8

A Theory of Truth and Semantic Representation

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1 Introduction

Two conceptions of meaning have dominated formal semantics of natural language. The first of these sees meaning principally as that which determines conditions of truth. This notion, whose advocates are found mostly among philosophers and logicians, has inspired the disciplines of truth-theoretic and model-theoretic semantics. According to the second conception meaning is, first and foremost, that which a language user grasps when he understands the words he hears or reads. This second conception is implicit in many studies by computer scientists (especially those involved with artificial intelligence), psychologists and linguists – studies which have been concerned to articulate the structure of the representations which speakers construct in response to verbal inputs.

It appears that these two conceptions, and with them the theoretical concerns that derive from them, have remained largely separated for a considerable period of time. This separation has become an obstacle to the development of semantic theory, impeding progress on either side of the line of division it has created.

The theory presented here is an attempt to remove this obstacle. It combines a definition of truth with a systematic account of semantic representations. These two components are linked in the following manner. The representations postulated here are (like those proposed by others; cf. e.g. Hendrix (1975) or Karttunen (1976)) similar in structure to the models familiar from model-theoretic semantics. In fact, formally they are nothing other than partial models, typically with small finite domains. Such similarity should not surprise; for the representation of, say, an indicative sentence ought to embody those conditions which the world must satisfy in order that the sentence be true; and a particularly natural representation of those conditions is provided by a partial model with which the (model describing the) real world will be compatible just in case the conditions are fulfilled.

Interpreting the truth-conditional significance of representations in this way we are led to the following characterization of truth: A sentence S, or discourse D, with representation m is true in a model M if and only if M is compatible with m; and

compatibility of M with m, we shall see, can be defined as the existence of a proper embedding of m into M, where a *proper embedding* is a map from the universe of m into that of M which, roughly speaking, preserves all the properties and relations which m specifies of the elements of its domain.

A theory of this form differs fundamentally from those familiar from the truth-theoretical and model-theoretical literature, and thus a substantial argument will be wanted that such a radical departure from existing frameworks is really necessary. The particular analysis carried out in the main part of this paper should be seen as a first attempt to provide such an argument. The analysis deals with only a small number of linguistic problems, but careful reflection upon just those problems already reveals, I suggest, that a major revision of semantic theory is called for.

The English fragment with which the analysis deals contains sentences built up from these constituents: common nouns, certain transitive and intransitive verbs (all in the third person singular present tense), personal and relative pronouns, proper names, and the particles *a*, *every*, and *if …* (*then*). These can be combined to yield the following sorts of compounds:

1   complex singular terms such as *a man, every woman, a man who loves every woman, every woman whom a man who owns a donkey loves*, etc. (We can embed relative clauses inside others and there is no upper bound to the depth of embedding!);
2   singular terms – i.e. complex terms of the kind just exemplified, proper names and personal pronouns – can be combined with verbs to yield sentences;
3   sentences may be joined with the help of *if* to form larger sentences of conditional form; sentences serve moreover as the sources of relative clauses.

The choice of this fragment is motivated by two central concerns: (a) to study the anaphoric behaviour of personal pronouns; and (b) to formulate a plausible account of the truth conditions of the so-called "donkey-sentences" (which owe their name to the particular examples in Geach (1962), the work that kindled contemporary interest in sentences of this type). As these donkey-sentences will play a prominent role in the theory developed below, let me briefly review the problem that they have been taken to present. We shall concentrate on the following two instances:

(1)   If Pedro owns a donkey he beats it
(2)   Every farmer who owns a donkey beats it.

For what needs to be said at this point it will suffice to focus on (1). For many speakers, including the author of this paper, the truth conditions of (1) are those determined by the first order formula

(3) $(\forall x)$ (Donkey(x) $\wedge$ Owns(Pedro,x) $\rightarrow$ Beats(Pedro,x)).

(As a matter of fact not all English speakers seem to agree that (3) correctly states the truth conditions of (1). Unfortunately an adequate discussion of diverging intuitions is not possible within the confines of the present contribution.)

The problem with (1) and (3) is that the indefinite description *a donkey* of (1) reemerges in (3) as a universal quantifier. How does an expression of a type which standardly (or so it always seemed) conveys existence manage to express universality in a sentence such as (1)? One way in which one might hope to explain this is by referring to the familiar equivalence between universal quantifiers with wide and existential quantifiers with narrow scope. Sentence (4), for instance, can be symbolized not only as (5) but also as (6).

(4) If Pedro owns a donkey he is rich
(5) $(\forall x) (Donkey(x) \wedge Owns(Pedro,x) \rightarrow Rich(Pedro))$
(6) $(\exists x) (Donkey(x) \wedge Owns(Pedro,x)) \rightarrow Rich(Pedro)$.

Out of these two (6) would appear to be the "natural" symbolization of (4) as it renders the indefinite *a donkey* as an existential quantifier. (5), we might be inclined to say, is adequate only for indirect reasons, viz. in virtue of its logical equivalence to (6). Note, however, that (1) cannot be captured by an analogue of (6). For in such a formula the scope of the existential quantifier would have to be restricted, just as it is in (6), to the antecedent alone; but then the quantifier would be incapable of binding the position corresponding to that occupied by *it* in the main clause of (1).

No one of the solutions to this problem that can be found in the existing literature strikes me as fully satisfactory. As I see the problem a proper solution should provide: (i) a general account of the conditional; (ii) a general account of the meaning of indefinite descriptions; and (iii) a general account of pronominal anaphora; which when jointly applied to (1) assign to it those truth conditions which our intuitions attribute to it. These requirements are met, I wish to claim, by the theory stated in the next two sections.

As earlier remarks implied, there are three main parts to that theory:

1 A generative syntax for the mentioned fragment of English (I have cast the syntax in a form reminiscent of the syntactic descriptions which are used by Montague; the reader may verify, however, that many other syntactic descriptions would be equally compatible with the remaining components of the theory);
2 a set of rules which from the syntactic analysis of a sentence, or sequence of sentences, derives one of a small finite set of possible non-equivalent representations; and
3 a definition of what it is for a map from the universe of a representation into that of a model to be a proper embedding, and, with that definition, a definition of truth.

The analysis thus obtained not only yields an account of the truth conditions of the donkey sentences (as well as of certain other notoriously problematic sentences which the fragment admits, such as e.g. some types of Bach-Peters sentences), it also reveals two more general insights concerning, respectively, personal pronouns and indefinite descriptions.

1 Personal pronouns, it has been pointed out, have a number of apparently distinct functions. Sometimes they seem to behave as genuinely referential terms, as e.g. the *he*

in *Pedro owns a donkey. He beats it*. Sometimes, as the *him* of *Every man who loves a woman who loves him is happy*, they appear to do precisely what is done by the bound variables of formal logic. Yet another occurrence, noted in particular by Evans (1977, 1980), who coined the term "E-type pronoun" for it, cannot be understood, or so it has been claimed, either on the model of a simple referential expression or on that of a bound variable. An example is the occurrence of *it* in *If Pedro owns a donkey he beats it*. The present theory brings out what these three different types have in common in that it offers, at the level of representation-formation a single rule which equally applies to each of them. This rule may interact in various ways with other rules, which are associated with different syntactic constructions, and this gives rise to the seeming multiplicity of functions which the recent philosophical and linguistic literature has noted. (There are several pronoun uses, such as "pronouns of laziness" and deictic pronouns, which have no instances within the fragment of English studied in this paper and which, therefore, cannot be discussed here. Such occurrences, however, can also be accommodated along the lines sketched in this paper.)

2   Indefinite descriptions are, on the account given here, referential terms, not existential quantifiers. When an indefinite has existential force it has that force in virtue of the particular role played by the clause containing it within the sentence or discourse of which it is part. It is true that the clausal roles which impose an existential, rather than a universal, reading upon indefinites are the more prominent; and this, I take it, has been responsible for the familiar identification of the indefinite article as a device of existential quantification. But they are not the only roles. The antecedent of a conditional, for instance, plays a role which is not of this kind; a simple clause which occurs in this role confers a universal interpretation on the indefinite descriptions it contains.

There is much that ought to be said about the conceptual implications of the present theory and about the range of its possible applications. But, as space is limited, I shall confine myself to a couple of brief remarks.

1   It should be stressed that truth as it is defined here applies not only to single sentences but also to multi-sentence discourse. This is of special importance where intersentential relations within the discourse (such as intersentential anaphoric links) contribute to its meaning. As will be seen below the links between anaphoric pronouns and their antecedents invariably have their impact on the discourse representation (irrespective of whether pronoun and antecedent occur in the same, or in different sentences) and thus on the truth conditions of the discourse, which the discourse representation embodies. Other intersentential relations, such as the relation which obtains between the sentences of past tense narratives on account of their sequential order – which is typically understood to convey the temporal relations between the events which the sentences report – can be encoded into the discourse representation with equal ease.

2   The role representations are made to play within the theory developed in this paper places substantial constraints on their internal structure. (Careful reading of the subsequent sections will, I hope, confirm this assessment.) This is of particular significance if, as I have already more or less implied, discourse representations can be regarded as the mental representations which speakers form in response to the verbal

inputs they receive. I should point out that the specific theory that is presented below does not render such identification essential. Even if the representations it posits are thought of as purely theoretical devices whose raison d'étre is to be found solely in the contribution they make to an effective account of certain semantic properties of sentences and sentence complexes, the theory may merit comparison with other schemes of linguistic description which have been applied to the same phenomena. But this is not how I would like to see the proposal of this paper myself. I conjecture that the structures which speakers of a language can be non-trivially described as forming to represent verbal contents are, if not formally identical, then at least very similar to the representations here defined.

If this identification is legitimate then a theory of the sort I have tried to develop brings to bear on the nature of mental representation and the structure of thought, a large and intricate array of data relating to our (comparatively firm and consistent) intuitions about the truth-conditions of the sentences and sentence sequences we employ. I very much hope that along these lines it may prove possible to gain insights into the objects of cognitive operations, as well as into these operations themselves, which are unattainable if these data are ignored, and which have thus far been inaccessible to psychology and the philosophy of mind precisely because those disciplines were in no position to exploit the wealth of linguistic evidence in any systematic fashion.

2   The Theory: Informal Preliminaries

2.1   Anaphoric pronouns

The analysis of pronominal anaphora I shall sketch is informed by the conviction that the mechanisms which govern deictic and anaphoric occurrences of pronouns are basically the same. This is an intuition that has guided many recent theories of pronominal reference; inevitably the account given here will resemble some of these in various respects.[1]

Our point of departure will be the hypothesis that both deictic and anaphoric pronouns select their referents from certain sets of antecedently available entities. The two pronoun uses differ with regard to the nature of these sets. In the case of a deictic pronoun the set contains entities that belong to the real world, whereas the selection set for an anaphoric pronoun is made up of constituents of the representation that has been constructed in response to antecedent discourse.

About deixis I shall have no more to say in this paper. But a little more needs to be said about anaphoric pronouns before we can proceed to the detailed analysis of some particular pieces of discourse.

The strategies used in selecting the referents of anaphoric pronouns are notoriously complex; they usually employ background assumptions about the real world, "grammatical" clues, such as the requirement of number and gender agreement between the anaphor and its antecedent, and the order in which the potential referents were introduced by the preceding discourse.[2]

The integration of these various factors often involves, moreover, what seem to be quite intricate patterns of inference. Efforts to understand these strategies have claimed much thought and hard work, but, in its general form at least, the problem appears to be far too complex to permit solution with the limited analytic tools that are available at the present time.[3]

About the strategies I shall have nothing more to say. Our concern will be, rather, with the sets of referential candidates from which they select. These entities will constitute the universes of the representations of which I spoke in Section 1. I have already said that these discourse representations, or DR's as I will call them for short, are formed in response to the discourses they represent and that their formation is governed by certain rules. These rules – and this is a new, and crucial, assumption of the theory – operate on the syntactic structures of the sentences of the discourse, and it is via them that syntactic form determines what the resulting DR will be like. This determination is not complete however. The syntactic structure does not, for instance, determine the anaphoric links between pronouns and their antecedents, which the DR makes explicit.

Most of the real work that the present theory will require us to do concerns the exact formulation of the rules of DR-formation. The exact formulation of these rules will be rather compact, and will betray, I suspect, little of either motivation or empirical implications to any but the initiated. I have decided therefore to first present a number of applications of the theory. I hope that if we proceed in this manner its formal features will reveal themselves more naturally and that the subsequent reading of the exact definitions in Section 3 will thus be less disagreeable than it would be without such preparation.

Let us begin by considering the two sentence discourse:

(7)   Pedro owns Chiquita. He beats her.

The DR for the first sentence of (7) will contain two elements, call them u and v, which represent, respectively, Pedro and Chiquita, and furthermore the information that the first of these, u, owns the second, v. Schematically we shall represent this information as follows:

$$m_1(7) \quad \boxed{\begin{array}{ll} u & \qquad\qquad v \\ . & \qquad\qquad . \\ \text{Pedro owns Chiquita} \\ u = \text{Pedro} \\ v = \text{Chiquita} \\ u \text{ owns } v \end{array}}$$

To incorporate the information contained in the second sentence of (7) we must extend structure $m_1(7)$. But to do that we must make two decisions, regarding the reference of, respectively, *he* and *her*. It is natural to understand *he* as referring back to *Pedro* and *her* as referring back to *Chiquita*. Let us agree to interpret the pronouns in this way and to expand $m_1(7)$ accordingly. What we get is:

m(7)

u   v
.   .
Pedro owns Chiquita
u = Pedro
v = Chiquita
u owns v
He beats her
u beats her
u beats v

I said that linking *he* with *Pedro* and *her* with *Chiquita* yields what seems the most natural reading of (7). "But", you might ask, "what *other* readings could (7) have?". The answer to that question depends on the setting, or context, in which (7) is supposed to be used. If (7) were uttered by a speaker who points at some individual other than Pedro while saying *he*, or at some being distinct from Chiquita when he says *her*, the gesture would recruit this demonstrated individual as referent for the pronoun. Similarly, if (7) were part of a larger discourse *he* or *her* could conceivably refer back to some other individual introduced by an earlier part of that discourse; and this could result in a genuine referential ambiguity. However, if (7) is used by itself, i.e., without preceding verbal introduction, and also in the absence of any act of demonstration, then – and this is another important hypothesis of our theory – there are no other potential referents for *he* and *her* than the discourse referents which have been introduced in response to *Pedro* and *Chiquita*. Let us agree that henceforth (except where the contrary is indicated explicitly) all our examples of simple and multi-sentence discourses shall be understood in the last of these three ways, i.e., as used without accompanying deictic gestures and not preceded by any related discourse.

Even when we understand (7) in this third way its anaphoric links are not fully determined by what we have said. For why cannot *he* and *her* both refer to *u*, say, or *he* to *v* and *her* to *u*? The reason is of course obvious: *he* must refer to a male individual, and *her* to a female one. But, obvious as the determining principle may be, it is not quite so easy to state it in a form that is both general and accurate. For what is it that determines an antecedently introduced discourse referent as male, rather than female, or neither male nor female? (7) allows us to infer that *u* is male because we know that *Pedro*, typically, refers to male individuals. But often the antecedent term which led to the introduction of a discourse item is not quite so explicit about the gender of its referent. Consider for example such terms as: *Robin*, *Hilary*, *the surgeon*, *the president*, *an officer in the Air Force*, *the professor*, *the professor's secretary*, *the first inhabitant of this cave*. Often we can do no better than guess whether the referent is male or female, or human or non-human. Some of these guesses are more educated than others. And not infrequently where the anaphoric link between the antecedent and some particular pronoun is clear on independent grounds it is in fact the gender of the pronoun which resolves the uncertainty.[4]

Applying the principle of gender agreement will thus often involve drawing various inferences from the information that is given explicitly; and as in all other processes

where inference can be involved, there appears to be no clear upper bound to its potential complexity.

There is a further complication that an exact statement of the principle must take into account. The gender of the pronoun that is used to refer to a certain object is not exclusively determined by the nature of that object, but, to some extent, also by the actual *form* of the anaphoric antecedent which made it available as a referent. Thus let us suppose that the name *Chiquita* in (7) actually refers to a donkey. In most situations we refer, or at any rate may refer, to a donkey by means of *it*. But in a discourse such as (7) this would be inappropriate. The name *Chiquita* highlights, one might wish to say, the fact that its referent is female, and this makes *she* the correct resumptive pronoun. But nonetheless the task of giving even an approximate formulation of the principle appears to be well beyond our present means. In what follows we shall ignore the principle of gender agreement, just as we ignore all other factors that help to disambiguate the reference of anaphoric pronouns. But where, in subsequent examples, the need for gender agreement clearly excludes certain anaphoric links I shall not bother to mention those without referring to the principle explicitly.

Clearly (7) is true, on the reading of it that is given by $m(7)$ if and only if the real Pedro stands to the real Chiquita in a relation of ownership and also in the relation expressed by the verb *beat*. Put differently, if M is a model, representing the world – consisting of a domain U_M and an interpretation function F_M which assigns to the names *Pedro* and *Chiquita* members of U_M and to the transitive verbs *own* and *beat* sets of pairs of such members – then (7) is *true in* M iff the pair $\langle F_M (\textit{Pedro}), F_M (\textit{Chiquita}) \rangle$ belongs both to $F_M (\textit{own})$ and to $F_M (\textit{beat})$. Moreover, the right hand side of this last biconditional is fulfilled if there is a map f of the universe of $m(7)$, i.e. the set $\{u, v\}$, into U_M so that all specifications of $m(7)$ are satisfied in M – i.e., f(u) is the individual denoted in M by *Pedro*, f(v) is the individual $F_M (\textit{Chiquita})$, and it is true in M that f(u) both owns and beats f(v), in other words, that $\langle f(u), f(v) \rangle$ belongs to both $F_M (\textit{own})$ and $F_M (\textit{beat})$.

Let us now consider

(8)   Pedro owns a donkey. He beats it.

The first sentence of (8) induces a DR that can be represented thus:

$$m_1(8) \quad \boxed{\begin{array}{ll} u & \qquad\qquad v \\ \cdot & \qquad\qquad \cdot \\ \text{Pedro owns a donkey} \\ u = \text{Pedro} \\ u \text{ owns a donkey} \\ \text{donkey } (v) \\ u \text{ owns } v \end{array}}$$

Once again there is no choice for the anaphoric antecedent of either *he* or *it* in the second sentence of (8). So the complete DR of (8) becomes:

m(8)

u	v
.	.

Pedro owns a donkey
u = Pedro
u owns a donkey
donkey (v)
u owns v
He beats it
u beats it
u beats v

(8) is true in the model M provided there is an element d of U_M such that $\langle F_M$ (*Pedro*), d$\rangle$ belongs to both F_M (*own*) and F_M (*beat*); and furthermore d is a donkey in M – formally d $\in F_M$ (*donkey*), if we assume that common nouns are interpreted in the model by their extensions. This condition is fulfilled if there is a map g from $U_{m(8)}(= \{u, v\})$ into U_M which preserves all conditions specified in m(8). Note that g(v) is not required to be the bearer in M of some particular name, but only to belong to the extension of the noun *donkey*.

Before turning to the donkey sentences (1) and (2) of Section 1.2 let us take stock of some principles applied in the construction of the DR's which we have encountered so far:

1   Certain singular terms, among them proper nouns and indefinite descriptions, provoke the introduction of items into the DR that function as the "referents" of these terms. We shall later address the question which singular terms give rise to such introductions and whether these introductions are obligatory or optional.
2   Other singular terms, viz. personal pronouns, do not introduce elements into the DR; instead they can only refer to items which the DR already contains.[5]

2.2   Conditionals

Our next aim is to construct a representation for the "donkey sentence" (1), which for convenience we repeat here:

(1)   If Pedro owns a donkey he beats it.

Before we can deal with (1) however, we must say something about conditionals in general.

The semantic analysis of natural language conditionals is a notoriously complicated matter, and it seems unlikely that any formally precise theory will do justice to our intuitions about all possible uses of sentences of this form. The literature on conditionals now comprises a number of sophisticated formal theories, each of which captures some of the factors that determine the meaning of conditionals in actual use.[6] Although these theories differ considerably from each other they all seem to agree on one principle, namely that a conditional

(9)   If A then B

is true if and only if

(10)   Every one of a number of ways in which A can be true constitutes, or carries with it, a way of B's being true.

Up to now this principle has generally been interpreted as meaning that B is true in, or is implied by, every one of a certain set of *relevant possible situations* in which A is true. (This is true in particular of each of the theories mentioned in the last footnote.) The analysis of truth in terms of DR-embeddability, however, creates room for a slightly different implementation of (10).

Where M is a model and m a DR for the antecedent A there may be various proper embeddings of m into M, various ways, we might say, of showing that A is true in M. This suggests another interpretation of (10), viz. that each such way of verifying A carries with it a verification of B. In what sense, however, could such way of verifying A – i.e. such a proper embedding of m – entail a verification of B? To verify B, in that sense of the term in which we have just been using it, we need a representation of B; but as a rule the content of B will not be represented in the DR m of A. To verify B in a manner consistent with some particular verification of A we must therefore extend the DR m involved in that verification to a DR m' in which B is represented as well. Thus we are led to an implementation of (10) according to which the conditional (9) is *true, given* a pair (m,m'), consisting of a DR m of A and an extension m' of m which represents B as well, iff

(11)   every proper embedding of m can be extended to a proper embedding of m'.[7]

This is not yet an explicit statement of the truth conditions of (9), for it fails to tell us anything about the target structures of the verifying embeddings, and about their relation to the situation, or model, with respect to which (9) is evaluated. Here we face all the options that have confronted earlier investigators. We may elaborate (11) by stipulating that (9) is true in a model M iff every proper embedding of m into M is, or is extendable to, a proper embedding of m' on M. Or we may insist that (9) is true in the possible world w iff every proper embedding of m into any of the (models representing the) nearest A-worlds induces some proper embedding m' into that world. Indeed, any one of the existing theories could be combined with the principle conveyed by (11).

Here we shall, primarily for expository simplicity, adopt the first of the options mentioned:

(12)   Let m be a DR of A and m' an extension of m which incorporates the content of B. Let M be a model. Then *if* A *then* B is true in M, given (m,m'), iff every proper embedding of m into M can be extended to a proper embedding of m' into M.

For conditionals in which there are no anaphoric links between antecedent and consequent, (12) boils down to the truth conditions for the material conditional. But where

such a link exists its implications are somewhat different. To see this let us apply the condition to (1). We have already constructed DR's of the kind needed in the application of (12) to (1), namely, $m_1(8)$, and $m(8)$. According to (12), (1) is true in M given $(m_1(8), m(8))$, iff every function f from $U_{m_t(8)}$ ($= \{u, v\}$) into U_M such that (i) $f(u)$ $= F_M$ (*Pedro*). (ii) $f(v) \in F_M$ (*donkey*), and (iii) $\langle f(u),f(v) \rangle \in F_M$ (*own*), can be extended to a function g from $U_{m(8)}$ into U_M such that $\langle g(u),g(v) \rangle \in F_M$ (*beat*). Of course, in the present case $U_{m(8)} = U_{m_1(8)}$ and consequently there is no question of *extending* f to g. So the above condition reduces to the stipulation that every f as described has the additional property that $\langle f(u),f(v) \rangle \in F_M$ (*beat*). Clearly this condition is equivalent to the truth in M of the formula (3) which we adopted in Section 1.2 as giving the truth conditions of (1).

It is easy enough, however, to come up with examples which do involve the extension of embeddings, e.g.:

(13)   If Pedro owns a donkey he lent it to a merchant.

If we extend $m_1(8)$ to a DR which incorporates the content of the consequent of (13) we get something like:

$$m(13)$$

u	v	w
.	.	.

Pedro owns a donkey
u = Pedro
u owns a donkey
donkey (v)
u owns v
he lent it to a merchant
u lent it to a merchant
u lent v to a merchant
merchant (w)

In relation to $m_1(8)$ and $m(13)$, (12) requires that every mapping f of the kind described in the preceding analysis of (1) can be extended to a function g from $\{u,v,w\}$ into U_M such that – if we assume for simplicity that *lent to* is interpreted in M as a set of ordered triples of members of U_M – (i) $g(w) \in F_M$ (*merchant*); and (ii) $\langle g(u),g(v),g(w) \rangle \in F_M$ (*lent to*).

2.3   Universals

One of the important insights that went into Frege's discovery of the predicate calculus was that the restricted quantification typical of natural language is expressible in terms of unrestricted quantifiers and truth functions. Our handling of indefinite descriptions, which formal logic treats as expressions of existential quantification, harmonizes with this insight. For, as can be seen for instance from $m_1(8)$, the introduction of a discourse referent u for an indefinite term is accompanied by two conditions, one to the effect

that u has the property expressed by the common noun phrase of the term, and the other resulting from substituting u for the term in the sentence in which it occurs.

I wish to propose a treatment of terms of the form *every* α that is in similar accord with Frege's analysis of restricted universal quantification. Again it will be easier to illustrate the proposal before I state it. Consider:

(14)   Every widow admires Pedro.

A representation for (14), like those for conditional sentences, involves a pair of DR's. The first of these states that some "arbitrary" item x satisfies the common noun *widow*; the second extends this DR by incorporating the content of the condition *x admires Pedro*. Thus we obtain:

$m_1(14)$

x
.
widow (x)

$m_2(14)$

x	u
.	.
widow (x)	
x admires Pedro	
u = Pedro	
x admires u	

The truth value of (14) in M is to be determined by $(m_1(14), m_2(14))$ in precisely the same way as that of (1) is determined by $(m_1(8), m(8))$. Thus (14) is true iff every correlation of x with an element a of U_M such that $a \in F_M$ (*widow*) can be extended to a proper embedding of $m_2(14)$, i.e., to a function g such that $g(u) = F_M$ (*Pedro*) and $\langle g(x), g(u) \rangle = \langle a, g(u) \rangle \in F_M$ (*admires*). Clearly this confers upon (14) the intuitively correct truth conditions.

In the same way

(15)   Every widow admires a farmer

licenses the construction of the following pair of DR's:

$m_1(15)$

x
.
widow (x)

$m_2(15)$

x	u
.	.
widow (x)	
x admires a farmer	
farmer (u)	
x admires u	

Again the condition that every association of x with an object a that is a widow in the sense of M can be extended to a proper embedding of $m_2(15)$ gives the correct truth conditions of (15); or, to be precise, the truth conditions it has on what is generally considered its most natural reading.

Consider now the second donkey sentence of Section 1.2:

(2)   Every farmer who owns a donkey beats it.

Sentence (2) gives rise to the following pair of DR's:

$m_1(2)$			$m_2(2)$	
x	v		x	u
.	.		.	.
farmer (x)			farmer (x)	
x owns a donkey			x owns a donkey	
donkey (v)			donkey (v)	
x owns v			x owns v	
			x beats it	
			x beats v	

So (2) is true in M iff every f such that $f(x) \in F_M$ (*farmer*), $f(v) \in F_M$ (*donkey*), and $\langle f(x),f(v)\rangle \in F_M$ (*own*) has the additional property that $\langle f(x),f(v)\rangle \in F_M$ (*beat*). This is exactly as it should be.

Our treatment of conditionals and universal sentences gives – for the cases, at any rate, that we have thus far considered – intuitively correct conditions of truth. But it seems at odds with the *general* definition of truth which I put forward earlier, according to which a discourse is true in M, given some representation m of it, iff *there is some* proper embedding of m into M. The semantic analyses of the sentences we have considered in this section refer to pairs of DR's rather than single DR's and involve conditions on *all* proper embeddings of a certain kind, instead of demanding the existence of at least one proper embedding.

To resolve this apparent conflict I must say a little more about the intuitive ideas behind the DR constructions of which we have now seen a few instances. Essential to the analysis of the majority of our examples was the way in which we have treated indefinite descriptions. It would be quite unsatisfactory if there were no other justification for that treatment than the observation that, combined with additional principles for DR-construction they give the truth conditions that speakers in fact associate with the sentences we have sampled. There is, however, a reason why we should *expect* a construction principle for indefinites such as we have applied, but no direct analogue of it for phrases of the form *every* α. Let us go back to the first sentence of (8). What justifies us in adding to the partial DR of (8) the element v as a "referent" for *a donkey* is this: as I already argued, the DR of a sentence functions as a partial description of how the world ought to be if the sentence is true. To fulfill that role the DR must represent whatever information has been encoded into it in such a way that the significance of that representation is unaffected when one extends it to incorporate further information – or, what comes in this connection to much the same, when the DR is identified as a certain substructure of a larger "real world" model via some proper embedding. The conditions $u = Pedro, donkey(v)$ and $u\ owns\ v$ which make up $m_1(8)$ clearly satisfy this requirement. They convey precisely the same information in any extension of $m_1(8)$ as they do in $m_1(8)$ itself.[8] The content of an existential sentence

has been exhausted once an individual has been established which satisfies the conditions expressed by the indefinite description's common noun phrase and by the remainder of the sentence.

But a universal sentence cannot be dealt with in such a once-and-for-all manner. It acts, rather, as a standing instruction: of each individual check whether it satisfies the conditions expressed by the common noun phrase of the universal term; if it does, you may infer that the individual also satisfies the conditions expressed by the remainder of the sentence. This is a message that simply *cannot* be expressed in a form more primitive than the universal sentence itself. The universal is thus, at the level of the DR to which it belongs, *irreducible*. The same is true of conditionals. *If* A *then* B functions as an instruction to check, and keep checking, whether the antecedent A has been satisfied, and to infer, when this is found to be so, that the consequent B must also hold. This too is a piece of information that cannot be represented in any more elementary form.

This means that when we form the DR of a universal sentence, such as (14), or of a conditional, such as (1), we cannot decompose the sentence in some such fashion as we were able to decompose, say, the first sentence of (8) when constructing $m_1(8)$. So the DR for (14) cannot itself be elaborated beyond the trivial initial stage:

$$m_0(14)$$

| Every widow admires Pedro |

in which the sentence (14) occurs as a condition, but nothing else does.

There is however, another way in which we can represent the internal structure of (14), namely by constructing separate DR's for its components, and by integrating these DR's into a structure in which their connection reflects the syntactic construction by means of which these different components are amalgamated into the complex sentence. This is, in fact, essentially, what I did when constructing the DR-pairs I earlier presented for (1), (14), (15), and (2).

But these pairs do not provide, by themselves, the structural representations to which we can apply our general definition of truth. To obtain such a representation for, say, (14) we must combine the pair $(m_1(14), m_2(14))$ with the DR $m_0(14)$. This gives us the following structure:

$$K(14)$$
$$m_0(14)$$

| Every widow admires Pedro |

$$m_1(14) \qquad\qquad m_2(14)$$

| x |
| . |
| widow (x) |

| x   u |
| .   . |
| widow (x) |
| x admires Pedro |
| x admires u |
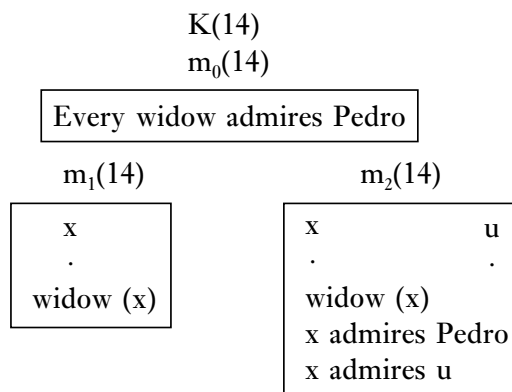
Similarly the complete representation for (1) will now look thus:

K(1)

m$_0$(1)

| If Pedro owns a donkey, he beats it |

m$_1$(1)   m$_2$(1)

u v		u v
. .		. .
Pedro owns a donkey		Pedro owns a donkey
u = Pedro		u = Pedro
donkey (v)		donkey (v)
u owns v		u owns v
		He beats it
		u beats it
		u beats v
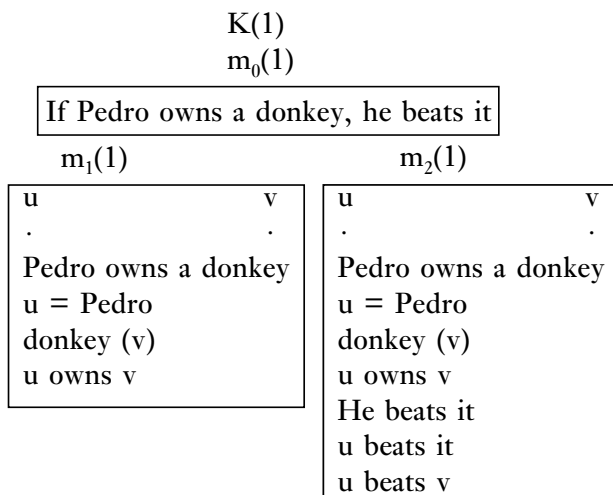
It may appear as if something is still missing from these structures. For what tells us that the subordinate DR's m$_1$(1) and m$_2$(1) represent the antecedent and consequent of a conditional, while m$_1$(14) and m$_2$(14) represent the components of a universal? The answer to this is simple: the necessary information is provided by the sentences in m$_0$(1) and m$_0$(14) whose components are represented by the subordinate DR's m$_1$(1), m$_2$(1), and m$_1$(14), m$_2$(14). In fact we shall assume that with each syntactically well-formed sentence is given a particular syntactic analysis of it, which specifies unambiguously its immediate components and the construction which forms the sentence out of these. (For the fragments we shall study in Section 3, this condition will be automatically fulfilled as each of its wellformed expressions has a unique syntactic analysis.) The role which, say, m$_1$(1) and m$_2$(1) play in the representation of (1) can thus be recognized by comparing their relevant entries, viz., *Pedro owns a donkey* and *he beats it*, with the syntactic analysis of the sentence (1) to be found in m$_0$(1). All this will be discussed in detail in Section 3.

  A representation of the sort just displayed, which involves structured families of DR's, will be called a *Discourse Representation Structure* or, for short, DRS. Each sentence or discourse induces the construction of such a DRS, and only where the sentence or discourse is comparatively simple will the DRS consist of a single DR only. Among the DR's that constitute a DRS there will always be one which represents the discourse as a whole. (In the two DRS's we displayed these are, respectively, m$_0$(14) and m$_0$(1).) This DR will be called *the principal* DR of the DRS.

  Once we assign to (1) the DRS K(1) the earlier conflict between the general definition of truth and our particular account of the truth value of a conditional can be resolved. We slightly modify the truth definition to read:

(16)   A discourse D *is true in* M, *given* a DRS K of D iff there is a proper embedding into M of the principal DR of K.

Let us try to apply (16) to (1) and its DRS K(1). (1) is true given K(1) iff there is a proper embedding of m$_0$(1) into M. Since the universe of m$_0$(1) is the empty set, there

is only one embedding from $m_0(1)$ into M, viz. the empty function, $\wedge$. What is it for $\wedge$ to be proper? $\wedge$ is proper iff the conditions of $m_0(1)$ are true in M of the corresponding elements of U_M. In the present case however there are no elements in $U_{m_0(1)}$, thus no corresponding elements of U_M; and there is only one condition in $m_0(1)$, namely (1) itself. Thus $\wedge$ is proper iff (1) is true in M.

It might seem at this point that we are trapped in a circle. But in fact we are not. To see that we are not it is necessary to appreciate the difference between (i) asking for the truth value in M of (1), given K(1); and (ii) asking for the truth value in M of some condition that belongs to some member of K(1). This second question has, as we saw earlier, a straightforward answer when the condition has the form of an atomic sentence. For in that case it is directly decided by the embedding and the function F_M. But when the condition is a complex sentence, e.g., a conditional or a universal, which permits no further analysis *within the very DR to which it belongs*, the answer involves an appeal to certain members of the DRS that are *subordinate* to that DR. Thus the condition (1) of $m_1(1)$ is to be taken as true in M iff it is true, in the sense defined earlier, *given* the pair $(m_1(1), m_2(1))$ of DR's subordinate to $m_0(1)$; and in *that* sense (1) is true in M, we saw already, iff M verifies the first order formula (3).

To see more clearly how the various components of our theory are to be fitted together, we should look at a few more examples.

The next example shows why it is that certain anaphoric connections are impossible. In

(17)   If Pedro owns every donkey then he beats it.

it cannot have *every donkey* for its antecedent. The reason for this becomes transparent when we try to construct a DRS which gives such a reading to (17):

<div align="center">

K(17)
m(17)

If Pedro owns every donkey he beats it.

</div>

m₁(17)

u . Pedro owns every donkey u = Pedro u owns every donkey

m₂(17)

u . Pedro owns every donkey u = Pedro u owns every donkey he beats it u beats it

m₃(17)

x . donkey (x)

m₄(17)

x . donkey (x) u owns x
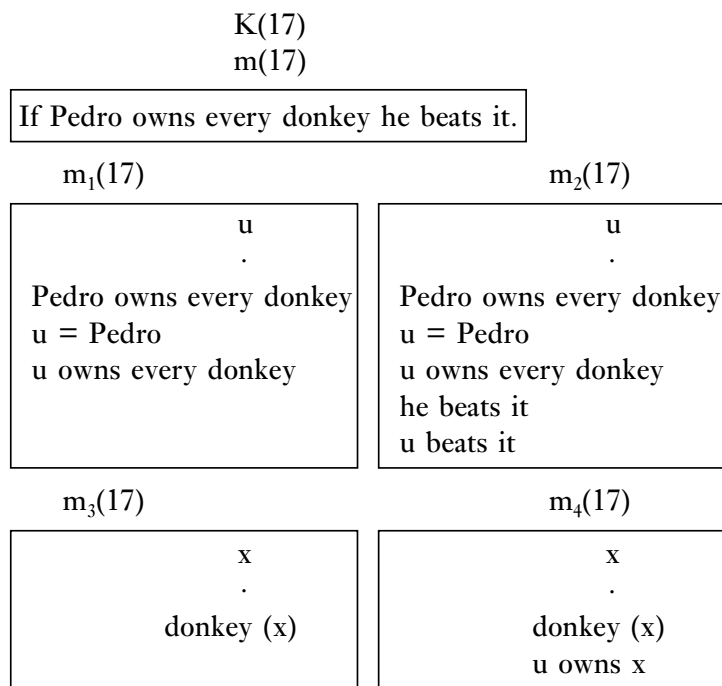
We cannot complete this DRS as intended, for the discourse referent x, which we want to assign to the pronoun *it* of $m_2(17)$, is not available, as it occurs only at the level of $m_3(17)$, which is below that of $m_2(17)$. A similar explanation shows why *it* cannot be anaphorically linked to *every* donkey in

(18)   Every farmer who owns every donkey beats it

and also why in

(19)   If Pedro likes every woman who owns a donkey he feeds it

it cannot be co-referential with *a donkey*, whereas such a link does seem possible in

(20)   If Pedro likes a woman who owns a donkey he feeds it.[9]

These last examples give, I hope, an inkling of the predictive powers of what in particular linguists might think constitutes the most unusual feature of the theory I have so far sketched: the fact that it handles singular terms of the forms *a β* and *every β* in entirely different ways. I hope that these and subsequent illustrations will help to persuade them that the conception of a perfect rule-by-rule parallelism between syntax and semantics is one that must be proved rather than taken for granted.[10] In fact, the data here presented point towards the conclusion that this conception is ultimately untenable.

Another feature that distinguishes the present account from many, albeit not all, existing theories of reference and quantification is its entirely uniform treatment of third person personal pronouns. This has already been apparent from the examples at which we have looked. It is further illustrated by such sentences as:

(21)   Every farmer courts a widow who admires him.

Occurrences such as that of *him* in (21) have been put forward as paradigms of the use of pronouns as bound variables – an identification that is natural, and in fact well-nigh inescapable, when one believes that the logical forms of natural language sentences are expressions of the predicate calculus. Indeed several earlier theorists have perceived a real chasm separating these pronoun uses from those which we find exemplified by, say, *her* in (7) and *he* in (7) and (8); and, looking at pronouns from this perspective, they have often felt helpless vis-a-vis the pronoun occurrences that have been of particular concern to us in this section, viz. those exemplified by (1) and (2). Forcing these either into the mold that had been designed for uses such as that in (7), or into that measured to fit occurences such as that of *him* in (21) turned out to be hopeless enterprises. Evans (1977, 1980) gives conclusive evidence against the latter of these two; but his own suggestions, which go some way towards assimilating the problematic pronouns to definite descriptions, do not appear to be fully satisfactory either.[11]

Note that the more unified treatment of these pronoun uses given here is possible partly because the same construction rule for pronouns operates both at the level of the principal DR's and at subordinate levels. Thus the DRS for (21) is constructed as follows (the numbers in parentheses which precede discourse referents and conditions indicate the order in which the operations are carried out; we shall often use this notational device):

$$m_0(21)$$

(0) Every farmer courts a widow who admires him.

$$m_1(21)$$

(1)   x
.
(1) farmer (x)

$$m_2(21)$$

(1) x   (2) v
.   .
(1) farmer (x)
(1) x courts a widow who admires him
(2) widow (v)
(2) v admires him
(2) x courts v
(3) v admires x

The rule for pronouns applies here in just the same way to the *him* of *v admires him* in $m_2(21)$ as it does for example to the *he* and *it* in the DRS construction of (8) or the *it* of (1) in the construction of the DR of (1).

3   The Formal Theory

3.1   Syntax

The time has come for a more formal and systematic presentation. We shall consider a fragment of English for which I shall give an explicit syntax and explicit formal rules for DRS construction. Our fragment will be exceedingly simple to start with, much simpler even than that of Montague (1973).[12] The syntax adopted resembles Montague's, but the resemblance is rather superficial; for the syntactic analysis of a sentence will play a much more modest role in the determination of its interpretation than it does in Montague grammar. In presenting the syntax I shall presume some familiarity with Montague grammar, specifically with Montague (1970a) and (1973). Our fragment, to which I shall refer as L_0, contains expressions of the following categories with the following basic members:

1	T (Term)	:	*Pedro, Chiquita, John, Mary, Bill, … ; he, she, it*
2	CN (Common Noun phrase)	:	*farmer, donkey, widow, man, woman, …*
3	IV (Intransitive Verb phrase)	:	*thrives …*
4	TV (Transitive Verb)	:	*owns, beats, loves, admires, courts, likes, feeds, loathes, …*
5	S (Sentence)	:	– –
6	RC (Relative Clause)	:	– –

Formation rules

FR1.   If $\alpha \in$ TV and $\beta \in$ T then $\alpha\beta' \in$ IV where $\beta' = him$ if $\beta = he$, $\beta' = her$ if $\beta = she$ and $\beta' = \beta$ otherwise.

FR2.   If $\alpha \in$ IV and $\beta \in$ T then $\beta\alpha \in$ S.

FR3.   If $\alpha \in$ CN then (i) *a* (*n*) α, and (ii) *every* α are in T.

FR4.k If $\phi \in$ S and the k-th word of ϕ is a pronoun then $\beta\phi' \in$ RC, where ϕ' is the result of eliminating the k-th word from ϕ and β is *who, whom, which*, according as the pronoun is *he* or *she*, *him* or *her*, or *it*, respectively.

FR5.   If α is a basic CN and $\beta \in$ RC then $\alpha\beta \in$ CN.

FR6.   If $\phi, \psi \in$ S then *if* ϕ, ψ and *if* ϕ *then* $\psi \in$ S.

Some comments

1   The rule schema FR4.k is defective inasmuch as it allows for wh-movement out of forbidden positions. Within the present fragment there are only two sorts of noun phrase positions to which wh-movement may not apply, those inside relative clauses and those inside the antecedents of conditionals. It is not difficult to modify the syntax in such a way that these restrictions are observed. For instance we could stipulate that each time a relative clause is formed all pronouns it contains are marked, and that the same is done to those occuring in the antecedent of a conditional at the time when antecedent and consequent are joined together. The rule of relative clause formation can then be altered so that it applies to unmarked pronouns only. Such a solution is rather ad hoc, so as it would moreover complicate the syntax as a whole, I have refrained from incorporating it. I must beg the reader to keep in mind that the syntax of this section is intended as no more than a convenient basis for the definition of DRS-construction rules, and that it has no pretentions of capturing important syntactic generalizations.[13]

2   The present fragment differs from most familiar versions of Montague grammar in that it contains neither variables nor indexed pronouns.[14] Consequently the syntactic analysis of a sentence of the present fragment tells us nothing about anaphoric relations.

3   Every well-formed expression of L_0 has a unique syntactic analysis. This is a feature that is bound to be lost at some point as we extend the present fragment. It allows us, however, to omit, while uniqueness of syntactic analysis obtains, all explicit reference to syntactic analyses in discussions and, particularly, in definitions where such reference becomes essential as soon as well-formed strings do not unambiguously determine their analyses.

4   When defining the process of DRS construction we shall have to specify the order in which various parts of a given sentence are to be treated. What we need here is, in essence, a specification of scope order. I shall assume in this paper that the scope relations within a sentence are directly determined by its syntactic construction. Thus the subject term of a simple clause will always have wide scope over the object term; the *if* of a conditional sentence will always have wide scope over the terms occurring in antecedent and consequent, etc. Let us call the formation rule which is applied last in the construction of an expression γ the *outermost rule* of γ. Where γ is a sentence and the outermost rule is FR6, γ is called a *conditional (sentence)*. If the outermost rule of γ is FR1 or FR2 and this rule forms γ by combining some IV or TV with the term α, α is said to *have*, or to *be the term with, maximal scope* in γ. If the outermost rule is FR1 and α begins with *every*, γ is called a *universal IV*; similarly, if the outermost rule of γ is FR2 and α begins with *every*, then γ is called a *universal sentence*.

By eliminating Montague's rule of substitution and quantification we have dispensed with one natural way of distinguishing between alternative scope relations – such as, for instance, the two possible relations between *a widow* and *every farmer* in

(22)   A widow admires every farmer.

Sentence (22) can be generated in only one way and according to that generation the subject has wide scope over the direct object as it enters the construction of the sentence at a later stage. No syntactic analysis would thus appear to convey upon (22) the reading given by

(23) $(\forall x)\ (\text{farmer}(x) \rightarrow (\exists y)\ (\text{widow}(y) \wedge \text{admires}(x, y)))$.

It might be thought that the construction of a DRS which imposes this latter reading upon (22) involves an order of application of the construction rules which contravenes the scope relations implied by the syntax. This problem too must be left for another paper.

5   We shall refer to the basic terms *Pedro, Chiquita, John, Mary*, … as the *proper names* of L_0 and to *he*, *she*, *it* as the *pronouns* of L_0. Terms of the form *every β* will be called *universal terms*.

6   I have admitted only compound common noun phrases consisting of a common noun and *one* relative clause. It would of course be possible to relax FR6 so that it can attach several relative clauses to the same head noun. Many of the resulting expressions, however, seem marginal at best. I have decided to cut the knot and keep such complex common nouns out of the fragment altogether.

3.2   Models and discourse representation

By a *model for* L_0 we shall understand a structure of the form $\langle U, F \rangle$ where (i) U is a non-empty set and (ii) F is an interpretation function which assigns an element of U to each of the proper names of L, a subset of U to each of its basic CN's and basic IV's, and a set of pairs of elements of U to each of the basic TV's.

We must now address ourselves to the main tasks of this section, the formulation of the rules of DRS-construction and of the definition of truth for L_0. To state the rules we shall have to decide on a format for DR's and DRS's. In choosing such a format I have been partly guided by considerations of notational convenience. In particular it is just a matter of convenience to specify (as I have already done in the examples discussed in the preceding section) that one or more discourse referents satisfy a certain predicate by adding to the relevant DR a sentence which is obtained by combining that predicate with, in the appropriate positions, these referents themselves; using them, that is, autonymously (a policy against which there can be no objection, given the symbolic nature which must be attributed to the discourse referents in any case). Almost all other features, however, of the DR-format I have chosen are determined by empirically significant aspects of the rules of DRS-construction.

Let V be a denumerable set of entities none of which is a basic expression of L_0 or a string of such expressions. V is the set from which the elements are drawn that make up

the universes of the DR's. We shall often refer to the members of V as *discourse referents*. For any subset X of V let $L_0(X)$ be the result of adding the members of X to the set of basic terms of L_0.

As all our earlier examples showed, the introduction of a discourse referent is always accompanied either by a condition which identifies it as the referent of a proper name or else by one which stipulates that it satisfies some common noun. These conditions cannot be expressed in $L_0(X)$; so we must slightly extend the notation which that language provides. We shall allow in addition to what $L_0(X)$ contains already, sentences of the form $u = \alpha$ where α is a proper name and $u \in X$, to express the former, and sentences of the form $\beta(u)$ where, again, $u \in X$ and $\beta \in CN$, to express the latter type of condition. We shall refer to the language obtained from $L_0(X)$ through these additions as $L_0'(X)$.

We shall limit ourselves here to the simplest type of discourse, that of a discourse constituted by a finite sequence of declarative statements, made by one and the same speaker. Formally we shall identify – as in fact we already did implicitly in Section 1.2 – such a discourse with the sequence of the uttered sentences. So let us, where L is any language, define an L-*discourse* to be any finite string of sentences of L.

The examples we considered in the preceding section were carefully chosen so that the same singular term would never occur more than once. This made it unnecessary to distinguish between different occurrences of the same expression. In general, however, different occurrences must be kept apart. The need for this is most obvious in connection with pronouns – it is only too common a phenomenon that the very same pronoun occurs twice in a bit of discourse, but each time refers to a different individual, as e.g. might be intended by someone using the sentence

(24)   If Bill courts a widow who admires him then Pedro courts a widow who admires him.

But in longer stretches of discourse other expressions are liable to recur as well. Although the DRS construction rules defined below only require us to keep track of the individual occurrences of certain expressions, little if anything would be gained by introducing a mechanism for distinguishing just *those* individual occurrences. In fact probably the simplest way to distinguish the individual expression occurrences is this: Let $D = \langle \phi_1, \ldots, \phi_n \rangle$ be an L_0-discourse and let $\langle \tau_1, \ldots, \tau_n \rangle$ be the sequence of the (uniquely determined) syntactic analyses of the sentences of D. It is easy to formulate an algorithm which assigns a unique index, – say, a positive integer – to each of the nodes of these analyses, and, by proxy, also to the expressions formed at any such node. For instance we enumerate first all the nodes of τ_1, in some order fixed by its structure, then those of τ_2, etc., until we have dealt with the entire discourse. There is no point to go into greater detail here. We shall simply assume that one such algorithm has been fixed. By an *occurrence* of an expression α *in* D we shall understand a pair $\langle \alpha, n \rangle$ where n is the index of a node of the syntactic analysis of one of the sentences of D to which α is attached.

The relation which holds between two expressions α and β if α is a subexpression of β has an obvious counterpart between expression occurrences: $\langle \alpha, n \rangle$ is a "suboccurrence" of $\langle \beta, m \rangle$ if $\langle \alpha, n \rangle$ occurs as part of the syntactic analysis of $\langle \beta, m \rangle$. I shall often

speak, by a minor sleight of hand, of one expression occurrence being a *subexpression* (*subformula*, etc.) *of* some other occurrence. No confusion should arise from this.

The construction of a DRS for D does not only require the separate identification of particular occurrences of expressions of L_0; we must also be able to keep track of different occurrences of the same expressions of $L_0'(X)$. However, as our examples have already indicated (and we shall soon make this fully explicit) the expressions from $L_0'(X) \backslash L_0$ which enter into DR's are always derived from corresponding expression of L_0. To be specific, they result either (i) through one or more substitutions of members of X for singular terms in some sentence of L_0; or (ii) from placing a member of X in parentheses behind a CN of L_0; or (iii) from combining a member of X with = and a proper name of L_0. In the first case we can label the $L_0'(X)$-sentence occurrence unambiguously with the index of the occurrence of the L_0-sentence from which it is obtained through successive substitutions; in the second case we assign the index of the relevant occurrence of the common noun; and in the third the index of the relevant occurrence of the proper name. In each of the cases (i), (ii), and (iii), we shall say that the sentence of $L_0'(X)$ is a *descendant* of the relevant expression of L_0, and similarly that the occurrence of the $L_0'(X)$-sentence is a *descendant of* the corresponding occurrence of an expression of L_0. Formally we shall represent any occurrence of such an expression also as a pair consisting of the expression together with the appropriate index.

There is one other notion which we have already defined for L_0 but which must also be extended to cover certain expressions of $L_0'(X)$ as well. This is the notion of the *outermost rule of* an expression. We shall need to refer to the outermost rule only of those sentences of $L_0'(X) \backslash L_0$ which result from making in sentences of L_0 one or more substitutions of members of V for occurrences of singular terms of $L_0(X)$. Any such substitution leaves the syntactic structure of the sentence in which it takes place essentially inviolate: it can only lead to some "pruning" of the syntactic tree, viz. where the replaced singular term occurrence is itself complex. In that case the subtree dominated by the node to which the singular term (α) is attached is deleted and replaced by a single node to which is attached the inserted (basic) term (u). The outermost rule FRi of the resulting sentence should *not* count as outermost rule of the syntactic analysis of the substitution result. For FRi is the rule which combines u with the remainder γ of the sentence, and this is a syntactic operation which, unlike the analogous operation that combines the replaced singular term with γ, should give rise to no further step in the DRS construction (the singular term α has after all just been dealt with!). Thus we should identify as the *outermost rule of* the substitution result, rather the outermost rule of γ. Since, as we already observed, each of the $L_0'(X)$-sentences in question results from a finite sequence of such substitutions the above stipulation defines the outermost rule of each such sentence.

Having extended the concept of the outermost rule of an expression to certain sentences of $L_0(X)$ we can now also apply the notions *conditional* and *universal sentence* to those sentences. Moreover, we shall call *atomic* those sentences of $L_0'(X)$ which consist either (i) of a discourse referent followed by an IV; or (ii) a TV flanked by two discourse referents; or (iii) a CN followed by a discourse referent in parentheses; or (iv) a discourse referent followed by = and a proper name of L_0.

Here is the definition of the "format" of Discourse Representations I have chosen, as well as of some related notions which we shall need in later definitions:
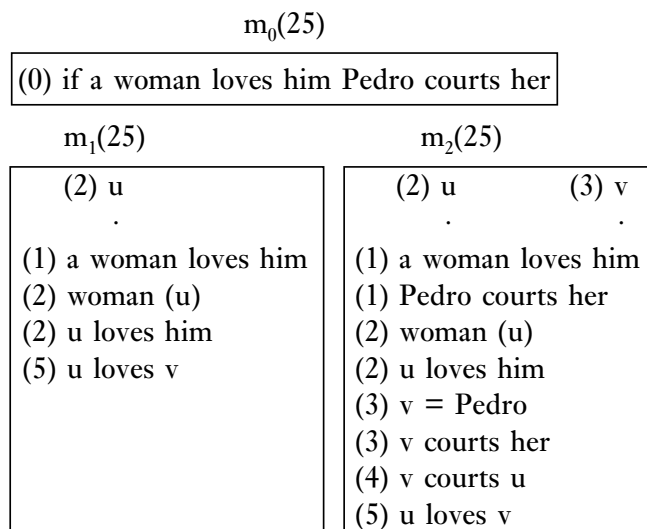
DEFINITION 1.   Let D be an L_0-discourse.

1   A *possible DR (Discourse Representation) of* D is a pair $\langle U, Con \rangle$, where
  (i)   U is a subset of V; and
  (ii)   Con is a set of occurrences in D of sentences of $L_0'(U)$.

2   Where m and m' are possible DR's for D we say that m' *extends* m if $U_m \subseteq U_{m'}$ and $Con_m \subseteq Con_{m'}$.

3   Let m be a possible DR for D. A sentence $\phi \in Con_m$ is called *unreduced in* m iff Con_m contains no descendant of ϕ. m is called *maximal* if each unreduced member of Con_m is either (i) an atomic sentence, (ii) a conditional, or (iii) a universal sentence.

We have seen in Section 2 that in general we must associate with a given discourse a Discourse Representation *Structure*, i.e. a partially ordered family of DR's, rather than a single DR. As it turns out the partial orders of those DRS's which our rules enable us to construct can always be defined in terms of the internal structure of their members. This makes it possible to define a DRS simply as a set of DR's.

   To show how the partial order can be defined in terms of the structure of the DR's that make up the DRS we have to make explicit the structural relationship that holds between a DR m which contains a conditional or universal sentence ϕ and the pair of DR's which must be constructed to represent the content of ϕ. But before we can do that we must first discuss, and introduce, a slight modification of the schema for representing conditionals and universals that we have used in our examples. So far we have represented a conditional *if* A (*then*) B by a DR m_1 of A together with an extension m_2 of m_1 which incorporates into it the information contained in B. There can be no objection to this schema as long as the information contained in A can be fully processed in m_1 before one extends it by processing B. It is not always possible, however, to proceed in this way, as is illustrated by (25).

(25)   If a woman loves him Pedro courts her.

The order in which the construction rules must be applied to yield a DRS which links *him* with *Pedro* and *her* with *a woman*, is indicated in the following diagram:

$$m_0(25)$$

(0) if a woman loves him Pedro courts her

$$m_1(25) \qquad\qquad\qquad m_2(25)$$

(2) u	(2) u (3) v
.	. .
(1) a woman loves him	(1) a woman loves him
(2) woman (u)	(1) Pedro courts her
(2) u loves him	(2) woman (u)
(5) u loves v	(2) u loves him
	(3) v = Pedro
	(3) v courts her
	(4) v courts u
	(5) u loves v

Not only is there duplication here of the conditions which occur both in $m_1(25)$ and $m_2(25)$ but some of the operations have to be performed simultaneously *and in the same way*, on the identical entries of these two DR's. It would be possible to characterize DRS-construction so that such entries are treated simultaneously in all the DR's in which they occur, and give rise in each of these DR's to the same descendants. But this is awkward, particularly where the treatment produces new subordinate DR's. It is easier to introduce into the second DR of the pair representing a conditional only the information conveyed by the consequent. In the case of (25) this will lead to a DRS of the form:

$$m_0(25)$$

if a woman loves him Pedro courts her

$m_1(25)$		$m_2'(25)$	
u		u	v
.		.	.
a woman loves him		Pedro courts her	
woman (u)		v = Pedro	
u loves him		v courts her	
u loves v		v courts u	
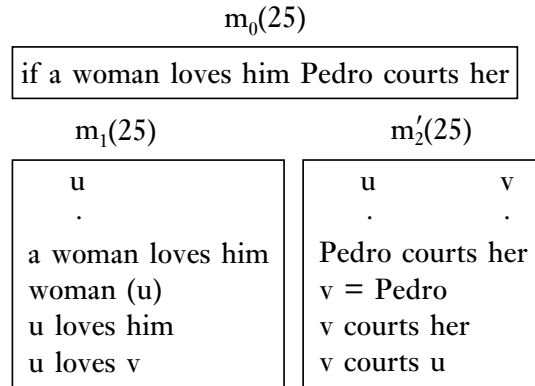
Similarly, we shall represent a universal sentence by a pair of DR's into the second of which we enter the information that the remainder of the sentence is true of the discourse referent which stands in for the singular term *every β* in question. For example the DRS K(15) for

(15)   Every widow admires a farmer

now becomes

$$K(15)$$
$$m_0(15)$$

Every widow admires a farmer

$m_1(15)$		$m_2'(15)$
x		u
.		.
widow (x)		x admires a farmer
		farmer (u)
		x admires u
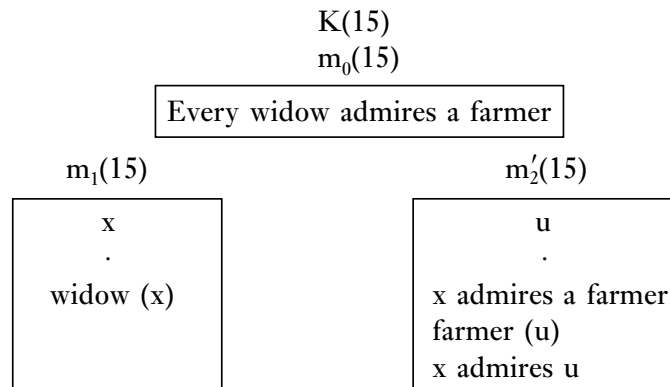
Evidently the second members of the representing pairs about which we have been speaking up to now can be reconstructed from these new pairs: where (m_1, m_2) is the old pair and (m_1, m_2') the pair which replaces it according to the present stipulation, m_2

is the union of m_1 and m_2', where the *union* of two DR's $\langle U_1, Con_1 \rangle$, $\langle U_2, Con_2 \rangle$ is the DR $\langle U_1 \cup U_2, Con_1 \cup Con_2 \rangle$ – thus, in particular, $m_2(15)$ is the union of $m_1(15)$ and $m_2'(15)$, and $m_2(25)$ that of $m_1(25)$ and $m_2'(25)$. Note that the truth clause (12) for conditionals and its analogue for universal sentences are not affected by this change.

Let us now describe how we can recognize two DR's m_1 and m_2 as representing a conditional or universal sentence that occurs among the conditions of the DR m. We first assume that m contains the occurrence $\langle \phi, k \rangle$ that ϕ is a conditional and that its antecedent and consequent are, respectively, $\langle \psi, r \rangle$ and $\langle \chi, s \rangle$.[15] We say that the pair of DR's $\langle m_1, m_2 \rangle$ *represents* $\langle \phi, k \rangle$ iff:

(i) $\langle \psi, r \rangle \in Con_{m_1}$ and every member of Con_{m_1} is a descendant of a subexpression of $\langle \psi, r \rangle$;

(ii) $\langle \chi, s \rangle \in Con_{m_2}$ and every member of Con_{m_2} is a descendant of a subexpression of $\langle \chi, s \rangle$.

Now suppose $\langle \phi, k \rangle$ is a universal sentence. Here it is convenient to distinguish between the case where the term with maximal scope is of the form *every β*, where *β* is a basic CN and that where it has the form *every βγ* with *β* a CN and *γ* a RC. Let us begin by considering the first of these. We say the pair $\langle m_1, m_2 \rangle$ *represents* $\langle \phi, k \rangle$ iff for some $x \in V$ (i) $x \in U_{m_1}$; (ii) $Con_{m_1} = \{ \langle \beta(x), i \rangle \}$; (iii) $\langle \phi', k \rangle \in Con_{m_2}$ and each member of Con_{m_2} is a descendant of a subexpression of $\langle \phi', k \rangle$, where i is the index of the occurrence of *β* in the term (occurrence) *every β* in question and ϕ' is the result of replacing that term occurrence in ϕ by x.

Now consider the case where the term with maximal scope has the form *every βγ*, where *β* is common noun and *γ* a relative clause. In this case $\langle m_1, m_2 \rangle$ *represents* $\langle \phi, k \rangle$ iff for some $x \in V$ (i) $x \in U_{m_1}$; (ii) $\langle \beta(x), i \rangle, \langle \delta, r \rangle \in Con_{m_1'}$ and every member of Con_{m_1} other than $\langle \beta(x), i \rangle$ is a descendant of an occurrence of a subexpression of $\langle \delta, r \rangle$; and (iii) $\langle \phi', k \rangle \in Con_{m_2}$ and every member of Con_{m_2} is a descendant of an occurrence of a subexpression of $\langle \phi', k \rangle$ – here i and ϕ' are as above, r is the index of the occurrence of *γ* in the relevant occurrence of *every βγ* and *δ* is determined as follows: let *ζ* be the sentence from which the relative clause has been formed through "wh-movement"; *δ* is obtained by substituting x in *ζ* for the pronoun occurrence which was eliminated in the transition from *ζ* to *γ*.

Next we must give the definition of *partial Discourse Representation Structures*.

DEFINITION 2. A *partial DRS (Discourse Representation Structure) for* D is a set K of possible DR's for D such that whenever m is a member of K and Con_m contains a conditional or universal sentence $\langle \phi, k \rangle$ then there is at most one pair of members m_1 and m_2 of K which represents $\langle \phi, k \rangle$.

We say that a member m' of K is *immediately subordinate to* m iff either (i) there is a conditional or universal sentence occurrence $\langle \phi, k \rangle \in Con_m$ such that m' is the first member of a pair which represents $\langle \phi, k \rangle$; or (ii) m is itself the first member of such a pair and m' is the second member of that pair. m' is *subordinate to* m iff there exists a finite chain of immediate subordinates connecting m and m'.

The rules for constructing DRS's will guarantee that they will always have a principal member. If the partial DRS K contains such a member it will be denoted as $m_0(K)$. Where K and K' are partial DRS's we say that K' *extends* K iff there is a 1–1 map f from K into K' such that for each $m \in K$ f(m) extends m. For $m \in K$ we denote as $K^{\geq}(m)$ the set consisting of m and all the members of K that are superordinate to m. We shall also write "U_K" for "$\cup_{m \in K} U_m$" and "$U_K^{\geq}(m)$" for "$U_M \cup \cup \{U_{m'}: m' \in K$ and m' is superordinate to m $\}$". We say that a partial DRS K is *complete* iff (i) every member of K is maximal; and (ii) whenever m is a member of K and Con_m contains an occurrence of $\langle \phi, k \rangle$ of a conditional or universal sentence K contains a pair which represents $\langle \phi, k \rangle$.

We can now proceed to give a precise statement of the rules for DRS-construction. It is they, I must repeat here, that carry virtually all the empirical import of the theory. Their exact formulation is therefore of the greatest importance. Instead of trying to do justice to all relevant linguistic facts at once, I shall begin stating the rules in a fairly simple manner. This will then serve as a basis for further exploration.

For the fragment L_0 there are five rules, one for proper names, one for indefinite descriptions, one for pronouns, one for conditionals and one for universal terms. The effect of applying a rule to a particular condition in some member of a DRS is always an extension of that DRS.

Only the rules for conditionals and universals lead to the introduction of new DR's. But this does not mean that the effect of each of the other rules is confined to the particular DR m which contains the condition to which the rule is applied. Thus, for instance – and this is a point we have so far neglected in our examples – the application of the rule for proper names will always result in the introduction of a new discourse referent into the principal DR of the DRS, even if the condition to which the rule is being applied belongs itself to some other member of the structure. (I shall argue below that the rule for proper names *must* operate in this fashion.) Directly connected with this is the need to refer, in the statement of the rule for pronouns, not just to the universe of the DR m that contains the relevant condition, but also to the universes of certain other members of the DRS – in fact, as it turns out, of all those members which are superordinate to m.

To state the first three rules let us assume that K is a partial DRS, that $m \in K$, that $\langle \phi, k \rangle \in Con_m$ is an unreduced member of m, and that $\langle \alpha, i \rangle$ is an occurrence of a term in $\langle \phi, k \rangle$ which has maximal scope in $\langle \phi, k \rangle$.

CR1.   Suppose α is a proper name. We add to $U_{m_0(K)}$ an element u from $V \setminus U_K$. Furthermore, we add to $Con_{m_0(K)}$ the occurrence $\langle u = \alpha, i \rangle$ and to Con_m the occurrence $\langle \phi', k \rangle$, where ϕ' is the result of replacing the occurrence of α in $\langle \phi, k \rangle$ with index i by u.

CR2. α is an indefinite singular term. (a) α is of the form $a(n)\beta$, where β is a common noun. We add to U_m an element u from $V \setminus U_K$ and to Con_m the occurrences $\langle \beta(u), r \rangle$ (where r is the index of the occurrence of β in $\langle \alpha, i \rangle$) and $\langle \phi', k \rangle$, where ϕ' is as under CR1. The other members of K remain unchanged. (b) α is of the form $a(n)\beta\gamma$, where β is a basic common noun and γ a relative clause. We add $u \in V \setminus U_K$ to U_m and expand Con_m with $\langle \beta(u), r \rangle$, $\langle \phi', k \rangle$ and the pair $\langle \delta, s \rangle$

where δ is determined as in the definition of *represents* given above, and s is the index of the occurrence of γ in $\langle \alpha, i \rangle$.

CR3.   Assume α is a pronoun. Choose a "suitable" member u from $U_K^{\geq}$ (m). Add $\langle \phi', k \rangle$ to Con_m, ϕ is as under CR1.

NB. I have given a deliberately "fudgey" formulation of this rule by inserting the word "suitable". To state what, in any particular application of the rule, the set of suitable referents is, we would have to make explicit what the strategies are that speakers follow when they select the antecedents of anaphoric pronouns. In the applications we shall consider below the restriction to "suitable" referents that I have built into CR3 will never play an overt role (although I will occasionally ignore, without comment, readings of the sampled sentences which would impose anaphoric links that are ruled out by various factors that enter into these strategies, such as e.g. the principle of gender agreement). Nonetheless, I have included "suitable" in the formulation of CR3, as a reminder that the rule is incomplete as it stands.

To state the last two rules let us assume that K and m are as above, that $\langle \phi, k \rangle$ is an unreduced member of Con_m and that ϕ is either a universal sentence or a conditional.

CR4.   Assume $\langle \phi, k \rangle$ is a conditional with antecedent $\langle \psi, r \rangle$ and consequent $\langle \chi, s \rangle$. We add to K the member $\langle \emptyset, \{\langle \psi, r \rangle\} \rangle$ and $\langle \emptyset, \{\langle \chi, s \rangle\} \rangle$.

CR5.   Assume $\langle \phi, k \rangle$ is a universal sentence and the term with maximal scope is $\langle every \ \beta, i \rangle$ with β a basic CN. We add, for some $u \in v \backslash D_K \langle \{u\}, \{\langle \beta(u), r \rangle\} \rangle$, and $\langle \emptyset, \{\langle \phi', k \rangle\} \rangle$, where r and ϕ' are as 2 pages above. Similarly, where the term with maximal scope is $\langle every \ \beta\gamma, r \rangle$ where $\beta \in$ CN and $\gamma \in$ RC the DR's that must be added are $\langle \{u\}, \{\langle \beta(u), r \rangle, \langle \delta, s \rangle\} \rangle$ and $\langle \emptyset, \{\langle \phi', k \rangle\} \rangle$, where, again, $u \in V \backslash V_K$ and s, δ, ϕ' are as in the statement of CR2.

Note that if K is a finite DRS, i.e. a finite set of finite DR's, then a finite number of applications of the rules CR1–CR5 will convert it into a complete DRS. Any complete DRS obtained from K by a series of rule applications is called a *completion of* K. Clearly, if K has a principal member, then so does every completion of K.

We can at last define the notion of a *complete DRS for* a discourse D. The definition proceeds by recursion on the length of D.

DEFINITION 3.   (i) Suppose D is a discourse consisting of one sentence ϕ. Let k be the index of ϕ in D. A *complete DRS (Discourse Representation Structure) for* D is any completion of the DRS $\{\langle \emptyset, \{\langle \phi, k \rangle\} \rangle\}$. (ii) Suppose that D has the form $\langle \phi_1, \ldots, \phi_n, \phi_{n+1} \rangle$ and that the set of complete DRS's for the discourse $D' = \langle \phi_1, \ldots, \phi_n \rangle$ has already been defined. Let k be the index of the occurrence of ϕ_{n+1} as last sentence of D. Then K is a *complete DRS for* D iff K is a completion of a DRS of the form $(K' - \{m_0(K')\}) \cup \{m\}$, where K' is some complete DRS for D' and m is the DR $\langle U_{m_0(K')}, Con_{m_0(K')} \cup \{\langle \phi, k \rangle\} \rangle$.

NB. It follows from this definition together with earlier remarks that every set of possible DR's which is a complete DRS for some discourse D contains a principal DR.

3.3   Truth

Our next task is to define truth. […]

There is just one feature of the definition that might be puzzling without a brief preliminary discussion. The evaluation of conditionals and universals as a rule involves only embeddings that respect certain previously assigned values to some of the discourse referents in superordinate positions. In other words we keep, in the course of such evaluations, certain functions fixed and consider only embeddings compatible with these functions. This means that the recursive definition underlying the characterization of the truth in M must be of a concept which is sensitive not only to the information encoded in the DRS but also to some partial function from the discourse referents of that DRS into U_M. If a sentence contains several nested embeddings of conditionals or universals, the maps considered in the evaluation of deeply embedded constructions may have to agree with several functions that have been stored, so to speak, along the way down to the conditional or universal concerned. However, as these stored functions must also be compatible with each other we need consider only single functions in this connection; intuitively these are the unions of the sets of different functions accumulated along the path towards the embedded construction.

Let K be a complete DRS for D and M a model of D. We shall give the definition of the *truth value of* D *in* M *given* K in two steps. The first stage will give a characterization, by simultaneous recursion, of two relations: (i) The relation which holds between a member m of K, a function f from U_m into U_M and a partial function g from U_K into U_M iff, as we shall express it, f *verifies* m *in* M *given* K, *relative to* g; and (ii) the relation which holds between m, an unreduced member $\langle \phi, k \rangle$ of $Con_{m'}$ a function f from U_m into U_M and a function g from U_K into U_M iff, as we shall say, $\langle \phi, k \rangle$ *is true in* M *under* f, *given* K, *relative to* g. The second stage uses the first of these two relations to define truth:

DEFINITION 4.   Let D be an L_0-discourse, K a complete DRS of D and M a model for L_0. D is *true in* M *on* K iff there is a function f from $U_{m_0(K)}$ into U_M which verifies $m_0(K)$ in M, given K, relative to $\wedge$. ($\wedge$ is the empty function!).

The recursive part of the definition is inevitably somewhat more involved.

DEFINITION 5.   Let D, K, M be as in Definition 4; let $m \in K$ and let g be a partial function from U_K into U_M.
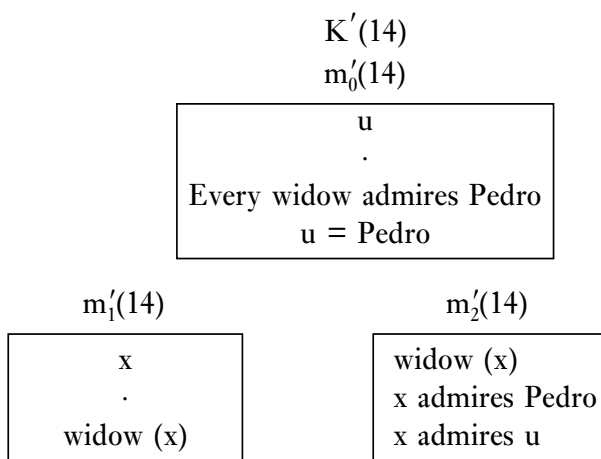 (i)   f *verifies* m *in* M *given* K, *relative to* g iff each unreduced member $\langle \phi, k \rangle$ of Con_m is true in M under f, given K, relative to g.
(ii)   Suppose $\langle \phi, k \rangle$ is an occurrence of an atomic sentence in Con_m. Then ϕ has one of the following four forms:
    (a) $u\alpha$, where $u \in V$ and $\alpha \in IV$;
    (b) $u\alpha v$, where $u, v \in V$ and $\alpha \in TV$;
    (c) $u = \alpha$, where $u \in V$ and α is a proper name;
    (d) $\alpha(u)$, where $u \in V$ and α is a basic common noun.

The question whether $\langle\phi, k\rangle$ *is true in* M *under* f *given* K, *relative to* g splits up into the corresponding four clauses below (we omit the qualification "in M under f, given K relative to g"):
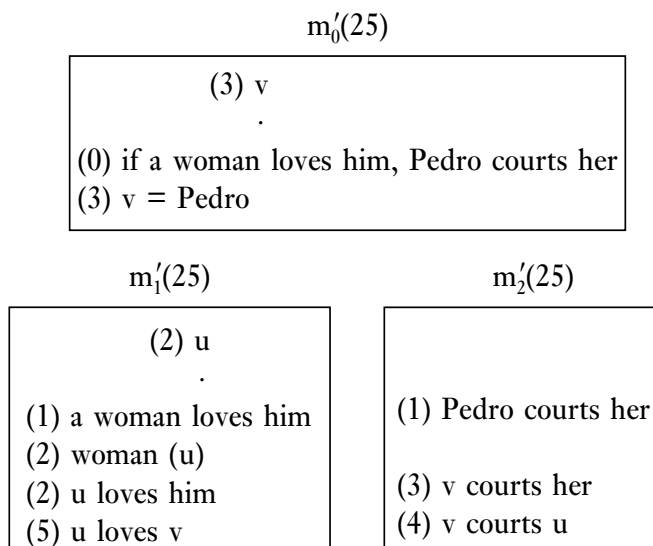
(a) $\langle\phi, k\rangle$ *is true* iff $f(u) \in F_M(\alpha)$;

(b) $\langle\phi, k\rangle$ *is true* iff $\langle f(u), f(v)\rangle \in F_M(\alpha)$;

(c) $\langle\phi, k\rangle$ *is true* iff $f(u) = F_M(\alpha)$;

(d) $\langle\phi, k\rangle$ *is true* iff $f(u) \in F_M(\alpha)$.

(iii) Suppose $\langle\phi, k\rangle$ is an occurrence of a conditional or universal sentence in Con_m. Then K will contain a unique pair $\langle m_1, m_2\rangle$ which represents $\langle\phi, k\rangle$. $\langle\phi, k\rangle$ *is true in* M *under* f *given* K, *relative to* g iff every map h from U_{m_1} into U_M which is compatible with $g \cup f$ and which verifies m_1 in M given K relative to $g \cup f$ can be extended to a function k from U_{m_2} into U_M and verifies m_2 in M given K relative to $g \cup f$.

We shall call a function which verifies m_0 (K) in M, given K, relative to $\wedge$ a *verifying*, or *truthful*, *embedding of* K *into* M. We shall also say of such a map that it *verifies* D *in* M *on* (*the reading provided by*) K.
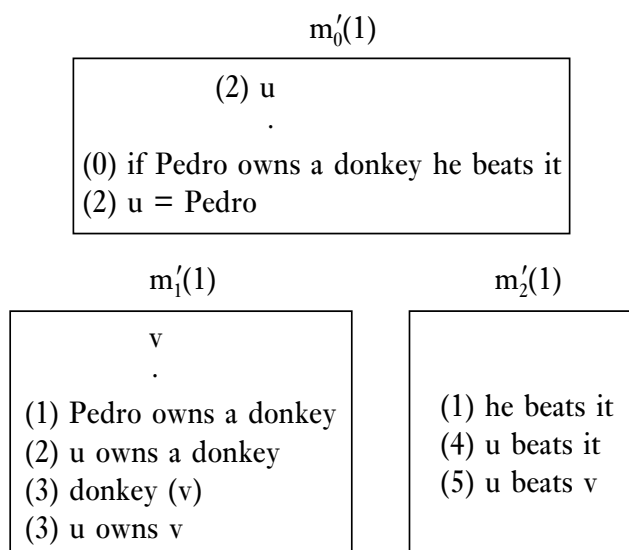
Many of the DRS's we have earlier displayed fail to be in complete agreement with the construction procedure as we have now formally described it. This is true, in particular, of the second representation I gave in Section 2.3 for (14). The DRS K(14) violates the rule CR1 in that the item u, which is introduced as the referent of the proper name *Pedro* should have been entered into the universe of $m_0(14)$ rather than into that of m(14). Let us give the DRS for (14) once more, this time in its proper form.

$$K'(14)$$
$$m_0'(14)$$

u
.
Every widow admires Pedro
u = Pedro

$$m_1'(14) \qquad\qquad m_2'(14)$$

x
.
widow (x)

widow (x)
x admires Pedro
x admires u

The need to place the discourse referent introduced by a proper name into the principal DR is illustrated by (25) for which I gave a DRS in Section 3.2. This DRS is unacceptable by our rules as the referent u in $m_2(25)$ is not accessible from the position of *him* in $m_1(25)$, to which, at step (5) it was nonetheless assigned. This difficulty would not have arisen had CR1 been properly applied in the first place. The correct DRS for (25) looks as follows:

$$m_0'(25)$$

(3) v
.
(0) if a woman loves him, Pedro courts her
(3) v = Pedro

$$m_1'(25) \qquad\qquad m_2'(25)$$

(2) u	
.	(1) Pedro courts her
(1) a woman loves him	
(2) woman (u)	(3) v courts her
(2) u loves him	(4) v courts u
(5) u loves v	

Let us, for good measure, also give a corrected version of the DRS for (1), as the analysis of that sentence motivated so much of what I have been saying, and yet its earlier representation also contains a violation of CR1:

$$m_0'(1)$$

(2) u
.
(0) if Pedro owns a donkey he beats it
(2) u = Pedro

$$m_1'(1) \qquad\qquad m_2'(1)$$

v	
.	(1) he beats it
(1) Pedro owns a donkey	(4) u beats it
(2) u owns a donkey	(5) u beats v
(3) donkey (v)	
(3) u owns v	

We already saw in Section 2 how important it is that the discourse referents available to a given pronoun must all occur in the same, or else in some superordinate, DR. This, we saw, accounts for the fact that *it* cannot have *every donkey* as its antecedent in a sentence such as (17) or (18), or be anaphorically linked to *a donkey* in (19). The reader will inevitably ask, however, why subordination is defined in the precise way it has been. Why, for instance is, where (m_1, m_2) represents a conditional or universal, m_2 subordinate to m_1 but not m_1 subordinate to m_2; or, to put it more directly, why may the elements of m_2 not serve as referents for pronouns in sentences belonging to Con_{m_1} while the members of U_{m_1} are admitted as referents for pronouns occurring in m_2?
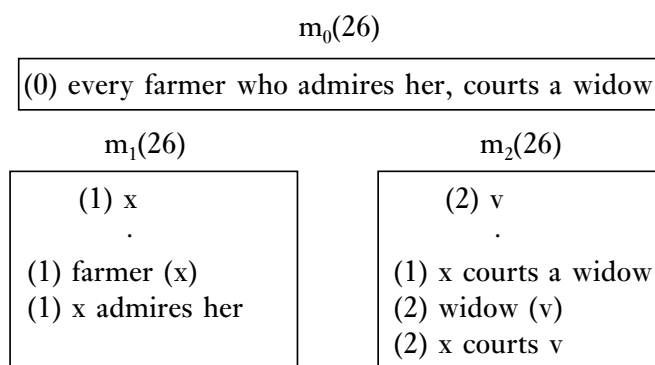
That the elements of m_1 must be available for the pronouns of m_2 is too central an assumption of our theory to permit tampering: our analysis of the crucial sentences (1) and (2) depended essentially on that hypothesis. But what about referents in m_2 for pronouns in m_1? Here is an example which shows that the sets of possible referents must be as we have specified them:

(26)   Every farmer who admires her courts a widow.

It is my intuitive judgement that in (26) *her* can be coreferential with *a widow*, but only if *a widow* has wide scope over *every farmer*. Such "wide scope" readings for indefinites that occupy positions which correspond to narrow scope according to our syntax are not discussed in this paper. A reading which (26) can *not* have is, according to my intuitions, the one given by

(27) $(\forall x)\,(\text{farmer}(x) \rightarrow (\exists y)\,(\text{widow}(y) \wedge \text{admires}(x, y)$
$$\wedge\ \text{courts}(x, y))) \cdot$$

To block this reading we must stipulate that the element v of $m_2(26)$ is not available to the pronoun in $m_1(26)$:

<div align="center">

$m_0(26)$

(0) every farmer who admires her, courts a widow

</div>

<div align="center">

$m_1(26)$ $m_2(26)$

</div>

(1) x . (1) farmer (x) (1) x admires her	(2) v . (1) x courts a widow (2) widow (v) (2) x courts v

Our theory seems to rule out a parallel reading for the conditional

(28)   If a farmer admires her, he courts a widow.

It predicts, that is, that (28) cannot mean what is expressed by (27). Again, *her* in (28) can be understood as coreferential with *a widow* if the latter is taken to have wide scope – as it normally would in, say,

(29)   If a farmer admires her he courts a certain widow
I have dated and therefore know quite well.

(28) appears to have still another reading, in which *a widow* is taken as generic, a reading that is approximated by

(30) $\forall x \forall y [\text{farmer}(x) \wedge \text{widow}(y) \wedge \text{admires}(x, y) \rightarrow \text{courts}(x, y)].$

Generics, however, are among the most recalcitrant constructions know to me. They will not be treated in this paper. Note also that

(31)   If Pedro admires her he courts a widow,

though understandable, on the assumption that *her* refers to *a widow*, does not sound natural – barely, more natural in fact than do (26) and (28) on their wide scope reading, given by

(32) $\exists y[\text{widow}(y) \wedge \forall x[\text{farmer}(x) \wedge \text{admires}(x, y) \rightarrow \text{courts}(x, y)]]$.

The reason is that in order to get a reading of (31) in which *her* and *a widow* are coreferential we have to suppose – just as we must in connection with (26) and (28) – that *a widow* has wide scope over the subject Pedro. In another paper we shall have more to say about why such readings tend to be somewhat unnatural.

Notes

1   Theories that to a greater or lesser degree accord with this intuition have emerged within Artificial Intelligence and Computer Science, as well as within Linguistics. A significant contribution of this kind that comes from the first field is Webber (1978). Examples of such theories that have been proposed by linguists are: the theories outlined in Bartsch (1976, 1979), Cooper (1975, 1979), Hausser (1974, 1979), Karttunen (1976).
    By no means every recent account of pronouns is predicated on the assumption that all cases of pronominal reference can be brought under one unifying principle. Cf. for instance Evans (1977, 1980), Lasnik (1976), Partee (1978).

2   There seems to be a rough preference for referents introduced by terms that appear in the discourse *before* the anaphoric pronoun over those that are introduced by subsequent terms, as well as a preference for referents that are introduced by terms that occur *near* the anaphor. (Thus the referent introduced by the last referential term preceding the anaphoric pronoun is, other factors permitting, a strong referential candidate.)

3   A large part of the research that has been done on anaphora by computer scientists and people working in Artificial Intelligence has been concerned with this problem – understandably enough, as the lack of effective routines for the detection of anaphoric antecedents has for many years been one of the main obstacles to producing satisfactory computer systems for question answering and translation. However useful some of this work may have been, I have the impression that its theoretical significance is rather limited. Indeed I much incline to the opinion expressed, for example, in Partee (1978, p. 80) that all we can reasonably expect to achieve in this area is to articulate orders of preference among the potential referents of an anaphoric pronoun, without implying that the item that receives the highest rating is in each and every case the referent of the anaphor.

4   We are much assisted in our making of such guesses by the spectrum of our social prejudices. Sometimes, however, these may lead us astray, and embarrassingly so, as in the following riddle

which advocates of Women's Lib have on occasion used to expose members of the chauvinistic rearguard: In a head-on collision both father and son are critically wounded. They are rushed into hospital where the chief surgeon performes an emergency operation on the son. But it is too late and the boy dies on the operating table. When an assistant asks the surgeon, "Could you have a look at the other victim?", the surgeon replies "I could not bear it. I have already lost my son." Someone who has the built-in conception that chief surgeons are men will find it substantially more difficult to make sense of this story that those who hold no such view.

5   As we have already observed, this is not quite correct, since a pronoun can be used deictically, in which case the referent need not belong to the DR; we shall, however, ignore the deictic use of pronouns in the course of this paper.

6   See for example Lewis (1973), Turner (1981), Veltman (1976), Kratzer (1979).

7   (11) is akin in spirit to the game theoretical analysis of *if … then …* sentences proposed in Hintikka and Carlson (1978), according to which a winning strategy for the defender of *if* A *then* B is a function which maps every winning strategy for the defender of A onto a winning strategy for the defender of B.

8   The fact that "existential" quantifier phrases can be represented in this manner is closely related to the familiar model theoretic proposition that purely existential sentences are preserved under model extensions.

9   I have found at least one speaker for whom (20) is distinctly less acceptable than for instance (1).

10   See for example Carlson (1976, Chapter I), which warns against this prejudice in similar terms.

11   Proposals similar to that of Evans can be found e.g. in Cooper (1979) and Hausser (1974). These suffer in my view from similar shortcomings.

12   The two fragments have roughly the same quantificational powers. But the present fragment lacks adjectives, prepositional phrases and intensional contexts.

13   One might have hoped that a theory of semantic processing such as the one attempted here could provide an explanation of why island-constraints exist and why they operate in precisely those linguistic contexts that are subject to them. I have not succeeded, however, in finding such an explanation.

14   See e.g. Montague (1970a,b; 1973), Partee (1975), Thomason (1976), Cooper and Parsons (1976), Cooper (1979).

15   With the *occurrence* $\langle \phi, k \rangle$ are associated, of course, particular *occurrences* of antecedent and consequent.

References

Bartsch. R. 1976. Syntax and semantics of relative clauses. In Groenendijk and Stokhof 1976, 1–24.

Bartsch, R. 1979. The syntax and semantics of subordinate clause constructions and pronominal reference. In Heny and Schnelle 1979, 23–59.

Bauerle, R., U. Egli, and A. von Stechow (eds). 1979. *Semantics from Different Points of View*. Berlin: Springer-Verlag.

Carlson, G., 1976, Reference to Kinds in English. Ph.D. Dissertation, University of Massachusetts, Amherst.

Cooper, R. H., 1975, *Montague's Semantic Theory and Transformational Syntax*. Dissertation, University of Massachusetts, Amherst. Published by Xerox University Microfilms.

Cooper, R. and T. Parsons. 1976. Montague grammar, generative semantics and interpretative semantics. In Partee 1976, 311–362.

Cooper, R. H. 1979. The interpretation of pronouns. In Heny and Schnelle 1979, 61–92.

Evans, G. 1977. Pronouns, quantifiers and relative clauses. *Canadian Journal of Philosophy* 7.

Evans, G. 1980. Pronouns. *Linguistic Inquiry*, 11.

Geach, P., 1962. *Reference and Generality*, Ithaca, New York: Cornell University Press.

Groenendijk, J. and M. Stokhof (eds). 1976. *Proceedings of the Amsterdam Colloquium on Montague Grammar and Related Topics*, Amsterdam Papers in Formal Grammar I. Centrale Interfaculteit, University of Amsterdam.

Hausser, R. R., 1974. Quantification in Extended Montague Grammar. Ph.D. Dissertation, University of Texas.

Hausser, R. R. 1979. How do pronouns denote? In Heny and Schnelle 1979, 93–139.

Hendrix, G. 1975. Partitioned Networks for the Mathematical Modelling of Natural Language Semantics. Ph.D. Dissertation, University of Texas.

Heny, F. and H. S. Schnelle (eds). 1979. *Selections from the Third Groningen Round Table* (*Syntax and Semantics*, vol. 10). New York: Academic Press.

Hintikka, J. and L. Carlsson. 1978. Conditionals, generic quantifiers and subgames. In: E. Saarinen (ed.), *Game Theoretical Semantics*, Dordrecht: D. Reidel.

Karttunen, L. 1976. Discourse referents. In McCawley 1976.

Kratzer, A. 1979. Conditional necessity and possibility. In Bauerle et al. 1979, 117–147.

Lasnik, H. 1976. Remarks on coreference. *Linguistic Analysis*, 2.

Lewis, D. 1973. *Counterfactuals*. Oxford: Blackwell.

McCawley, J. D. (ed.). 1976. *Notes from the Linguistic Underground* (*Syntax and Semantics*, vol. 7). New York: Academic Press.

Montague, R. 1970a. English as a formal language. In B. Visentini et al. (eds), *Linguaggi nella societa e nella tecnica*, Milan: Edizione di Communita, 189–224. Repr. in Thomason 1974, 188–221.

Montague, R. 1970b. Universal grammar. *Theoria* 36, 373–398. Repr. in Thomason 1974, 222–46.

Montague, R. 1973. The proper treatment of quantification in ordinary English. In K. J. J. Hintikka, J. M. E. Moravcsik and P. Suppes (eds), *Approaches to Natural Language*, Synthese Library 49, Dordrecht: Reidel, 221–42. Repr. in Thomason 1974, 247–70.

Partee, B. 1975. Montague grammar and transformational grammar. *Linguistic Inquiry* 6, 203–300.

Partee, B. 1978. Bound variables and other anaphors. In D. Waltz (ed.), *Tinlap-2, Theoretical Issues in Natural Language Processing-2*, New York: Association for Computing Machinery, 248–80.

Thomason, R. H. (ed.). 1974. *Formal Philosophy. Selected Papers of Richard Montague*. New Haven, Conn.: Yale University Press.

Thomason, R. H. 1976. Some extensions of Montague grammar. In: B. Partee (ed.), *Montague Grammar*, New York: Academic Press, 77–117.

Turner, R. 1981. Counterfactuals without possible worlds. *Journal of Philosophical Logic* 10, 453–93.

Veltman, F. 1976. Prejudices, presuppositions and the theory of conditionals. In Groenendijk and Stokhof 1976, 248–81.

Webber, A. 1978. A Formal Approach to Discourse Anaphora. Report 3761, Boston, Mass.: Bolt, Beranek and Newman.