

14. Some speakers of English do apparently allow reflexives to act as referential pronouns; for them, but not for us, sentence (i) is ambiguous with respect to whether Bill voted for himself or for John.

(i) John voted for himself, and Bill did, too.

It appears that we would have to posit a substantial difference in grammars for these two dialects, but we have not worked out an explicit treatment for the other dialect so far.

15. Thomason (1976) captures these restrictions via a recursive syntactic characterization of the property "exposed to reflexivization", and Bennett (1976) via an abstract syntactic marker "*" for subscripted pronouns in reflexivizable positions. This seems to be another case where some device of considerable power is needed, and by restricting our syntax to disallow either of the above solutions, we are forced to represent the "missing subject" explicitly in the semantics.

16. We use the term "VP-deletion" for historical continuity; the issues to be discussed seem to be independent of whether the phenomenon is treated as deletion or as interpretation of an empty or "Pro" VP.

17. We are skirting the difficult issue of "antecedent-contained" VP-deletion, illustrated by (i) and (ii) below, not because we think it is irrelevant, but because we haven't found an adequate treatment of it and the problems raised by pronouns in "simple" VP-deletion cases are difficult enough.

(i) Sam $\text{VP}[\text{put everything that Mary told him to VP}[____] \text{ into the suitcase}]$.

(ii) Sam $\text{VP}[\text{put more shirts than he wanted to VP}[______] \text{ into the suitcase}]$.

However, it must be noted that these examples seem to be incompatible with the basic identity condition stated above, so a good account of the antecedent-contained cases might radically change our view of the "ordinary" cases.

Sag offers some additional examples in which the antecedent appears not to be a syntactic VP constituent; it remains to be seen whether it is possible to define a level of logical form which will predict the impossibility of examples like (14) without placing any syntactic constraints on the antecedent.

18. But it might turn out that VP-deletion should be split into two cases, a bound-variable type occurring only within sentences, and a non-bound-variable type occurring both within and across sentences, with a quantifying-in approach appropriate for the former. Our remarks here would then apply only to the latter.

19. The semantic type of VP's in our fragment is $\langle\langle s, f(\text{NP}) \rangle, t \rangle$, since we treat VP's as taking their subjects as arguments. Technically, the translation of an empty VP should be IP_i , where IP is of type $\langle s, f(\text{VP}) \rangle$. We need an intensional rather than extensional variable to account for cases like (i).

(i) John wants to catch a fish. Bill wants to, too.

In what follows, we will not be careful about the intension/extension distinction, and will use the simpler PTQ type for ease of exposition except when showing specific derivations from our fragment.

20. The translation is in simplified PTQ types. The official translation for our type system would be:

$$O' = \lambda \mathcal{P} [\mathcal{P} \{ \wedge \lambda x_i [1' (\wedge \lambda P [P \{ x_i \}])] \}]] .$$

21. This remark applies to the official translation given in footnote 20.

22. In the type theory of our fragment, we could either use the same translation as that given in footnote 20, or to make the semantic identification of LAMB with SELF1, use the translation of the reflexive rule R20.

23. It has been pointed out to us by Robin Cooper (personal communication) and is discussed in Bigelow (1978), that there is a major difference between Montague's treatment of the meanings of variables and that of Cresswell (1973). Montague treats the meaning of variables on a par with the meanings of indexicals like *I* and *here* by making assignments of values to variables a part of the context; Cresswell treats variables as essentially syncategorematic and lets them take themselves as meanings. We have not yet tried to work out the consequences of Cresswell's approach for our family of problems.

24. Sag and Williams both build this restriction into their definitions of alphabetic variance.

25. We state these conclusions tentatively in hopes that some logician will be able to show us a way of construing meanings of variables, or of rethinking VP-deletion, for which these problems can be solved within a compositional and purely model-theoretic semantics.

26. Ewan Klein pointed out to BHP at the conference that on Gazdar's treatment of reflexives via a "distinguished variable", where coindexing of a reflexive and a non-reflexive is not possible, the same effect can be achieved indirectly, as in the following sketch of a derivation of (i):

- (i) Every man convinced himself that he loved Mary.
 (a) he loved Mary: $\text{love}'(x_0, m)$
 (b) convince himself that he loved Mary:
 $\lambda r(\text{convince}'(r, i, \wedge \text{love}'(x_0, m)))$
 (c) treat *every man* as quantified in with respect to x_0 , which in our system means translating it as $\lambda P[P\{x_0\}]$ and storing $\langle \text{every man}', 0 \rangle$.

We avoided the distinguished variable treatment of reflexives in our fragment because of problems which Ewan Klein has since shown us may not be insurmountable; see Engdahl (1980) for discussion. If distinguished variables are used for reflexives, the reflexive problems discussed in this Appendix do not arise, but there may be other problems about multiple reflexives. As far as we are concerned, the issue is still open.

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