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PRONOUNS AND QUANTIFIER-SCOPE IN ENGLISH*

0. INTRODUCTION

The quantifier $\forall x$ of predicate logic is a composite symbol formed from the symbol $\forall$, which selects a semantical rule to be used in evaluating the sentence in which it appears, and the variable x, which helps indicate which term positions are bound.[1] In fact, we can formulate first order logic so that the quantifier $\forall x$ is syntactically composite, consisting of a variable binding device x (or $\hat{x}$, to use Russell's notation), and a truth value determining device $\forall$. Stalnaker [17] shows there are advantages to be gained by maintaining a separation between these two roles of the quantifier in quantified modal logic.

In this paper, we will present a theory of quantifier expressions in English which makes a more radical claim about the separation of the two aspects of the quantifier. We will distinguish anaphoric from semantical quantifier scope, anaphoric scope corresponding to the variable binding role, and semantical scope corresponding to the truth value determining role. This will allow variables to be bound even though they do not lie in the semantical scope of a quantifier phrase.

We will motivate this view by explaining difficulties in the analysis of sentences in the neighborhood of Geach's famous donkey example. We will show that both Montague's original theory of quantifiers and Hintikka's Game Theoretic Semantics fail to treat (1) correctly:

(1) If John owns a donkey, then he feeds it.

If 'if' in (1) is bound, then the wrong semantical rule for the quantifier is selected, whereas if the right rule is selected, 'it' is left unbound.

Our discussion of responses to this problem will locate two main strategies for treating 'it' in (1). The first, adopted by Partee [14], Evans [1], and Cooper [0], is to treat 'it' something like a disguised description, with the result that 'it' is not bound by 'a donkey'. The second strategy, adopted by Hintikka [5] and Kamp [6], is to treat 'it' something like a bound

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variable, but at the cost of adjusting the rules for conditionals. By reviewing these attempts, we hope to assemble evidence that 'it' is indeed bound in (1), while at the same time showing that the solution for problems like those posed by (1) is not to be found in changing the rules for 'if . . . , then'.

It will be difficult to verify our theory on the basis of its treatment of donkey sentences alone. Such sentences involve a number of readings, and can evoke conflicting intuitions in the parties to the controversy. In Section 4, we will present independent evidence which helps to support our thesis concerning quantifier scope. In the final sections, we will explain our theory and then discuss some of its limitations. The appendix contains the formal details of our approach.

1. HOW DONKEY SENTENCES POSE PROBLEMS FOR MONTAGUE'S PTQ AND HINTIKKA'S GAME THEORETIC SEMANTICS

1.1. *Montague's PTQ*

Under what we will call its standard reading, (1) says that John feeds any donkey he owns. Barbara Partee, however, posits another reading for (1) – not, we think, without stretching our intuitions – under which it says that there is a certain donkey such that if John owns it, then he feeds it. We will show that although there is an analysis in Montague's system PTQ [10] which gives (1) Partee's interpretation, there is no analysis for the standard reading.

The relationship in PTQ between quantifier phrases like 'a donkey' and bound variables appears in a transformation-like rule by which quantifier phrases may be introduced into a sentence containing free variables. Suppose, for example, we have already constructed (2):

(2) x walks and x talks.

The quantifier rule takes a term phrase such as 'a donkey' and combines it with a formula such as (2) by substituting the term phrase itself for the first (leftmost) occurrence of a variable (x in this sentence) and substituting a pronoun of the appropriate gender for all other occurrences of the same free variable. The term 'a donkey' would combine with (2) to give (3):

(3) A donkey walks and it talks.

Although we are omitting much of the detail contained in the explicit statement of the quantification rule, we can describe Montague's treatment of quantifier scope through the notion of an analysis tree.

An analysis tree for a sentence is a graphic display of how the sentence was constructed, with each branching point corresponding to the application of one syntactic rule. Consider sentence (4):

(4) A woman loves every man.

Montague's semantics would interpret (4) given the partial syntactic analysis (5) to mean that there is a woman such that she loves every man.

(5)
a woman loves every man
a woman   *y* loves every man
every man   *y* loves *x*

Here 'a woman' has widest scope, as does (Ex) in the first order logic translation:

$$(Ex)(Wx \;\&\; (\forall y)(My \supset Lxy)).$$

Montague's semantics would interpret (4) given the partial syntactic analysis (6) to mean for every man, there is some woman who loves him.

(6)
a woman loves every man
every man   a woman loves *x*
a woman   *y* loves *x*

Here 'a woman' has small scope, as does (Ey) in its first order logic translation:

$$(\forall x)(Mx \supset (Ey)(Wy \;\&\; Lyx)).$$

Thus, when we define quantification as a rule that combines a particular term phrase with an open sentence, the scope of quantifier phrases is determined by their order of introduction into the sentence.

The rules of PTQ allow the formation of a conditional from any two formulas, so we can easily derive (7):

(7) If John owns *x*, then John feeds *x*.

To derive Partee's interpretation of (1) we use the quantification rule to introduce 'a donkey' into (7), which produces tree (8):

(8) If John owns a donkey, then John feeds it.

a donkey   If John owns x, then John feeds x

Given syntactic analysis (8), Montague's interpretation of (1) is (9):

(9) $(Ex)(x$ is a donkey & (John owns $x \supset$ John feeds x)).

Now let us attempt to derive the standard reading of (1) in PTQ. To provide a model for the attempt, let us first analyze (10), where there is no pronominal anaphora of 'a donkey':

(10) If John owns a donkey, then John is happy.

Sentence (10) can be treated as a conditional composed from 'John owns a donkey' and 'John is happy'; furthermore, 'John owns a donkey' can be analyzed as the result of applying the quantifier rule to 'a donkey' and 'John owns x'. So, (10) may be given analysis tree (11):

(11) If John owns a donkey, then John is happy

John owns a donkey   John is happy

a donkey   John owns x

The interpretation given to (10) on analysis (11) translates to (12):

(12) $(Ex)(x$ is a donkey & John owns $x) \supset$ John is happy.

Since there is no bound x in the consequent, it follows from predicate logic that (12) is equivalent to (13):

(13) $(\forall x)((x$ is a donkey & John owns $x) \supset$ John is happy).

Notice that when we give the conditional wide scope over the quantifier, as we do in (11), the resulting interpretation (13) makes a *general* claim about donkeys. On the other hand, giving the quantifier wide scope produces interpretation (9), which makes a claim about some donkeys. Since the standard interpretation of (1) makes a general claim, let us attempt to derive (1) with analysis (14), which gives 'a donkey' narrow scope:

(14) If John owns a donkey, then John feeds x

John owns a donkey   John feeds x

a donkey   John owns x

Unfortunately, (14) is not an analysis of (1) because the variable x remains in the consequent. When the quantifier rule for 'a donkey' is applied, 'John owns x' and 'John feeds x' have not yet been joined. The rule operates on 'John owns x' only, with the consequence that it cannot convert the variable in 'John feeds x' to 'it'. Our problem is that if the conditional is given widest scope in the analysis in order to ensure the general reading, then we are unable to set up variable binding between 'a donkey' in the antecedent and 'it' in the consequent. The theory we will present in this paper overcomes this problem by allowing 'it' to count as bound in (1) even though the semantical scope of the quantifier is narrower than the scope of 'if . . . , then'.

1.2. *Game Theoretic Semantics*

Our next task will be to show that problems about donkey sentences similar to those we discussed concerning PTQ arise in Game Theoretic Semantics [15] (hereafter GTS), a radically different approach to semantics for natural languages.

The central idea in GTS is that the semantical analysis of a sentence is determined by the truth values of all atomic sentences on the basis of a game played by two opponents: Nature and Myself. The play begins with the sentences to be evaluated. The syntactic shape of this sentence, and various rules of ordering, determine exactly what kind of move is to be made and which player is to make it. If the sentence has the shape (A or B), and the or-rule is to be applied, then Myself may choose either A or B, and play continues with the one Myself chooses. If the sentence has the shape (A and B), then Nature gets to choose either conjunct. If we think of Myself as representing an attempt to show the original sentence true, then Myself's move for disjunction represents the fact that (A or B) is true if and only if either A is true or B is true. If we think of Nature as representing the attempt to falsify the sentence, then Nature's play for (A and B) represents the fact that (A and B) is false if and only if either A is false or B is false. The play continues until we are left with a single atomic sentence. If this sentence is true, Myself wins, and if it is false, Nature wins. The original sentence is ruled true just in case Myself can win a game for that sentence, and it is false if Nature can win.

Given the rules for 'and' and 'or', the rules for 'every' and '$a(n)$' come as no surprise. Since '$a(n)$' indicates existential quantifier, which is like a long disjunction, the rule for '$a(n)$' involves Myself's choice of an instance with which to continue the game. Given a sentence of the shape (15):

(15) $\ldots a(n)\ N R \ldots$

Myself may choose some name n, and play continues with (16):

(16) nN and $\ldots nR \ldots$

The rule for 'every' is similar, save that Nature gets to choose the instance. Given a sentence of the shape (17), Nature chooses a name n, and play continues with (18):

(17) $\ldots$ every $N R \ldots$

(18) not (nN) or $\ldots nR \ldots$

Although the semantic rules of GTS ordinarily apply to a sentence on the basis of its syntactic form, GTS appears to have an advantage over PTQ in that the syntactic structure assigned to a sentence need not predetermine how the sentence is to be decomposed semantically. In fact, GTS includes an ordering restriction which says that the conditional rule is inapplicable to a sentence if there is pronoun cross-reference between antecedent and consequent (and similarly for conjuncts, disjuncts, etc.). Consider sentences (1) and (10):

(1) If John owns a donkey, then he feeds it.

(10) If John owns a donkey, then John is happy.

In the analysis of (10), we apply the semantic rule for conditionals first because (10) has the form (if A, then B), and there is no anaphora across the conditional. However, we must apply the rule for 'a donkey' first in (1) because there is cross-reference from antecedent to consequent there. Instead of treating scope as a syntactic matter (as in PTQ), GTS determines relative scope of quantifiers and connectives on the basis of the order in which the semantic rules are applied.[2] The result is that (1) will be evaluated with wide scope for the quantifier, even though the syntax assigns it conditional form. This new flexibility, however, does not solve our problem in deriving the standard reading. Once 'a donkey' is given wide scope in (1), whether by virtue of a syntactic or semantic rule, Partee's reading is selected.

Hintikka [4] and Saarinen [15] offer a straightforward solution to this problem. They posit two different semantic rules for phrases of the shape '$a(n)$ X', the normal rule which picks the existential interpretation, and the generic rule, which picks the universal interpretation. Given that '$a(n)$ X' has these two possible readings, we simply pick the generic interpretation for the donkey sentence to obtain the right truth-conditions.

The view that '$a(n)$' is ambiguous as between normal and generic readings is supported by such examples as (19), which are normally interpreted in the generic sense:

(19) A donkey is an animal.

Unfortunately, the claim that '$a(n)$' has two readings in (1) does not work as an explanation of its truth-conditions. First, we know that 'a donkey' in sentences like (1) usually has the generic reading. So what explains the fact that the normal reading is suppressed? Second, consider sentence (20):

(20) If John owns a donkey, then he feeds a donkey.

Here the second occurrence of 'a donkey' does not take the generic interpretation, while the first one naturally takes it. If 'a donkey' were merely ambiguous, it should take two readings in its second occurrence in (20). Third, if the standard reading of (1) is to be explained by the claim that 'a donkey' takes the generic reading, then replacement of 'a donkey' with 'some donkey' should change the meaning of (1), while replacement of 'a donkey' with 'all donkeys' should preserve meaning. Exactly the reverse behavior is observed. (21) and (1) take the same reading, while (22) and (1) differ in meaning:

(21) If John owns some donkey, then he feeds it.

(22) If John owns all donkeys, then he feeds them.

The evidence we have supplied in our reply to the view that the standard reading of (1) results because of ambiguity of 'a donkey' provides support for the theory we are going to present in this paper. On our view, the quantifier phrase 'a donkey' usually takes the reading associated with the existential quantifier. Furthermore, sentences of the shape 'if . . . , then' usually have the readings which result from giving the conditional widest scope. The reason that 'a donkey' in (1) usually takes the general reading is that giving the conditional wide scope over the existential quantifier results in an overall universal reading, as we saw in our analysis of (10). The reason that the second 'a donkey' in (20) does not take the general reading is that, regardless of whether we analyze 'a donkey' with wide scope or narrow scope, the corresponding interpretations (23) and (24) both select the existential reading:

(23) (Ex) (x is a donkey & (John owns a donkey $\supset$ John feeds x))

(24) John owns a donkey $\supset$ (Ex)(x is a donkey & John feeds x).

Finally, 'a donkey' and 'some donkey' have pretty much the same effect in (1) and (21), while 'all donkeys' has a very different effect because 'a donkey' selected the existential quantifier all along. We must admit that there are differences in the degree to which (1) and (21) allow the general interpretation. Some informants find the general interpretation of (21) somewhat forced. We can accommodate these differences in our theory, however, by claiming that '*a*' and 'some' have different tendencies for accepting analyses with narrow scope.

2. THE DEFINITE DESCRIPTION STRATEGY

We turn now to a number of suggestions about donkey sentences that involve treating anaphoric pronouns as definite descriptions. These views have the advantage that they allow the truth determining scope of 'a donkey' in (1) to range over the antecedent only, but they have the disadvantage that the relationship they posit between 'a donkey' and 'it' is not like variable binding. In exploring what we think is wrong about these attempts, we want to motivate the view that 'it' should be treated as a bound variable. At the same time, we will maintain that when it comes to truth-evaluations, the scope of 'a donkey' is narrow.

Partee [14] has tried to solve the problem posed by donkey sentences by suggesting that 'it' in (1) is a special kind of pronoun of laziness. A pronoun of laziness is a pronoun such as 'he' in (25), which is simply a replacement for its antecedent:

(25) If John owns a car, then he will drive.

The 'it' in (1) is not a pronoun of laziness in this typical sense since (1) is not equivalent to (26), whereas (25) is equivalent to (27):

(26) If John owns a donkey, then John feeds a donkey.

(27) If John owns a car, then John will drive.

Partee suggests that the surrogate for 'it' in (1) is a description constructed from the material surrounding the antecedent, for example, 'the donkey John owns'. On this view, (1) is derived at the surface level from (28):

(28) If John owns a donkey, then John feeds the donkey John owns.

Gareth Evans [1] proposes a variant of Partee's view about donkey sentences. He argues quite forcefully that the scope of quantification in sentences such as (1) and (29) extends only over the first subsentence:

(29) Few MPs came to the party, but they had a good time.

We have already seen the difficulty with the view that 'a donkey' takes widest scope in (1). If 'few MPs' were to take the widest scope in (29), the sentence would be equivalent to (30):

(30) It is true of few MPs that they both came to the party and had a good time.

But (29) entails that few MPs came to the party, while (30) is compatible with there having been many MPs at the party, though few that enjoyed it.

Evans concludes from his extensive analysis of such examples that we must develop a theory which allows a pronoun to have a quantifier expression as an antecedent, even though the semantical scope of that expression does not include the pronoun. This is exactly the position we want to take in this paper. However, Evans goes on to reason that such pronouns must be unbound, and concludes that there are pronouns (which he calls 'E-type pronouns') that have quantifier phrases as antecedents, but which cannot be treated as bound variables. He argues that such E-type pronouns have a referential use; that is, they refer to either an object or a class which can be determined by the meaning of the phrases surrounding the quantifier in the sentences in which they appear. Evans views 'they' in (29) as a referential pronoun which picks out the class of MPs who came to the party. Since these pronouns play more the role of names than that of variables on this analysis, the scope of quantifiers which are antecedents of such pronouns can be analyzed as narrowly as we like.

Evans carefully distinguishes this view from that of Partee, who, as we noted above, treats the 'it' in (1) as a special brand of pronoun of laziness. His proposal is a theory about the *semantics* of E-type pronouns and so he does not need to stipulate syntactic transformations to derive (1) from (26). His view is that E-type pronouns have referents, and that a semantical theory of how their referents are fixed involves a description which is constructed from the meaning of other phrases in the sentence.

There is much that is appealing in Evans' view that reference of E-type pronouns is fixed by certain descriptions, but, unfortunately, his analysis will not work for our stubborn donkey example. The problem is that on the standard reading, 'it' in (1) fails Evans' own test for E-type pronouns. Evans points out that when a pronoun like 'it' has a referent, then we should be able to answer such questions as, 'which thing do you mean?', that is, we should have a particular thing "in mind" if the pronoun is to function referentially. But it does not make sense to ask this question about the 'it' in (1) on the standard interpretation because 'it' refers, if to anything, to *whichever* donkey John owns. If we apply the semantical rule which Evans provides for fixing the referent of 'it' in (1), we discover that the consequent of (1) is true only if John owns one donkey. Because Evans uses a description to fix the referent of 'it' once and for all, he has no way to accommodate the fact that (1), on the standard interpretation, is true if John happens to own several donkeys and feeds each one.

This objection to Evans' view underscores a more general problem with any theory which attempts to read 'it' in (1) as a definite description, namely, that the definite description signals uniqueness, while the 'it' in (1) does not. This difficulty can be emphasized by the oddity which results from giving (31) Partee's analysis. The result is (32):

(31) If John buys an egg, then he must buy eleven others with it.

(32) If John buys an egg, then he must buy eleven others with the egg which John buys.

If John buys an egg, (32) entails that John buys exactly one egg. However, (31) must be compatible with his having bought a dozen eggs.[3]

Cooper [0] presents a theory of anaphoric pronouns that handles the 'it' in (1) like a definite description. However, his treatment of pronouns is much more flexible than Evans' because the semantical rule which must be satisfied in order to fix the referent of the pronoun is arbitrary, and is determined by pragmatic features of the discourse. By adjusting the condition, Cooper is able to provide a theory that unifies the treatment of anaphoric and deictic pronouns.

Nevertheless, our objections to Evans' theory apply equally well to Cooper's. No matter how the semantical conditions are provided, the description strategy forces 'it' in (1) to pick out an object uniquely and this is not what happens on the standard interpretation of (1).

3. THE CONDITIONAL STRATEGY

A second major strategy for dealing with donkey sentences is to treat 'it' in (1) something like a bound variable, and to explain why (1) takes the general reading by adjusting the semantical rules for conditionals. On the whole, theories of this kind are more successful than those that use the description strategy. However, there are problems with making conditionals bear the burden of selecting the right quantifier truth-conditions.

3.1. *GTS with Subgames*

In [4], Hintikka and Carlson treated sentences of the shape (if A, then B) as equivalent to (not A or B). In a later paper, [6], they point out that (if A, then B) makes an assertion whose force does not come into play at all *until* the antecedent A has been verified (or otherwise asserted with this intention in mind). They spell out this intuition using the concept of a subgame.

To evaluate a conditional, we first process the antecedent. (This corresponds to a complete playing off of an entire subgame correlated with the antecedent.) Only after we make clear to ourselves what the world would be like if the antecedent were true do we move on to consider what the consequent says *on this assumption.* We begin the play for the antecedent with reversed roles (so that choices Myself would ordinarily make fall to Nature, and *vice versa*). This has the effect of giving an analysis of the *negation* of the antecedent, and so it results in giving Nature choices for '$a(n)$', and giving Myself choices for 'all'. As a result, the analysis has the effect of changing the sign of the quantifier from existential to universal. If Myself can win the subgame for the antecedent, then this represents the fact that the antecedent is false, and no further processing of the sentence is necessary; Myself simply wins the game for the whole conditional. However, if Myself loses the subgame for the antecedent, then we must begin a second game with the consequent. Then the winner of the game for the whole conditional is the winner for this second subgame.

It is important to notice that since the subgame for the antecedent is processed with reversed roles, 'a donkey' in (1) selects the universal quantifier's truth-conditions. As a result, the subgame theory selects the standard reading for (1) without stipulating that 'a donkey' is ambiguous. Not only that, when a game for the consequent is played out, Nature and Myself already have selected instances for the general terms that appeared in the antecedent. So the referents of pronouns which have these general terms as antecedents are fixed by the referents of the names which we used to replace them. This theory has the attraction that we can treat 'it' in (1) in something vaguely like the referential way recommended by Evans, while at the same time obtaining the correct truth-conditions.

It is worthwhile to reflect for a moment on exactly why the subgame strategy has succeeded. The evaluation of (1) treats 'a donkey' with narrow scope because the subgame for the antecedent began in response to the application of the conditional rule. Nevertheless, subgame theorists have found a way to maintain the linkage between values selected for 'a donkey' during the subgame, and the value of 'it' in the consequent. In effect, their theory maintains the variable binding across the conditional despite the fact that the process of calculating truth-conditions gives 'if . . . , then' wide scope over 'a donkey'.

The subgame strategy is appealing to us because it supports our view that a kind of variable cross-reference is possible outside the truth evaluation scope of a quantifier. Nevertheless, there is a serious difficulty with subgames. Notice that the theory requires that the game for the antecedent be played out entirely; otherwise, we will lack names that determine the referents of the pronoun in the consequent. As a result, Hintikka and Carlson cannot accommodate backwards pronominalization. On their account, we must evaluate the antecedent of (33) before we work on the consequent:

(33) When a parent speaks to him, a child should listen.

When we do so, we encounter the pronoun 'him' before any game has been played to resolve its antecedent.

It is interesting that Hintikka and Carlson adopt a global constraint on their semantic theory which marks sentence (33) as ungrammatical. Their Progression Principle says that we always proceed left to right in evaluating a sentence. They say that this principle 'is in keeping with our psycholinguistic intuitions as to how the understanding of a sentence actually proceeds' [5: 81]. However, if this principle is correct, then their analysis of conditionals is inadequate for it cannot give any account of backwards pronominalization.

Perhaps Hintikka and Carlson might seek a way out of this difficulty by giving up the Progression Principle, and stipulating instead that we must play the first game on whichever subsentence contains a general term. However, this would take away what was intuitively pleasing about their rule for conditionals, and furthermore, it would still not work for sentences that contain both forward and backward pronominalization across a conditional as (34):

(34) If a man can find the money to pay for it, he will buy a fancy car.

Here any attempt to play a game out on either subsentence is foiled by the presence of a pronoun (either 'he' or 'it') whose antecedent lies in the sentence for which we have not begun a subgame.

One might try to avoid this difficulty by adopting a transformation rule which exchanges pronouns with their antecedents so that all general terms will turn up in the antecedent of a conditional. (34) might be transformed to (35) before any game is played:

(35) If a man can find the money to pay for a fancy car, he will buy it.

The trouble with this is that 'a car' will be given the universal interpretation when (35) is processed, giving (35) the reading which entails that a millionaire will continue to buy cars until he cannot pay for any more. Sentence (35) will take this reading, but (34) clearly does not.

A second difficulty with subgames emerges when Hintikka and Carlson see that they are required to adopt the subgame strategy to explain features of pronominalization across disjunctions and conjunctions [5: 86]. Although the subgame account is convincing for 'if . . . , then', it is not clear why a subgame should be entirely played out for a left disjunct or conjunct. Not only that, if the subgame strategy is used for disjunctions, then sentences with the shape (if A, then B) and (not A or B) turn out to be semantically equivalent; yet it was our intuition that these are not equivalent which motivated the choice of special rules for 'if . . . , then' initially. This difficulty leads us to believe that a proper treatment of anaphoric pronouns must not depend on adjustments in the rules for connectives. *Prima facie*, the correct place to adjust the rules for a theory of general terms and their anaphors is in the rules for general terms and pronouns.

Our theory will not rely on any special treatment of 'if . . . , then'. For simplicity, we will treat the English conditional as material implication. However, alternative rules for 'if . . . , then' are compatible with our approach. (See the Appendix for details.)

3.2. *Kamp's Theory*

Kamp [6] proposes a method for dealing with donkey sentences which selects the universal reading for (1) on the basis of a special treatment of the conditional. His theory has the advantage over subgames that it handles backwards pronominalization. However, other problems with the theory help underscore our view that the rules for connectives are the wrong place to look for a solution to the problems surrounding anaphoric pronouns.

One unusual feature of Kamp's approach is that 'a donkey' is not treated like a quantifier, but is analyzed, at least initially, more like a sorted free variable. When a sentence like (36) is analyzed, we obtain a structure called a discourse representation, which has something of the semantical effect of (37):

(36) John owns a donkey and he feeds it.

(37) John owns x & x is a donkey & John feeds x.

To calculate the truth value of (36) on a model, we assign values for x in (37), and any assignment that makes (37) true verifies (36). As a result, the truth-conditions for (36) are those of (38):

(38) (Ex) (John owns x & x is a donkey & John feeds x).

When a sentence contains a conditional, the free variables in discourse representations are tied up in a different way. The structure one obtains for the antecedent and consequent of (1) are (39) and (40) respectively:

(39) John owns x & x is a donkey.

(40) John feeds x.

Following the intuition that a sentence with the form (if A, then B) means that any way of making A true is also a way of making B true, Kamp adopts a rule for conditionals which tells us to try every way of assigning values for x in the antecedent. If the consequent is true on all assignments that make the antecedent true, the conditional is verified. Kamp's rule for conditionals gives (1) the interpretation (41):

(41) $(\forall x)$((John owns x & x is a donkey) $\supset$ John feeds x),

which amounts to the standard reading.[4]

This solution to the problems posed by (1) has interesting parallels with the theory we will present. Despite the fact that (1) is first analyzed as composed of (39) and (40), thus giving 'if . . . , then' wide scope, the connection between 'a donkey' and 'it' in the original is maintained by the variable x. Since no quantifier is selected by 'a donkey' during analysis into discourse representations, Kamp is free to choose the correct way of binding up x after the decomposition of (1) is complete. Kamp overcomes the problem of backwards anaphora by allowing simultaneous analysis of the antecedent and consequent of (1). He preserves the cross-reference between pronouns and their anaphors with variables, and he ensures wide scope for variable binding by postponing the binding process until the completed discourse representations are used to determine a sentence's truth-conditions.

The theory we will present resembles Kamp's strategy here because the first order formula which interprets a sentence on our approach gives quantifiers wide scope. However, our proposal differs from Kamp's because he relies on a special rule for 'if . . . , then' to ensure that the universal rather than existential quantifier is selected for final binding. We will rely on an adjustment in the rule for general terms.

One symptom of the problem we find with Kamp's theory is that it does not attempt to spell out the semantical treatment for 'or', 'and', or 'not'. It is hard to predict whether Kamp will be able to develop plausible and simple rules for connectives other than 'if . . . , then'. In particular, we do not see how to add negation to his theory without also adding *ad hoc* stipulations about quantifier selection when free variables are finally bound up. We believe that such stipulations are needed to give (42) the right interpretation:

(42) It is not the case that John owns a donkey.

The problem is that if we give (42) either discourse representation (43) or (44), then the free variable x will be bound by an existential quantifier. However, we need some way to select the universal quantifier to obtain (45), the natural reading:

(43) $-(x$ is a donkey & John owns $x)$

(44) x is a donkey & $-$ John owns x

(45) $(\forall x) - (x$ is a donkey & John owns $x)$.

Our objection to Kamp is similar to our objection to subgames. In both cases, the extension of the theory to connectives other than 'if . . . , then' is neither obvious nor natural. This leads us to conclude that selection of the right rule of evaluation for 'a donkey' cannot be fully explained with a local adjustment to a conditional rule.

4. INDEPENDENT EVIDENCE FOR OUR VIEW

We hope to have assembled enough evidence in our discussion of the donkey sentences to interest the reader in our proposal that there are two kinds of quantifier scope. However, we have been frustrated in attempts to use variants of donkey sentences to support our own theory because of (sometimes heated) disagreements between informants.

These disagreements are probably caused by two sorts of perturbing influences, which may even interact. First, though we maintain that 'a donkey' is usually to be treated as an existential quantifier, examples such as (19) clearly demonstrate that 'a donkey' also has a generic reading. An explanation of what causes these readings is well beyond the scope of this paper, for the emergence of the generic reading undoubtedly depends on world knowledge. Compare (19), for example, with (46)–(50):

(19) A donkey is an animal.

(46) A donkey is an omnivore

(47) A donkey in that pen is an omnivore.

(48) A donkey in that genus is an omnivore.

(49) A donkey is fat.

(50) A pig is fat.

The second perturbation present in the donkey sentences results from the fact that there are often two or more ways to assign scope to 'a donkey' in a sentence, resulting in different readings. We claim that 'a donkey' in (1) "usually" takes narrow scope, but we cannot deny the existence of Partee's reading (at least for some informants), where it takes wide scope. In view of these complications, we believe that donkey sentences are dirty evidence for treating theories of anaphora. In this section, we will prevent evidence for our position which avoids these perturbations, and which serves, we believe, as a better kind of challenge to theories of anaphora.

Suppose, for a moment, that 'no man' in (51) has widest scope:

(51) No man may enter unless he is wearing shoes.

This interpretation of (51) is represented by (52):

(52) $(\forall x)$ (x is a man $\supset$ – (x may enter unless x is wearing shoes)).

However, (52) is equivalent to (53), which entails (54):

(53) $(\forall x)$ (x is a man $\supset$ – (if – (x wears shoes), then x may enter))

(54) $(\forall x)$ (x is a man $\supset$ (– (x wears shoes) & – (x may enter))).

Since (54) entails that no man may enter, (52) does not represent (51). We conclude that 'no man' does not have widest semantical scope in (51), and so widest scope must be held by 'unless'.

On the other hand, 'he' in (51) clearly acts as a bound variable. It is not a pronoun of laziness, nor is the description strategy even remotely plausible here, as can be seen in (55):

(55) No man may enter unless the man who may enter is wearing shoes.

The correct truth-conditions for (51) are those of (56):

(56) $(\forall x)$ (x is a man $\supset$ (if x may enter, then x is wearing shoes)).

In (56), the anaphora between 'a man' and 'he' in (51) is expressed by variable binding.

It is interesting to note that subgames can handle (51) properly as long as 'unless' is traded for 'if . . . , then' in the appropriate way before processing. However, we believe that Kamp's theory will have a difficult time with (51). Experiments using the obvious modification of his rule for 'every' to handle 'no' result in discourse representations which cannot set up the proper cross-reference between 'no man' and 'he'. This underscores our previous contention that Kamp may have difficulty handling negation.

A second line of evidence for our view has to do with sentences which contain disjunctive terms such as 'Al or Bill'. Consider (57):

(57) If John owns Al or Bill, then John feeds him.

Here we intend 'him' to be anaphoric, so that (57) has the sense of (58):

(58) If John owns Al, then John feeds Al, *and* if John owns Bill, then John feeds Bill.

Notice that 'him' in (57) is not a pronoun of laziness. Replacing it with 'Al or Bill', 'Al', 'Bill', 'Al and Bill', or even 'the thing John owns' changes the meaning of (57). It should be clear, then, that (57) involves cross-reference between 'him' and 'Al or Bill'.

Suppose that we try to explain the cross-reference by claiming that (57) is derived by applying 'Al or Bill' to 'If John owns x, then John feeds x'. The difficulty is that the semantical rule for the application of the disjunctive term $(m \vee s)$ to an open sentence $\emptyset(x)$ should rule $\emptyset(m \vee s)$ true just in case $\emptyset(m)$ is true *or* $\emptyset(s)$ is true. Applying this rule to (57), we obtain reading (59), which (57) never means:

(59) If John owns Al, then John feeds Al, *or* if John owns Bill, then John feeds Bill.

These difficulties we have encountered with (57) almost exactly parallel the problems raised by (1). To appreciate the parallel, imagine a world where Al and Bill are the only donkeys. In this world, (1) and (57) are (extensionally) equivalent, and the misreading (59) of (57), which results from assuming 'Al or Bill' has wide semantical scope corresponds exactly to Partee's reading of (1).

5. THE POSITIVE THEORY

We are now ready to present our theory. Our guiding intuition will be that the selection of the universal reading of (1) is accomplished by giving the conditional widest scope. Nevertheless, the resulting analysis of (1) will represent the relationship between 'a donkey' and 'it' as that of variable binding.

There would seem to be an insurmountable difficulty with any attempt to give 'if . . . , then' wide scope in (1) because then the truth value of (1) ought to depend on the values of 'John owns a donkey' and 'John feeds it'. However, 'John feeds it' does not have a truth value unless 'it' has a referent, and nothing about the standard rule for 'if . . . , then' provides one.

The solution to this problem is to provide a definition of truth on a model which is not fully compositional. We do not demand that the truth value of (1) be a function of the separately calculable values of its subexpressions. Our theory, however, does satisfy a weaker form of compositionality, where the truth value of a sentence on an analysis is uniquely determined by the truth value of the atomic sentences. Both Kamp's theory and subgames are similar to our theory in providing definitions of truth which are not fully compositional.

There are several equivalent ways of presenting our approach to quantifier expressions in English. For simplicity, we will formulate it as a set of rules which are used to take sentences of a primitive subset of English into first order logic. The output formulas of the theory are intended to represent the semantical interpretations given to the input sentences. We could have presented the theory as a set theoretic semantics which converts a sentence's phrase structure into the conditions a model must meet when the sentence is true; however, the method we will use here has the advantage that any reader familiar with first order logic may easily generate and check the interpretations our theory gives.

A detailed account of our rules and the syntax of the subset of English to which they apply, appears in the Appendix. In order to help motivate the technical material, we will present our treatment of (57) in an informal way.

The analysis of (57) begins with the application of rule (60):

(57) If John owns Al or Bill, then John feeds him.

(60) $\ldots$ if A, then $B \ldots \rightarrow \ldots (-(A) \vee B) \ldots$.

This rule simply interprets 'if . . . , then' as material implication. Alternative treatments of 'if . . . , then' could be used at this point without causing major adjustments to our theory. (See the Appendix.) The result of applying rule (60) to (57) is (61):

(61) (— (John owns Al or Bill) $\vee$ John feeds him).

Next, we apply a rule for complex terms to '— (John owns Al or Bill)', the left disjunct of (61). Ordinarily, we would count 'John owns Al or Bill' false just in case both 'John owns Al' *and* 'John owns Bill' are false. This corresponds to rule (62):

(62) $\ldots - \emptyset(a \vee b) \ldots \rightarrow \ldots (-\emptyset(a) \mathbin{\&} -\emptyset(b)) \ldots.$

However, applying rule (62) to the left disjunct of (61) yields (63) where 'him' has lost its reference to 'Al' and 'Bill':

(63) (— (John owns Al) & — (John owns Bill)) $\vee$ John feeds him.

To maintain the anaphora, we must analyze (61) so that 'him' is first replaced with 'Al' and then 'Bill' during the application of the rule for 'Al or Bill'. We need a rule which allows rule (62) to be applied *locally* to the left disjunct, while at the same time performing *global* replacement of names for anaphoric pronouns. Rule (64) has this effect:

(64) $\ldots - \emptyset(a \vee b) \ldots \rightarrow [\ldots - \emptyset(a) \ldots]^a \mathbin{\&} [\ldots - \emptyset(b) \ldots]^b,$

where $[\ ]^a$ is the operation that replaces anaphors of (a or b) with a, and similarly for $[\ ]^b$. The result of applying (64) to (61) is (65), which gives the correct truth-conditions for (57):

(65) (— (John owns Al) $\vee$ John feeds Al) & (— (John owns Bill) $\vee$ John feeds Bill).

By generalizing the rule for 'a donkey' in the same way, we may generate the standard reading of (1). After the rule for 'if . . . , then' is applied, we obtain (66):

(66) — (John owns a donkey) $\vee$ John feeds it.

The rule that records the semantical information that — (John owns a donkey) is true just in case — (John owns x) is true for every value of x which is a donkey reads: $-\emptyset(\mathrm{a}\,P) \rightarrow (\forall x)(-(x\,P) \vee -\emptyset(x))$. Rule (67) is the result of modifying this rule so that it performs global replacement of x for anaphors of 'a donkey':

(67) $\ldots - \emptyset(\text{a } P) \ldots \rightarrow (\forall x)(-(x\ P) \vee [\ldots - \emptyset(x) \ldots]^x)$,

where $[\ \ ]^x$ replaces anaphors of 'a P' with x. The result of applying (67) to (66) is (68), which is the standard reading:

(68) $(\forall x)(-(x \text{ donkey}) \vee (-(\text{John owns } x) \vee \text{John feeds } x))$.

If we reverse the order in which we apply the rules to (1), we may also derive Partee's reading. Here we apply a rule for 'a donkey' to the entire sentence. Since we are interested in the conditions under which this sentence is true, not false, we need to apply Rule (69), which corresponds to the rule that $\emptyset$('a donkey') is true just in case $\emptyset(x)$ is true for some value of x. The result of applying (69) to (1) is (70):

(69) $\ldots \emptyset(\text{a } P) \ldots \rightarrow (Ex)(xP \;\&\; [\ldots \emptyset(x) \ldots]^x)$.

(70) $(Ex)(x \text{ donkey } \& \text{ (if John owns } x\text{, then John feeds } x))$.

When we apply the rule for 'if . . . , then', we obtain (71):

(71) $(Ex)(x \text{ donkey } \& \ (-(\text{John owns } x) \vee \text{John feeds } x))$.

6. BLOCKED INTERPRETATIONS

As it stands, our theory assigns sentences interpretations which they have rarely or never. Nothing stops us from applying the rule for 'Al or Bill' to (57) before the rule for 'if . . . , then'. The effect is to give the complex term wide semantical scope, and so the resulting interpretation is (72):

(72) $(-(\text{John owns Al}) \vee \text{John feeds Al}) \vee (-(\text{John owns Bill}) \vee \text{John feeds Bill})$

Clearly we will need to add principles for ordering the application of rules to ensure that 'Al or Bill' has narrower semantical scope than 'if . . . , then'. We also may block unwanted readings for sentences containing quantifiers by adding scope restrictions. 'any' seems to demand wide semantical scope, while 'no' demands narrow scope. The quantifiers 'some', 'a', and 'every' seem to fall somewhere in between, with wide scope depending on pragmatic features and stress. However, they rarely have wider scope than the connectives 'and', 'or', 'if . . . , then', etc.

When we introduce 'not' to our theory, we will need to make further restrictions on ordering. The rule for 'not' prefixes — to a sentence and converts the verb phrase containing 'not' from negative to positive. If this rule is applied first to (73), followed by the rule for 'a donkey', the result is (74), which is at best a rare interpretation of (73):

(73) John does not feed some donkey.

(74) $(\forall x)(-(x \text{ donkey}) \vee -(\text{John feeds } x))$.

If we require, however, that 'not' take narrow semantical scope, by delaying the application of its rule, we will generate the normal reading of (73). This and many other examples suggest that 'not' normally takes the narrower possible semantical scope.

Although restrictions on ordering are helpful, they do not remove all unwanted readings. If we evaluate (75), by applying the rule for 'if . . . , then' first, followed by the intuitively correct rule for 'every', we obtain a reading which is equivalent in first order logic to (76):

$$\ldots - \emptyset(\text{'every'}) \ldots \rightarrow (Ex)(xP \,\&\, [\ldots - \emptyset(x) \ldots]^x.$$

(75) If John owns every donkey, then John feeds it.

(76) $(\forall x)(x \text{ donkey} \supset \text{John owns } x) \supset (Ex)(x \text{ donkey} \,\&\, \text{John feeds } x)$.

However, most people can make sense of (75) only when 'it' is not an anaphoric pronoun.[5] Notice, though, that (76) lacks variable binding across 'if . . . , then', and 'John feeds it' is rendered by the predicate logic representation of 'John feeds some donkey'. Our theory predicts that if (75) makes sense at all, 'it' no longer counts as a truly anaphoric pronoun, for 'it' is interpreted the same way 'some donkey' is treated in the sentence 'If John owns every donkey, then John feeds some donkey'. On the other hand, our theory does not explain why (75) has no anaphoric reading at all because it does predict a reading.

The problem with (75) is not an isolated occurrence. Our theory has trouble with 'every' on other counts. It predicts readings for (77)–(80), ((77) and (78) are drawn from Kamp [6: 41–42]), and yet none of these has anaphoric readings.

(77) Every man that owns every donkey feeds it.

(78) If John likes every woman who owns a donkey, John feeds it.

(79) John owns every donkey and John feeds it.

(80) John owns every donkey or John feeds it.

Sentence (81) would be ambiguous between two readings on our theory, and yet it has only one reading:

(81) Every man feeds some donkey who likes him.

Notice that if we find a good way to block readings for (75), and (77)–(81), we must still predict readings for the following variants of (78)–(80), where 'every' is replaced by 'a':

(82) If John likes a woman who owns a donkey, John feeds it.

(83) John owns a donkey and John feeds it.

(84) John owns a donkey or John feeds it.

We must admit that we are not entirely sure how to handle these cases, but we have a conjecture concerning 'every' which may help. Sentences (85) and (86) suggest that 'every' demands narrow anaphoric scope so that it never allows anaphors which lie across a sentence boundary:

(85) Every man owns some donkey and it bites him.

(86) Every man owns some donkey that bites him.

Adopting this principle immediately blocks readings for (75), (78)–(80), and (85). The blocked reading for (77) can be explained by pointing out that the application of the rule for 'every man' in (77) leaves 'it' and 'every donkey' on opposite sides of a disjunction, and so separated by a sentence boundary. Notice that only the correct readings for (81) and (86) are generated on these grounds, for the only way to avoid separating 'every donkey' and its anaphor is to apply the rule for 'every man' first.

In any case, the explanation of blocked readings using restrictions on semantical and anaphoric scope needs more work. We also need to explore the relationship between the restrictions we have proposed and the results on blocked readings achieved by Kamp [6] and Hintikka [5].

7. PLURAL PRONOUNS

Our theory gives incorrect interpretations to sentences containing plural pronouns. Neither interpretation which our theory gives to (87) is correct.

(87) If John owns all donkeys, then John feeds them.

Something like Evans' theory seems more appropriate for plural pronouns. Following his lead, we might claim that a plural pronoun like 'them' picks out a set which has been introduced in the interpretation of a phrase or sentence in which its antecedent appears. ('them' in (87) picks out the set of donkeys that John owns.) Once this "salient set" has been established, a sentence of the form (*P* 'them'), for example, 'John feeds them', asserts that ***all*** things in this set have the property *P*. This "universal interpretation" for plural pronouns is not affected by the "quantity" of the general term which serves as its antecedent. In sentences (88)–(91) the consequent asserts that John feeds ***all*** donkeys he owns:

(88) If John owns most donkeys, then he feeds them.

(89) If John owns some donkeys, then he feeds them.

(90) If John owns 27 donkeys, then he feeds them.

(91) If John owns few donkeys, then he feeds them.

Examples like (92)–(94) illustrate that the specification of just which set is the salient one is not an easy matter, and probably depends on information about the world and other pragmatic matters:

(92) Either John bought some donkeys or he stole them.

(93) John dislikes most women, but he respects them.

(94) John dislikes a few women, but he respects them.

(92), the salient set cannot consist of donkeys John bought, because then the second disjunct would claim that John stole all donkeys he bought. Sentence (93) has two interpretations; the stronger one entails that John respects all women, and not just those that he dislikes. On the other hand, the primary reading of (94) seems to go the other way, for it claims that John respects the few women he dislikes, and not all women. An adequate theory of plural pronouns which deals with these issues lies beyond the scope of this paper.

8. CONCLUSION

We have shown how our theory handles many difficult cases of pronominalization across connectives, including the donkey example, and examples containing disjunctive terms. This is clearly an advance over Montague Grammar, Evans' Referential Theory, and GTS. GTS with subgames can also handle the donkey example. However, we argued it suffers from two deficiences: it cannot handle backwards pronominalization, and it forces unmotivated and unintuitive adjustments to the rules for connectives. Kamp's theory *does* handle backwards pronominalization, but it is not clear how to extend his theory to handle 'and', 'or', and 'not'. Our theory avoids these difficulties. Regardless of whether this means we win the day, we believe that our analysis of the strengths of the partially successful theories supports our central contention that a proper treatment of quantifiers in English requires the separation of the two kinds of quantifier scope.

APPENDIX

We present here the formal details of our theory of quantifiers and anaphora in English. We will make no attempt to lay out a complete set of rules for blocked interpretations here, but we hope to treat this matter more carefully in another paper. However, we will remind the reader of Section 6 of this paper where methods are discussed for eliminating some unwanted readings which the theory of this Appendix will generate.

We will begin with the syntax for a subset of a variant of English, which also includes the vocabularly of first order logic. To simplify the stipulation of the rules, we assume that every general term in a sentence has been labelled with a unique variable, and that all its anaphoric pronouns have been replaced with this variable. The question as to which pronouns are anaphoric for which general terms is decided by semantic and pragmatic considerations that lie outside the scope of this paper. In the notation of this language, we write $(n)^x$ for the general term n labeled by variable x.

The rules for the syntax of this language follow.[6] We use underlining to indicate notation that is mentioned rather than used in order to avoid thickets of quotes. We also assume that the logical notation $-$, $\supset$, &, $\vee$, (,) is mentioned in these rules (as it is in this sentence).

Sentence = {*I am wrong.*}

Common-Noun = {*donkey, man*}

Transitive-Verb = {*owns, feeds, likes, bites, is, sold, does not own, does not feed, does not like, does not bite*}

Term = {*John, Al, Bill, I*}

Variable = $\{x, y, z, x', y', z', \ldots\}$

Quantifier = {*a, some, no, every*}

If $P \in$ Common-Noun, then $P \in$ Common-Noun-Phrase.

If $R \in$ Transitive-Verb and $n \in$ Noun-Phrase, then $nR, Rn \in$ Intransitive-Verb-Phrase.

(We use 'nR' for the result of concatenating n with R, etc.)

If $P \in$ Common-Noun-Phrase, and $Q \in$ Intransitive-Verb-Phrase, then P *that* $Q \in$ Common-Noun-Phrase.

If $P \in$ Common-Noun-Phrase, and $Q \in$ Quantifier, and $x \in$ Variable, then $(QP)^x \in$ General-Term.

If $n \in$ General-Term $\cup$ Term $\cup$ Variable, then $n \in$ Noun-Phrase.

If $n, m \in$ Noun-Phrase, and $R \in$ Transitive-Verb, then $nRm \in$ Sentence, and n *or* $m \in$ General-Term

If $A, B \in$ Sentence, and $x \in$ Variable, then *if* A, *then* B, A *or* B, A *and* B, A *unless* B, $(A \rightarrow B)$, $(A \,\&\, B)$, $(A \vee B)$, $-(A)$, $(\forall x)A$, and $(Ex)A \in$ Sentence.

All sets defined are closures under application of the above rules.

We will now present a set of rewrite rules which takes sentences of this language into one or more formulas of first order logic.[7] In what follows, square brackets are used to indicate the portion of a sentence to which the rewrite rules are to apply. The input to our set of rules is any members of Sentence surrounded by square brackets. To obtain a sentence of first order logic at the end of the process, we stipulate that square brackets surrounding any sentence to which no rule may be applied are removed. We assume that $A, B \in$ Sentence, $n, m \in$ Noun-Phrase, $P \in$ Common-Noun, and $Q \in$ Intransitive-Verb-Phrase. When $(n)^x$ is a general term labelled by x, $\emptyset(n)^x$ is any sentence containing $(n)^x$ whose first symbol is not $-$ and $\emptyset(x)$ is the result of replacing x for all occurrences $(n)^x$ in $\emptyset(n)^x$. An/x is the result of replacing each occurrence of x in A with n,[8] if n is a Term, and with $(n)^x$ otherwise.

R1 $[\ldots A$ and $B \ldots] \to [\ldots (A \,\&\, B) \ldots]$

R2 $[\ldots A$ or $B \ldots] \to [\ldots (A \vee B) \ldots]$

R3 $[\ldots$ if A, then $B \ldots] \to [\ldots (-(A) \vee B) \ldots]$

R4 $[\ldots n$ does not V $m \ldots] \to [\ldots -(n$ Vs $m) \ldots]$ where V is *own*, *feed*, *like*, or *bite* and Vs is the result of adding s to V.

R5 $[\ldots -(-(A)) \ldots] \to [\ldots A \ldots]$

R6 $[\ldots -(A \,\&\, B) \ldots] \to [\ldots -(A) \vee -(B) \ldots]$

R7 $[\ldots -(A \vee B) \ldots] \to [\ldots -(A) \,\&\, -(B) \ldots]$

R8 $[(A \,\&\, B)] \to ([A] \,\&\, [B])$, if no one variable appears in both A and B.

R9 $[(A \vee B)] \to ([A] \vee [B])$, if no variable appears in both A and B.

R10 $[\ldots -\emptyset(\text{a } P)^x \ldots] \to (\forall x)(-(xP) \vee [\ldots -\emptyset(x) \ldots])$

R11 $[\ldots -\emptyset(\text{no } P)^x \ldots] \to (Ex)(xP \,\&\, [\ldots \emptyset(x) \ldots])$

R12 $[\ldots -\emptyset(\text{every } P)^x \ldots] \to (Ex)(xP \,\&\, [\ldots -\emptyset(x) \ldots])$

R13 $[\ldots -\emptyset(n \text{ or } m)^x \ldots] \to [\ldots -\emptyset(x) \ldots]^{n/x} \,\&\, [\ldots -\emptyset(x) \ldots]^{m/x}$

R14 $[\ldots -\emptyset(\text{a } P \text{ that } Q)^x \ldots] \to (\forall x)(-(xP) \vee [(-(xQ) \,\&\, \ldots -\emptyset(x) \ldots)]$

R15 $[\ldots -\emptyset(\text{no } P \text{ that } Q)^x \ldots] \to (Ex)(xP \,\&\, [(xQ \,\&\, \ldots \emptyset(x) \ldots)])$

R16 $[\ldots -\emptyset(\text{every } P \text{ that } Q)^x \ldots] \to (Ex)(xP \,\&\, [(xQ \,\&\, \ldots -\emptyset(x) \ldots)])$

R17 $[\ldots \emptyset(\text{a } P)^x \ldots] \to (Ex)(xP \,\&\, [\ldots \emptyset(x) \ldots])$

R18 $[\ldots \emptyset(\text{no } P)^x \ldots] \to (\forall x)(-(xP) \vee [\ldots -\emptyset(x) \ldots])$

R19 $[\ldots \emptyset(\text{every } P)^x \ldots] \to (\forall x)(-(xP) \vee [\ldots \emptyset(x) \ldots])$

R20 $[\ldots \emptyset(n \text{ or } m)^x \ldots] \to [\ldots \emptyset(x) \ldots]^{n/x} \vee [\ldots \emptyset(x) \ldots]^{m/x}$

R21 $[\ldots \phi(\text{a } P \text{ that } Q)^x \ldots] \to (Ex)(xP \mathbin{\&} (xQ \mathbin{\&} \ldots \phi(x) \ldots)])$

R22 $[\ldots \phi(\text{no } P \text{ that } Q)^x \ldots] \to (\forall x)(-(xP) \vee [(-(xQ) \vee \ldots - \phi(x) \ldots)])$

R23 $[\ldots \phi(\text{every } P \text{ that } Q)^x \ldots] \to (\forall x)(-(xP) \vee [(-(xQ) \vee \ldots \phi(x) \ldots)])$

The rules for 'some' are the same as for 'a', and the rule for 'unless' is the rule for 'or'. Any formula of predicate logic which results from applying these rewrite rules to a sentence of our syntax is an interpretation of that sentence.

To illustrate the operation of the rules involving relative clauses we give the analysis of a Bach–Peters sentence:

A man that owns it feeds a donkey that bites him.

[(a man that owns y)^x feeds (a donkey that bites x)^y]

(Ex) (x man & [(x owns y and x feeds (a donkey that bites x)^y)]) R21.

(Ex) (x man & (Ey) (y donkey & [(y bites x & (x owns y & x feeds y))])) R21.

The purpose of R6 and R7 is to allow us to move negations into positions where R10–R16 may be applied. R5 cancels double negations so that R17–R23 can be applied. The purpose of R8 and R9 is illustrated by the following pair of examples:

[John owns (a donkey)^x unless John sold x].

[(John owns (a donkey)^x $\vee$ John sold x)] R2 (for 'unless').

(Ex) (x donkey & [(John owns x $\vee$ John sold x)]) R27.

[John owns (a donkey)^x unless I am wrong].

[(John owns (a donkey)^x $\vee$ I am wrong)] R2.

([John owns (a donkey)^x $\vee$ [I am wrong]]) R9.

(Ex) (x donkey & [John owns x]) $\vee$ [I am wrong] R17.

Note that if we had not applied R9 in the second example, we would have derived:

$$(Ex)(x \text{ donkey } \& \text{ (John owns } x \vee \text{I am wrong)}),$$

which is only a weak interpretation for the original sentence. The rules R8 and R9 have the effect of allowing us to adjust the scope of the quantifier introduced by R10–R23 so that it matches the scope of the anaphora in the original sentence.

One might think that our theory depends on the use of material implication as the interpretation of 'if . . . , then', for it may appear that only that interpretation would place 'a donkey' in (1) in a negated disjunct. However, our theory can be extended to handle strict implication and some other intensional accounts of 'if . . . , then'. Since our theory outputs formulas of first order logic as interpretations of English sentences, the appropriate method of expressing intensions should take the form of counterpart theory. Let us presume then that the sentences of our language are to be indexed by possible worlds, and that the evaluation of any sentence begins in the real world. We introduce a set $w, w', w'', \ldots$ of possible world variables, (sortal) quantifiers which bind them, and a relation R to express accessibility of possible worlds. If we attach world variables to the square brackets in our rewrite rules, then the following rule may be used in place of (R3):

(R3′) $[\ldots \text{if } A, \text{then } B \ldots]w \to (\forall w')(-(wRw')) \vee$
$[\ldots(-(A) \vee B)\ldots]w'$.

In order to ensure that world variables are treated correctly at the end of the translation process, we stipulate that when no rules can be applied to A, $[A]\,w$ amounts to the result of inserting w into an extra slot for world variables in the predicates of A. To ensure that this insertion is carried out properly, we need a simple modification of rule (R10):

(R10′) $[\ldots - \emptyset(\text{a } P)^x \ldots]\,w \to (\forall x)(-([xP]\,w) \vee$
$[\ldots - \emptyset(x)\ldots]\,w)$.

Similar modifications are needed for rules (R9)–(R12), (R14)–(R19), and (R21)–(R23).

The following derivation shows that the theory so amended produces a correct interpretation of (1):

If John owns a donkey, then John feeds it.

[If John owns (a donkey)x, then John feeds x] w.

$(\forall w')(-(wRw') \vee [-(\text{John owns (a donkey)}^{x}) \text{ or John feeds } x]\, w')$ R3′.

$(\forall w')(-(wRw') \vee (\forall x)(-([x \text{ donkey}]\, w) \vee [-(\text{John owns } x) \vee \text{John feeds } x]\, w))$ R10.

$(\forall w')(-(wRw') \vee (\forall x)(-(x \text{ donkey at } w) \vee -(\text{John owns } x \text{ at } w') \vee \text{John feeds } x \text{ at } w'))$.

Similar methods will work to capture the Routley–Meyer semantics for entailment. However, we do not see how to extend the theory to cover subjunctive conditionals.

NOTES

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This paper is truly a joint effort and it could not have been written without the contribution of both authors. Garson, though, deserves credit (or blame) for first seeing the need for two kinds of quantifier scope, and also for devising essentials of the positive theory.

[1] We adopt the convention that the formal constants of this paper name themselves. So we omit quotes and corners from formulas which contain no English vocabulary, and we enclose sentences in the text which contain English words with single quotes.

[2] We should point out that by adding transformations to PTQ, we can achieve the same effect.

[3] Partee has since abandoned her view in response to examples due to Irene Heim which have kinship with our (31).

[4] The reader should be aware that our discussion of Kamp's theory has omitted many of its important features. The simplified exposition we have given was designed to show the connection between Kamp's approach and our own, and it does not include enough detail to account for many of the theory's powerful predictions.

[5] One way to avoid the problem posed by sentences like (75) is to introduce a rule that eliminates readings where what was taken to be an anaphoric pronoun loses its antecedent in this way. We might then reject any readings where a pronoun loses its antecedent.

In a previous version of this paper, we had attempted to formulate a rule which would block readings in sentences (75), and (77)–(81), in this way. However, the reader found a serious problem in our definition. We still think the idea is worth further effort, which we will leave to another paper.

[6] The reader has pointed out that our syntax is too weak with respect to the way it accommodates relative clauses. A more elaborate, and more standard treatment of relative clauses can be introduced without changing the essentials of our theory, though we admit, it would require further complicating rules R14–R16 and R21–R23.
[7] We would reformulate these rules so that they take sentences into Skolem Normal Form. The rules are simplified because no quantifiers are introduced, and so there is no need to place them in positions of widest scope to ensure variable binding. The replacement of general terms with variables and function symbols automatically provides for global binding. From the point of view of Kowalski's [7] treatment of natural language processing, the results *are* just the interpretation of English sentences.
[8] Note that there are not two quantifier clauses. This is because there is only *one* quantifier. There are two kinds of *scope* for one quantifier. So, managing both kinds of scope must be done in a single rule, roughly by adopting global treatment of variables and local treatment of quantifier selection.

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