Negation in Situation Semantics and Discourse Representation Theory

ROBIN COOPER AND HANS KAMP

1 Introduction

The project of putting Situation Semantics and Discourse Representation Theory (DRT) together has a history going back to the early eighties when Barwise and Kamp investigated the topic. However, nothing concrete resulted from the research. After a decade we think it might be appropriate to try again in the hope that the two theories might illuminate each other.

The relationship Situation Semantics and DRT that Barwise and Kamp proposed was remarkably straightforward: With each DRS (DRS, discourse representation structure) K of the DRT fragment considered and each embedding function f for the universe of K one could associate a situation type $S(K)$, such that the situations supporting K would be precisely those of type $S(K)$. In particular, a maximal situation w (i.e., a situation comprehending the entire world in which it is situated) would be one in which f correctly embeds K iff w is of the type $S(K)$. The fragment investigated was that of Kamp 1981, in which the only complex DRS conditions are implications $K_1 \rightarrow K_2$; more complex DRS languages were meant to be considered, but the enterprise never got beyond this first stage. Since that early effort many things have changed, both within Situation Semantics and within DRT, and so the little that was then accomplished neither fits the terminology nor the prevalent conceptions of today. Nevertheless, the first part of the present investigation follows its predecessor quite closely. The main differences are (i) we no longer make use of the situation-theoretic notions of situation type and event type as they were conceived then; and

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(ii) the basic DRS language with which we start is one in which complex conditions are not implications, but are formed with a one-place negation operator on DRS's. This second change is not occasioned by a change in DR-theoretical perspective, but motivated by a formal as well as by an expositional consideration. The formal motive is this: While arguably simpler than the DRS language of Kamp 1981, the DRS language which has negation as its only operator exceeds the earlier language in expressive power; in fact, unlike the earlier language it is equivalent to full classical first order predicate calculus.[1] The expositional consideration relates to our desire to investigate some of the alternatives that present themselves for the interpretation of the logical operators within a situation semantic framework. Here negation appears to be of particular interest, not least because the treatment of negation has been a topic of discussion within Situation Semantics quite independently from its potential connections with DRT. And it seemed to us that a first look at this matter would benefit from a stark environment, in which no other operators complicate the picture.

There are three approaches to putting together the two theories that we think might be fruitful to pursue:[2]

1. give a situation semantics for a language of DRSs as defined, for example, by Kamp and Reyle (forthcoming). This could be done by defining the conditions under which a DRS describes a situation. We could define a *describe* relation which holds between a DRS and a situation iff the situation is correctly described by the situation.
2. give a model of DRSs as objects in situation theory. This might be just another way of giving a situation semantics for a DRS language, but with the constraint that each DRS is related to a particular situation theoretic object (e.g., a parametric situation type). Now, since DRSs are identified with situation theoretic objects, the *describe* relation will be a relation between situation theoretic objects, so that the corresponding part of DRT becomes effectively a branch of situation theory.
3. start from some version of situation semantics, e.g., Cooper 1991 (in preparation) or Gawron and Peters 1990 and incorporate the dynamic aspects of DRT.

We pursue the first, which is the most conservative of these approaches, providing a simple DRS language with a very conservative situation semantics. We will discuss problems that arise with the interpretation of negation

[1] As it stands the fragment defined in Kamp 1981 is not able to express, for instance, classical negation. Of course, it would have been easy enough to add, say, the sentential constant F. To be precise, this would be a DRS condition which is never verified.

[2] A rather different approach which involves the situation schemata of Fenstad et al. 1987 is taken by Sem 1987.

and suggest that in order to give a reasonable account of negation we must give up one of the following:

1. the 'indefinite as variable' or 'singular noun-phrase' interpretation of indefinite noun phrases
2. persistence of the content of negative sentences
3. the situations described by sentences with indefinite NPs in the scope of negation do not need to support negative facts about all members of some universal set of individuals

The way that we choose to resolve these issues may have important consequences for situation theory since the discussion turns on characterizing the kind of situation which supports information corresponding to "John doesn't own a car". Is there a single negative infon corresponding to this information and, if so, what kind of infon is it? Or does this information correspond to a set of infons which must be supported and, if so, what is the structure of this set? Must all the infons in the set be supported by a single situation? It seems that detailed analysis of natural language might provide important input to the discussion of such situation theoretical questions. We should like to emphasize, however, that the paper's central focus is a semantic one. The problem of interpreting negative sentences is a central problem of semantics. That the exploration of this question should have led us to consider the kind of entities that the ontology supporting a satisfactory situation semantic treatment of natural language negation should include is hardly surprising. Modern semantic research has taught us that issues of ontology cannot be kept distinct from questions of (natural language) semantics any more than they can be kept separate from questions of logic and we therefore feel that the paper should have potential readers beyond those who have a declared interest in the functioning of natural language for its own sake.

2 DRS Language L_0

We shall start by defining a simple DRS language L_0 in the style of Kamp and Reyle (forthcoming).

1. Vocabulary
   a. a set V of discourse referents
   b. a set N of proper names
   c. a set R_1 of 1–place predicates
   d. a set R_2 of 2–place predicates
2. DRSs and DRS-conditions
   a. if U is a (finite) subset of V and Con a (finite) set of DRS-conditions, then $\langle U, Con\rangle$ is a DRS.
   b. if $x, y \in V$ then $x = y$ is a DRS-*condition*.
   c. if $x \in V$ and $\alpha \in N$, then $\alpha(x)$ is a DRS-*condition*.

d. if $x \in V$ and $\alpha \in R_1$, then $\alpha(x)$ is a DRS-*condition*.
e. if $x, y \in V$ and $\alpha \in R_2$, then $x\alpha y$ is a DRS-*condition*.
f. if K is a DRS, then $\neg K$ is a DRS-*condition*.

Well-formedness

Suppose K is a DRS and γ a DRS- condition. The *set of undeclared discourse referents* of $K(\gamma)$, $\overline{U}(K)(\overline{U}(\gamma))$, is defined as follows:

a. if $K = \langle U, Con\rangle$, then $\overline{U}(K) = (\bigcup_{\gamma \in Con} \overline{U}(\gamma)) - U$
b. if $\gamma = x = y$, then $\overline{U}(\gamma) = \{x, y\}$
c. if $\gamma = \alpha(x)$, then $\overline{U}(\gamma) = \{x\}$
d. if $\gamma = x\alpha y$, then $\overline{U}(\gamma)) = \{x, y\}$
e. if $\gamma = \neg K$, then $\overline{U}(\gamma) = \overline{U}(K)$

A DRS K is *well-formed* iff $\overline{U}(K) = \emptyset$.

3 Situation Semantics for L_0.

In this section we define a conservative situation semantics for L_0 using elements from the style of situation semantics used in Cooper 1989 and Cooper 1991 (in preparation).

We will characterize a relation *describe* which may hold between a use, $\underline{K}$, of a DRS, K or a condition γ in $\underline{K}$, a situation (a situation which could be described by $\underline{K}$ or γ), an environment for $\underline{K}$ and a lexicon for L_0.

For the purposes of this paper we will assume that the notion of a use of a DRS is clear. A full explication of this notion in situation theoretic terms would take us beyond the scope of this paper since it would involve modeling DRSs as situation theoretic objects, i.e., the second of the approaches we listed in section 1.

As usual, a situation is an object in situation theory which is defined by the collection of infons that it supports, where an infon is a situation-theoretic object which has a relation, an appropriate number of arguments (depending on the arity of the relation) and positive or negative polarity. Also as usual we use '$\models$' to represent the support relation. Thus we might characterize a situation as follows:

$$s \models \langle\langle \text{see}, a, b; 1\rangle\rangle$$
$$s \models \langle\langle \text{see}, b, a; 0\rangle\rangle$$

Here s is the situation which contains the information that a sees b and that b does not see a.

An environment for a DRS use $\underline{K}$ determines a partial anchoring for the discourse referents in U_K to individuals and a lexicon for the DRS language L_0 assigns the names in L_0 to individuals and the predicates in L_0 to relations. We shall construe both environments and lexica as special kinds of situations.

If $W \subseteq V$ and $U_K \subseteq W$ and e is a situation, then g is an *e-anchor for a use* $\underline{K}$ if g is a function with domain W and range included in the set of individuals such that for any $x \in W$ if $e \models \langle\langle \text{Anc}, \underline{K}, x, a; 1\rangle\rangle$ then $g(x) = a$. (Intuitively the situation e is used here as an environment for $\underline{K}$. We may characterize a *proper environment* for $\underline{K}$, i.e., one that assigns something to at least one of the discourse referents in U_K, as a situation which supports an infon of the form

$$\langle\langle \text{Anc}, \underline{K}, x, a; 1\rangle\rangle$$

for at least one discourse referent in U_K.)

For $W \subseteq V$ we define

$$g_1 \approx_W g_2 \text{ iff } \begin{array}{ll}\text{(i)} & W \subseteq \text{Dom}(g_1) \cap \text{Dom}(g_2), \text{ and} \\ \text{(ii)} & \text{for all } x \in W, g_1(x) = g_2(x)\end{array}$$

A *lexicon for* L_0 is a situation *lex* such that

(i) for each $\alpha \in N$ there is an individual a, such that

$$lex \models \langle\langle \text{Anc}, \alpha, a; 1\rangle\rangle$$

(ii) for each $\alpha \in R_1$ there is a 1–place relation P such that

$$lex \models \langle\langle \text{Anc}, \alpha, P; 1\rangle\rangle$$

(iii) for each $\alpha \in R_2$ there is a 2–place relation R such that

$$lex \models \langle\langle \text{Anc}, \alpha, R; 1\rangle\rangle$$

If *lex* is a lexicon for L_0 and α is a name or predicate of L_0, we write $lex(x)$ for the entity e such that

$$lex \models \langle\langle \text{Anc}, \alpha, e; 1\rangle\rangle$$

Suppose that K is the simple DRS:

x
John(x) smile(x)

We shall say that a use $\underline{K}$ of K describes a situation which supports the infon $\langle\langle r, a; 1\rangle\rangle$, with respect to an environment which anchors the discourse referent x to the individual a and a lexicon which anchors 'smile' to r and 'John' to a. We now make this notion of description more precise.

If $\underline{K}$ is a use of a DRS K, s and *env* are situations and *lex* a lexicon for L_0, $\underline{K}$ *describes* s with respect to *env* and *lex* iff there is some *env*-anchor g for $\underline{K}$ such that s satisfies K with respect to g and *lex* according to the following definition.

Where K is a DRS, γ a DRS condition, s a situation, g an *env*-anchor for some situation *env*, such that $\overline{U}(K) \subseteq \text{Dom}(g)$ and $\overline{U}(\gamma) \subseteq \text{Dom}(g)$, and *lex* a lexicon for L_0, we define the relation *s satisfies K (or γ) with respect to g and* lex, ${}_s[\![\{{}^{K}_{\gamma}\}]\!]_{g,lex}$ by recursion:

(i) ${}_s[\![K]\!]_{g,lex}$ iff ${}_s[\![\gamma]\!]_{g,lex}$ for each $\gamma \in Con_K$.
(ii) if $\gamma =$ '$x = y$', then ${}_s[\![\gamma]\!]_{g,lex}$ iff $g(x) = g(y)$
(iii) if $\gamma = \alpha(x)$ where $\alpha \in N$, then ${}_s[\![\gamma]\!]_{g,lex}$ iff $g(x) = lex(\alpha)$
(iv) if $\gamma = \alpha(x)$ where $\alpha \in R_1$, then ${}_s[\![\gamma]\!]_{g,lex}$ iff $s \models \langle\!\langle lex(\alpha), g(x); 1\rangle\!\rangle$
(v) if $\gamma = x\alpha y$ where $\alpha \in R_2$, then ${}_s[\![\gamma]\!]_{g,lex}$ iff $s \models \langle\!\langle lex(\alpha), g(x), g(y); 1\rangle\!\rangle$
(vi) if $\gamma = \neg K$, then ${}_s[\![\gamma]\!]_{g,lex}$ iff ${}_{s'}[\![K]\!]_{g',lex}$ for *no* actual situation s' and *no* anchoring g' such that $g' \approx_{\mathrm{Dom}(g)-U_K} g$.

In clause (vi) we quantify over situations, and a brief elucidation is required of what that amounts to. We assume that intuitively each situation is situated in a given world, that, from its own perspective, it is *actual*, and that with it all other situations are actual that are also situated in that world. We prefer, however, to state this intuition without having to refer to the world as a distinct individual. So we assume instead that with each situation s is associated a class of situations Sit(s), whose members are precisely those situations that are actual from the perspective of s (are 'coactual with s', one might say). With Sit(s) (in fact with any class of situations, but we will need the notions here only for classes of this particular sort) we can associate a class of individuals or objects, Ind(Sit(s)), and a class of relations, Rel(Sit(s)). We do this by first defining the classes of individuals and relations associated with an infon.

(i) If σ is a basic infon of the form

$$\langle\!\langle R, a_1, \ldots, a_n; i\rangle\!\rangle$$

then $\mathrm{inds}(\sigma) = \{a_1, \ldots, a_n\}$, and
$\mathrm{rels}(\sigma) = \{R\}$

(ii) If σ is an infon of the form[3]

$$\tau_1 \wedge \tau_2 \text{ or } \tau_1 \vee \tau_2$$

then $\mathrm{inds}(\sigma) = \mathrm{inds}(\tau_1) \cup \mathrm{inds}(\tau_2)$, and
$\mathrm{rels}(\sigma) = \mathrm{rels}(\tau_1) \cup \mathrm{rels}(\tau_2)$

We can now define the sets of individuals, inds(s), and relations, rels(s) associated with a situation s as

$$\bigcup_{s\models\sigma} \mathrm{inds}(\sigma)$$
$$\bigcup_{s\models\sigma} \mathrm{rels}(\sigma)$$

respectively. Finally, the individuals and relations associated with a class of situations Sit(s), Ind(Sit(s)) and Rel(Sit(s)) can be defined as

$$\bigcup_{s'\in\mathrm{Sit}(s)} \mathrm{inds}(s')$$
$$\bigcup_{s'\in\mathrm{Sit}(s)} \mathrm{rels}(s')$$

Sit(s) is assumed to satisfy the following conditions:

[3]Other complex infons could be included here depending on the version of situation theory adopted.

(i) $s \in \text{Sit}(s)$

(ii) For each n place relation R in Rel(Sit(s)) and any sequence $a_1, \ldots, a_n$ of individuals in Ind(Sit(s)) that is appropriate[4] for R, there is an $s' \in \text{Sit}(s)$ such that

$$s' \models \langle\langle R, a_1, \ldots, a_n; 1\rangle\rangle \text{ or } s' \models \langle\langle R, a_1, \ldots, a_n; 0\rangle\rangle.$$

(iii) For any situations s_1 and s_2 in Sit(s), there is a situation s_3 such that for every infon σ, if $s_1 \models \sigma$ or $s_2 \models \sigma$ then $s_3 \models \sigma$

(iv) for no $R \in \text{Rel}(\text{Sit}(s))$, $b_1, \ldots, b_n \in \text{Ind}(\text{Sit})(s))$ and $s' \in \text{Sit}(s)$ do we have $s' \models \langle\langle R, b_1, \ldots, b_n; 1\rangle\rangle$ and $s' \models \langle\langle R, b_1, \ldots, b_n; 0\rangle\rangle$[5]

The quantification over s' in the negation clause (vi) is to be understood as quantification over Sit(s). All quantifications over situations in this paper will be understood in this way. Neither here nor later do we take the trouble of making the restriction to Sit(s) explicit.

4 The Treatment of Negation

In this section we will discuss the treatment of negation in clause (vi) and some alternatives to it.

One comment concerns the role of the described situation s in the negation clause (vi). s does not occur on the right hand side of this clause. So $\neg K$ describes an actual situation s (according to the given *env* and *lex*) if and only if it describes (according to *env* and *lex*) any other actual situation. The "locality" of the described situation, which might be thought to be of the essence of situation semantics, has thus been obliterated. According to (vi) utterances of negated sentences relate to the described situation only in a trivial sense; what they really describe is the world at large. This may seem so much at variance with the spirit of situation semantics that the reader might be inclined to think that we simply chose the wrong clause. Perhaps we did; but we did have a reason. The reason is that sentences which give rise to DRS conditions of the form $\neg K$, with U_K non-empty, often appear to have the force of quantifying over all there is. Consider for instance the sentence 'John doesn't own a car'. Often such a sentence is

[4]The restriction to $a_1, \ldots, a_n$ that are appropriate to R is to avoid category violations, such as would occur, say, if the property of being green were to be combined with the number 19. The matter is of no importance to what is to come and we will henceforth ignore it.

[5]The values of the function Sit, as characterized here, are closely related to the *infon algebras* defined in Barwise & Etchemendy 1990, p. 39. Indeed, Sit(s) is much like an infon algebra stripped of its lattice structure, provided by '$\Rightarrow$'. Part of this structure can be reintroduced by defining: $s \leq s'$ iff for each infon σ: if $s \models \sigma$ then $s' \models \sigma$, where the set of infons is defined as the set of all combinations $\langle\langle R, b_1, \ldots, b_n; i\rangle\rangle$ where $b_1, \ldots, b_n$ is a sequence, of the right length and appropriate to R, of individuals from Ind(Sit(s)), and i is a polarity. Our conditions do not guarantee that $\langle \text{Sit}(s), \leq\rangle$ is a lattice, however, let alone a distributive lattice. We have opted here for the comparatively weak conditions (i)–(iv) we have given, since they are all we need in this paper.

used to assert that there is no car owned by John anywhere in the world. There being no car owned by him in the local situation s is not enough to make the sentence true; if there happened to be a car he owned but which was not part of this situation, the sentence would still be false. It was with the intention to capture this intuition that we formulated (vi) the way we did. We wish to emphasize, however, that we do not offer this as a conclusive argument for defining negation as in (vi), but only as prima facie motivation. There are other ways to achieve this intuitive effect in situation semantics and we will come back to this point below.

The effect of (vi), we just observed, is to make negated sentences global in their semantic import: they describe the world, not the local situation. The logic going with this, one would expect, is classical logic, not the weaker logic associated with the partiality that is inherent in the description relation between utterances and situations. In fact, the logic generated by (i)–(vi) turns out to be a curious mixture of classical logic (for those DRSs in which all relevant components are in the scope of $\neg$) and a weaker partial logic (the by now quite well-known "Strong Kleene Logic") for the DRS for which this is not so.

An alternative that immediately comes to mind in a situation semantics is one that makes use of the part-of relation, $\trianglelefteq$, between situations. We assume a simple part-of relation such that

$$s \trianglelefteq s' \quad \text{iff} \quad \forall \sigma \, s \models \sigma \rightarrow s' \models \sigma$$

Using this notion we can formulate (vi.1).

(vi.1) If $\gamma = \neg K$, then ${}_s[\![\gamma]\!]_{g,lex}$ iff for no actual situation s' such that $s \trianglelefteq s'$, and no anchoring g', such that $g' \approx_{\mathrm{Dom}(env)-U_K} g$, ${}_{s'}[\![K]\!]_{g',lex}$

Interestingly, replacing (vi) by (vi.1) in the above definition does not alter the extension of the *describe* relation.

Let us define: $s \vdash^1_{g,lex} K$ iff ${}_s[\![K]\!]_{g,lex}$ according to clauses (i)–(v), (vi) and $s \vdash^2_{g,lex} K$ iff ${}_s[\![K]\!]_{g,lex}$ according to clauses (i)–(v), (vi.1). We first observe

(1) Each DRS K that does not contain any occurrences of $\neg$ is persistent, i.e., whenever $s \trianglelefteq s'$ and ${}_s[\![K]\!]_{g,lex}$, then ${}_{s'}[\![K]\!]_{g,lex}$. Evidently, this fact is independent of the choice between (vi) and (vi.1), since these clauses do not come into play for such K.
The relevant claim is proved by induction on the complexity of K; more precisely, we show by induction on K

(2) (a) for all K, s, g, lex,
(*) $s \vdash^1_{g,lex} K$ iff $s \vdash^2_{g,lex} K$.
(b) K is persistent. (Both as regards $\vdash^1$ and as regards $\vdash^2$; the two are by (a) indistinguishable!)

Base Case: for K $\neg$-free (*) is obvious.

Inductive Case:

(1) Suppose K has the form

$\langle\{\vec{x}\}C_1(\vec{x}_1),\ldots,C_n(\vec{x}_n),\neg K_1,\ldots,\neg K_m\rangle$

where $C_1(\vec{x}_1),\ldots,C_n(\vec{x}_n)$ are atomic conditions and $\neg K_1,\ldots,\neg K_m$ are all the complex conditions in Con_K. Suppose that $s \vdash^1_g K$ (we keep *lex* fixed throughout the argument and won't mention it explicitly). Then

(i) s supports $\langle\langle lex(C_i), g(\vec{x}_{i1}),\ldots,g(\vec{x}_{ik}); 1\rangle\rangle$ (with $i = 1,\ldots,n$ and k the length of the sequence x_i)

(ii) for no s' and no $g' \approx_{V-\vec{x}} g$, $s' \vdash^1_{g'} K_j$ $(j = 1,\ldots,m)$. Then by the induction hypothesis for no s' and no $g' \approx_{V-\vec{x}} g$, $s' \vdash^2_{g'} K_j$. So obviously for $s' \trianglerighteq s$ and $g' \approx_{V-\vec{u}} g$, $s' \vdash^1_{g'} K_j$. So by clause (vi′) $s \vdash^2_g K$.

(2) Suppose that $s \vdash^2_g K$. Then again

(i) above holds, together with

(ii) for no $s' \trianglerighteq s$ and no $g' \approx_{V-\vec{x}} g$, $s' \vdash^2_{g'} K_j$ $(j = 1,\ldots,m)$. So by the induction hypothesis for no $s' \trianglerighteq s$ and no $g' \approx_{V-\vec{x}} g$, $s' \vdash^1_{g'} K_j$. By persistence of K_j there is no actual situation s'' such that $s'' \vdash^1_{g'} K_j$. For suppose s'' were such a situation. Then for any actual situation s''' such that $s'' \trianglelefteq s'''$ and $s \trianglelefteq s'''$ $s''' \vdash^1_{g'} K_j$.
Since s and s'' are both actual situations, s''' exists and we have a contradiction. So we have shown for $j = 1,\ldots,m$ that there is no s' and no $g' \approx_{V-\vec{x}} g$ such that $s' \vdash^1_{g'} K_j$. It follows by (vi) that $s \vdash^1_g K$. □

The equivalence of $\vdash^1$ and $\vdash^2$ supports the claim made in Kratzer 1989 that her generic negation is persistent and independent of the situation described. Kratzer defines her generic negation semantically by a clause which formally resembles (vi.1) rather than (vi). So a proof of these claims seems called for. Exactly how to carry out such a proof on the basis of the semantics she develops is not straightforward, as the details of (something corresponding to) the relation of support—and thus of the verification or truth of atomic sentences by, or in, situations—is not made fully explicit. However, even if we assume that verification of atomic sentences is to be made precise along the lines assumed here (which, we believe, are consonant with the received views on this matter within situation semantics), some indispensable ingredient to the proof of Kratzer's claim is still missing.

In order to push the induction through we must consider not only negation but also each of the other operators which the object language may contain. In the proof just given we were spared this additional effort, as '¬' is the only operator for forming complex conditions that can be found in the DRS language we are studying. But in general things won't be that simple, and in particular for Kratzer, whose central concern is with counterfactual conditionals, a formalization of the language she studies would be bound to have additional operators. As our proof shows, these additional operators will not interfere with the argument as long as they preserve persistence. Indeed this is a property that Kratzer seems to want (and that seems to be warranted by the truth clauses for conditionals she proposes). So it may be presumed that an argument like the one we have just given would apply for her languages, too. Still it ought, we thought, to be pointed out that an argument is required.

Thus, somewhat surprisingly perhaps, the restriction in (vi.1) to extensions of the described situation s does not have any locality effect at all. So, if a local notion of negation is what we want we will have to try something else. The next characterization we consider is (vi.2) in which we still quantify over anchors, but in which the quantification over situations has been done away with.

(vi.2) If $\gamma = \neg K$, then ${}_s[\![\gamma]\!]_{g,lex}$ iff for no $g' \approx_{\mathrm{Dom}(g)-U_K} g$, ${}_d[\![K]\!]_{s,g',lex}$

This is like the previous definition except that there is no quantification over described situations. This, however, is not persistent in that situations of which s is a part could support infons required by K, i.e., K could describe situations parts of which could be described by $\neg K$. The previous version maintained persistence but at the expense of quantifying over all actual situations to make sure that there would be no larger situation which would support the offending infons. It is still the case that no negative information is required locally in the described situation, i.e., there is no requirement that any negative infons be supported.

This leads us to a third alternative which follows the lead of partial semantics as originally used by Kleene (1952). (For a more linguistic application see Kamp 1975). It uses a negative satisfaction relation, $[\![\,]\!]^-$, in addition to the satisfaction relation we have already used.

(vi.3) If $\gamma = \neg K$, then ${}_s[\![\gamma]\!]_{g,lex}$ iff for all g' such that $\mathrm{Dom}(g') = \mathrm{Dom}(g) \cup U_K$ and $g' \approx_{\mathrm{Dom}(g)-U_K} g$, ${}_s[\![K]\!]^-_{g',lex}$

Now, of course, we need to characterize $[\![\,]\!]^-$.

Definition of $[\![\,]\!]^-$.

(i) ${}_s[\![K]\!]^-_{g,lex}$ iff ${}_s[\![\gamma]\!]^-_{g,lex}$ for some $\gamma \in Con_K$

(ii) if $\gamma =$ '$x = y$', then ${}_s[\![\gamma]\!]^-_{g,lex}$ iff $g(x) \neq g(y)$

(iii) if $\gamma = \alpha(x)$ $(\alpha \in N)$, then ${}_s[\![\gamma]\!]^-_{g,lex}$ iff $g(x) \neq lex(\alpha)$

(iv) if $\gamma = \alpha(x)$ where $\alpha \in R_1$, then ${}_s[\![\gamma]\!]^-_{g,lex}$ iff $s \models \langle\langle lex(\alpha), g(x); 0\rangle\rangle$

(v) if $\gamma = x\alpha y$ where $\alpha \in R_2$, then ${}_s[\![\gamma]\!]^-_{g,lex}$ iff $s \models \langle\langle lex(\alpha), g(x), g(y); 0\rangle\rangle$

(vi) if $\gamma = \neg K$, then ${}_s[\![\gamma]\!]^-_{g,lex}$ iff ${}_s[\![K]\!]^-_{g',lex}$ for some g' such that $\mathrm{Dom}(g') = \mathrm{Dom}(g) \cup U_K$ and $g' \approx_{\mathrm{Dom}(g)-U_K} g$.

Now finally we have the presence of negative information in the described situation. It is required that the described situation support a negative infon in the case of clauses (iv) and (v). Thus we have persistence. We also have a doubly negated DRS describing exactly the same situations as the DRS without negation.

However, we have gained this at some expense. We have introduced two satisfaction relations and we seem to have partial semantics twice in the system: once with the satisfaction relations where we can talk of a DRS being positively or negatively satisfied by a situation or neither and once again in the situation theory where we can talk of a situation as settling an issue by supporting a positive or negative infon or not settling the issue. It seems that there is overkill in the system.

There is another potential problem. Consider the DRS corresponding to *John doesn't own a car*:

$$\begin{array}{|l|}\hline x \\ \hline \text{John}(x) \\ \neg \begin{array}{|l|}\hline y \\ \hline \text{car}(y) \\ \text{own}(x,y) \\ \hline\end{array} \\ \hline\end{array}$$

According to the present proposal, this DRS will only describe situations which support negative facts for all objects in the universe since we universally quantify over anchors. Thus again we have maintained persistence at some considerable expense. While we only have one situation, that situation is required to support a great deal of negative information and it seems unintuitive to require that somebody perceiving a situation supporting the information that John does not own a car should be aware of this large number of negative facts. For an example that seems to us to be particularly compelling, consider the sentence 'John does not have a child', and the situation s which supports the information that John is a one month old baby, peacefully asleep in his cot. Such a situation can surely support the information corresponding to the content of an utterance of this sentence without supporting information about every single human being in the world.[6]

One way that we could try to solve this problem is to use a negative parametric infon with a restricted parameter. Thus we could say that the

[6] The referee for this paper points out that this could be ameliorated by placing restrictions on the domain of quantification by limiting the domain of anchors provided for the DRS. While this would certainly be better than quantifying over all objects in the universe it still means that for every object provided by the context there would have to be a negative fact supported by the described situation. This still seems undesirable in a case where there might be a thousand relevant cars or where there is no obvious relevant context set as in the example 'John does not have a child'.

DRS corresponding to 'John doesn't own a car' describes a situation which supports the infon

$$\langle\langle \text{own}, \text{j}, \text{X} | \langle\langle \text{car}, \text{X}; 1\rangle\rangle; 0\rangle\rangle$$

We could place the following constraints on support for parametric infons.

1. If $\sigma(\vec{X})$ is a positive basic parametric infon with parameters $\vec{X}$ then

$$s \models \sigma(\vec{X}) \;\rightarrow\; \exists g \exists s' \in \text{Sit}(s)\, s' \models \sigma(\vec{X})[g]$$

2. If $\sigma(\vec{X})$ is a negative parametric basic infon with parameters $\vec{X}$ then

$$s \models \sigma(\vec{X}) \;\rightarrow\; \sim\exists g \exists s' \in \text{Sit}(s)\, s' \models \overline{\sigma(\vec{X})}[g]$$

We could introduce similar clauses for complex infons.

There are three problems with trying to pursue a solution along these lines. Firstly, there may be problems inherent in the notion of restricted parameters. (See Westerståhl 1990 for a discussion from the point of view of formalizing situation theory, and Cooper 1991 for a discussion from a more linguistic perspective.) Secondly, it is not currently standard to talk of parametric infons being supported, although unsaturated infons may be supported. However, nobody has to our knowledge suggested that unsaturated infons can have their argument roles restricted in the manner that it has been suggested that parameters can be restricted. Thirdly, and perhaps most importantly for the present discussion the DRT syntax does not provide us with an adequate base for deriving this infon since it does not distinguish the status of the two conditions that would lead to the restriction and the infon in which the restricted parameter occurs.

It may be thought that we can get around these problems by using quantified infons rather than parametric infons and relating the DRS under discussion to the infon

$$\overline{\exists x \langle\langle \text{car}, x; 1\rangle\rangle \wedge \langle\langle \text{own}, \text{j}, x; 1\rangle\rangle}$$

This would, of course, involve using a situation theory which allows such infons which are suspicious because they do not appear to be persistent. Given normal assumptions about duals this infon is identical with

$$\forall x \langle\langle \text{car}, x; 0\rangle\rangle \vee \langle\langle \text{own}, \text{j}, x; 0\rangle\rangle$$

If we wish to avoid problems with lack of persistence we might make use of our collections of coactual situations and say that a situation s supports this infon just in case

$$\forall x \in \text{Obj}(\text{Sit}(s))\;\; s \models \langle\langle \text{car}, x; 0\rangle\rangle \vee \langle\langle \text{own}, \text{j}, x; 0\rangle\rangle$$

i.e.,

$$\forall x \in \text{Obj}(\text{Sit}(s))\;\; s \models \langle\langle \text{car}, x; 0\rangle\rangle \text{ or } s \models \langle\langle \text{own}, \text{j}, x; 0\rangle\rangle$$

This means that our potentially local negation represented by the dual of an existentially quantified infon turns out to be local at the expense of introducing a large number of negative facts into the described situation. Thus in this respect a treatment along these lines would not improve on the Kleene negation represented by clause (vi.3) above.

Another way of trying to avoid this predicament is to use the other kind of quantified infons which is provided by situation theory, namely those whose relations are generalized quantifier relations with two argument roles for properties, as discussed, for example, in Gawron and Peters 1990, Richard Cooper 1991a, 1991b, and Cooper 1991. For the treatment of indefinites this would involve a return to the traditional view that indefinites are existential quantifiers (combined with some kind of E-type account in the spirit of Cooper 1976 and Evans 1980 to explain the recalcitrant facts about donkey pronouns that File Change Semantics and DRT explain via the "indefinites = free variables" assumption). On such a treatment a situation s will be described by a sentence such as

John owns a car.

if s supports an infon of the form $\langle\langle \text{Exist}, P, Q; 1\rangle\rangle$, where, roughly, P and Q are the properties of being a car and being something owned by John, respectively, and **Exist** is the generalized quantifier which holds between P and Q if their extensions have something in common. Similarly, s is described by

John doesn't own a car.

if it supports the corresponding negative infon $\langle\langle \text{Exist}, P, Q; 0\rangle\rangle$. If we treat generalized quantifiers along the lines suggested in Cooper 1991 then there need be no implication that a situation s that supports this negative infon also needs to support all the basic negative infons which we wish to avoid, although these infons would need to be supported somewhere in a coherent collection of situations including s. (For the purposes of this paper we can take coherent collections of situations as discussed in Cooper 1991 to correspond to the notion Sit(s) discussed here.)

To explore the implications of the proposal somewhat more closely, let us begin by looking in greater detail at its implications for a quantificational sentence which does not raise the problem of indefinites, say, (1).

(1) Every executive is happy.

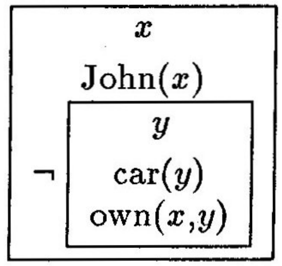
will describe a situation s in virtue, and only in virtue, of s supporting the fact that the property of being an executive is included in the property of being happy. Similarly,

Some executive is happy.

correctly describes s in virtue of s supporting the fact that the property of being an executive and the property of being happy overlap. In other words, the first sentence describes s in virtue of $s \models \langle\langle \text{Every}, P_1, Q_1; 1\rangle\rangle$

where P_1 and Q_1 are the relevant properties and the second describes s in virtue of $s \models \langle\langle \text{Exist}, P_1, Q_1; 0 \rangle\rangle$.

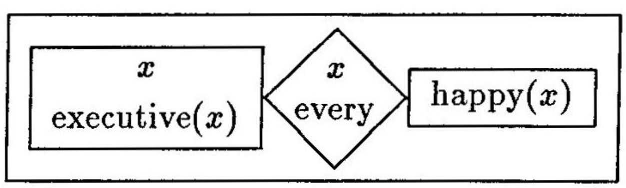
We can apply this proposal also to the *describe* relation for DRSs. For instance, for the DRS for *John doesn't own a car*,



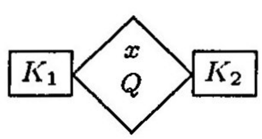
it entails that a situation s is described by it if there is an anchor a such that $a(x) = \text{John}$, $s \models \langle\langle \text{named}, \text{'John'}, a(x); 1 \rangle\rangle$ and $s \models \langle\langle \text{Exist}, P_2, Q_2; 0 \rangle\rangle$, where P_2 is the property of being a car and Q_2 the property of being owned by John.

It seems possible to hold that a situation might support this last infon without having to support, for each and every car c in the entire world, the negative infon $\langle\langle \text{own}, j, c; 0 \rangle\rangle$. This is not to deny that information directly supported by s might enable us to infer, for any car c that c is not owned by John. As standardly assumed in situation theory, we want to distinguish between information that is directly supported by a situation and further information that is implied by that information (in virtue of constraints), i.e., information that is *carried* by the situation but not supported by it.

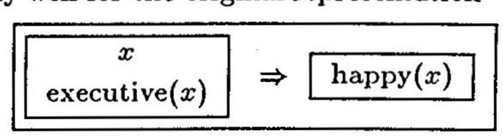
Before we can say any more about the constraints that are relevant in this connection, there are a number of issues that we must address first. To begin with, note that the present proposal seems particularly well suited to DRSs in which quantification is represented by a duplex condition, as in the following DRS for the sentence "Every executive owns a car".[7]



[7]This kind of representation, involving a so-called 'duplex condition'

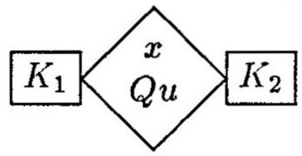


to represent the quantificational information of the sentence has been current in DRT for some time. (See Kamp and Reyle (forthcoming), Chapter 4). However, the point at issue now obtains equally well for the original representation



According to our proposal the duplex condition of this DRS describes s just in case s supports $\langle\langle \text{Every}, P_2, Q_2; 1\rangle\rangle$, where P_2 and Q_2 are the properties of being an executive and of being a car, respectively; and the same goes for the DRS itself. We can generalize this to duplex conditions of the general form given in footnote 7. A situation s is described by a duplex condition

(2)



relative to an anchor g and lexicon *lex* iff s supports an infon with the relation Qu, arguments P and Q (the properties determined by the DRSs K_1 and K_2) and polarity 1:

(3) $\quad {}_s[\![(2)]\!]_{g,lex}$ iff $s \models \langle\langle Qu, P, Q; 1\rangle\rangle$

In order that (3) may be considered as part of a compositional account of the *describe* relation, we must clarify how in general the properties P and Q are determined by K_1 and K_2. Trying to do this leads us to a number of issues in the comparison between DRT and situation semantics which we will point out here but not at this point attempt to resolve.

The first issue involves the use of complex infons. If we wish to represent a property corresponding to a DRS with conditions $C_1, \ldots, C_n$ obtained say by abstracting over a parameter X corresponding to a discourse referent x then the obvious candidates are properties such as

(4) a. $[X \mid s \models C_1 \wedge \ldots \wedge C_n]$
b. $[X \mid \models_{\mathrm{Sit}(s)} C_1 \wedge \ldots \wedge C_n]$
c. $[X, \mathrm{S} \mid \mathrm{S} \models C_1 \wedge \ldots \wedge C_n]$

defined in terms of the complex parametric infon $C_1 \wedge \ldots \wedge C_n$.[8] However, the careful reader will have noted that we have not used complex infons so far. This reflects the DR-theoretic intuition that "the building blocks of reality are simple," i.e., that the constituents of those structures—be they possible worlds, models or situations—in relation to which DRSs can be true, or verified or supported, correspond to atomic DRS conditions, but that the structures do not in general have constituents which correspond in a similar way to complex formulae or DRS conditions. Hence it might be regarded as undesirable to rely on a complex algebra of infons and properties in order to be able to account for the simple conditions in DRT.

A second issue involves the notion of resource situation. There is nothing in a DRS to determine which resource situation s should be used in the property (4a). We might elect to use the more general properties (4b)

[8]See Cooper 1991 for a simple characterization of the kinds of properties we are using here.

or (4c). But that would seem to preclude an essential feature of context dependence for quantified sentences. (See Cooper 1991, for more discussion.) One approach to this issue would be to say that the DRS itself, as an expression of a language, should not explicitly refer to a resource situation (after all, natural languages do not refer explicitly to resource situations). Rather the resource situation should be introduced by interpreting the DRS relative to a context which provides a resource situation. This might suggest that resource situations do not play any role in the kind of discourse phenomena which are treated in the construction of DRSs and this seems to us an open question.

A third issue involves the compositional use of the kind of *describe*-relation we have been defining. It is not obvious how to construct the properties (4) given our definitions. Rather what is suggested by this is the assignment of complex (conjunctive) infons as the situation theoretic interpretation of simple DRSs, from which then it would be straightforward to construct the properties. This raises the reservations about the relationship between complex infonic structure and simple DRS conditions which we noted above. In order to construct something appropriate in terms of description conditions it seems that we might be forced to use sets rather than properties, interpreting the abstraction over the discourse referent x in DRS K as something like

$$\{a \mid \exists g(\mathrm{Dom}(g) = \mathrm{U}_K \cup \{x\} \wedge g(x) = a \wedge {}_s[\![K]\!]_{g,lex})\}$$

However, the remarks about resource situations apply equally to this proposal.

It is now time to remember that the reason we had for bringing up this discussion had to do not with duplex conditions (or the sentences thereby represented) but with negative existentials such as 'John doesn't own a car'. Unfortunately, standard DRT does not represent such sentences or their unnegated counterparts with the help of duplex conditions. For instance, (5)

(5) John owns a car.

is represented, in line with the DRT thesis that "indefinites act as free variables" as

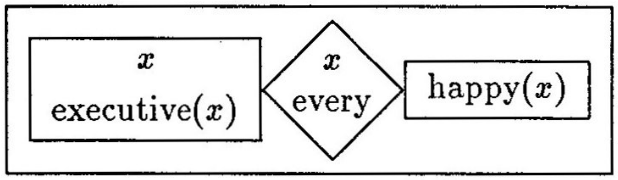
(6)

x y
John(x)
car(y)
owns(x,y)

Applying the kind of proposals we have been discussing to a DRS of this form is problematic because the DRS does not tell us which of its parts contribute to the characterization of the property P and which to that of the property Q. For example, the proposal is meant to yield that s is described by the sentence (5) iff s supports the infon

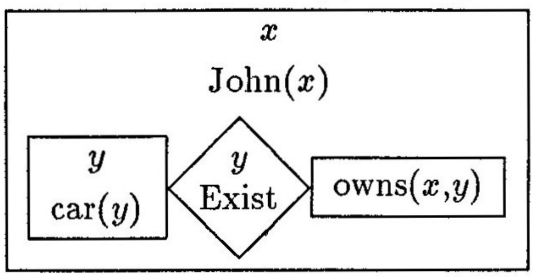
$$\langle\langle \text{Exist}, [\text{Y} \mid s_r \models \langle\langle \text{car}, \text{Y};\ 1\rangle\rangle], [\text{y} \mid \models_{\text{Sit}(s)} \langle\langle \text{own}, \text{j}, \text{y};\ 1\rangle\rangle];\ 1\rangle\rangle$$

(where **j** is the referent of the given use of 'John'). But how is this infon to be reconstructed from (6)? What tells us that the property of being a car is to become the first property and that of being owned by **j** part of the second? With DRSs for quantifying NP's involving other determiners, such as for instance *every*, this problem does not arise. For instance, the DRS of *Every executive is happy* has the form



Here the conditions that identify restrictor and nuclear scope are formally separated, and so a systematic identification of the properties P and Q is straightforward. To guarantee an unambiguous interpretation of the DRSs representing existential information we need a similar representation, involving something like duplex conditions for sentences containing indefinites. For instance, for (5) we ought to have some such DRS as

(7)

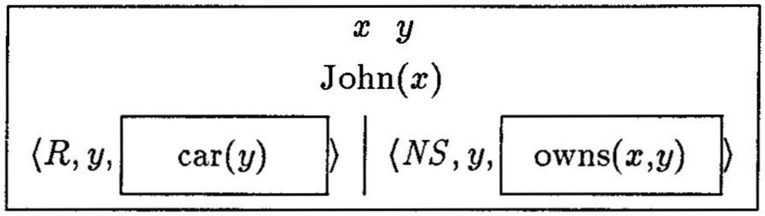


To represent indefinites along these lines means giving up on DRT's original explanation of donkey anaphora. For now it has become quite opaque why the discourse referents introduced by indefinites should be available to pronouns in cases where those introduced by quantifying NPs such as those beginning with *every* are not. We should note in this connection, however, that that original account has been much under attack recently.[9] In the light of these recent criticisms representations of indefinites along the lines of (7) now appear a good deal more defensible than they seemed four or five years ago; rather different principles are then to be held responsible for the distinct anaphoric properties of **a**-phrases and **every**-phrases.

Even if we retained the original principle according to which indefinites introduce discourse referents at their "own" levels, it would of course be possible to refine DRS-structure in such a way that a DRS for a sentence containing an indefinite NP directly encodes the information needed to separate its material into restrictor and nuclear scope. For instance, we

[9] See, e.g., Kadmon 1987, 1990, Heim 1990, Chierchia 1991, Neale 1990.

could simply mark the two sets of conditions as belonging to the restrictor and the nuclear scope of the relevant discourse referents, as in



This looks very much like a paradigm case of eating one's cake and having it, without bothering to give a justification for either.

A proposal along these lines may well come to look a good deal less ad hoc, however, if it could be embedded within a more general account of how utterance material is to be divided into that which contributes to the topic and that which contributes to the comment. Admittedly the topic-comment distinction is still in need of substantial clarification at the conceptual and methodological level, and consequently a detailed theory of how utterances are divided into topic and comment may still be a long way off. But it is nevertheless evident that the distinction—whatever it may come to precisely—is crucial to the explanation of a considerable variety of linguistic phenomena, especially those relating to discourse and text. For the further development of a theory such as DRT, with its commitment to confront precisely those aspects of semantics, a viable topic-comment theory is therefore an eventual must. If and when a thus revised DRT will be in place, the question of how to represent indefinites will have to be assessed again.

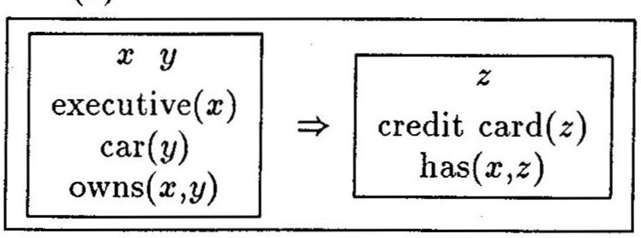
In what follows we will ignore the present problem and simply assume that the parts of a given DRS that identify restrictor and nuclear scope of the infons of the form $\langle\langle \text{Exist}, P, Q; i \rangle\rangle$ can somehow be recognized as such.

The second problem relates, as we said, also to DRT's treatment of indefinites as variables. It is a problem that does not arise for the sentences we have so far considered, but it does arise for a sentence such as

(8) If an executive owns a car he has a credit card.

The DRS for (8) is

(9)



Here we have a universal quantification over two variables, not one. What would it be for this condition (or, if you prefer, the DRS (9) which consists of this condition only) to describe the situation s? Again, if we stand by our present proposal, s should support a corresponding infon. But which infon? The structure of (9) suggests that its constituents ought to be (i) the *relation* that holds between x and y when x is an executive, y is a car and x owns y, (ii) the *relation* which holds between x and y if x owns a credit card, and (iii) the *polyadic* quantifier **Every** which holds between two binary relations R and S if the extension of the former is included in that of the latter.

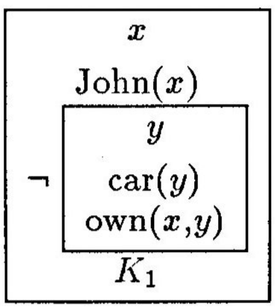
It would be unproblematic to admit such polyadic quantifiers. However, doing so would involve a certain amount of work and would distract from the issues that interest us here. An alternative where indefinites are treated as generalized quantifiers might be obtained by extending the kind of quantification over situations introduced in Cooper 1991 to the analysis of conditionals. Here we merely note the problem as one for further investigation.

At last, we return to the sentence which prompted this long excursus into the treatment of quantification, namely,

(10) John doesn't own a car.

with its DRS

(11)



According to the proposal now before us, (11) describes s, in an environment of which we may assume that it anchors x to the actual referent j of 'John' iff

$s \models \langle\langle \text{named}, \text{'John'}, x;\ 1\rangle\rangle$ and
$s \models K$ iff $s \models \langle\langle \text{named}, \text{'John'}, x;\ 1\rangle\rangle$ and
$s \models \langle\langle \text{Exist}, [\text{Y} \mid s_r \models \langle\langle \text{car}, \text{Y};\ 1\rangle\rangle], [\text{Y} \mid \text{Sit}(s) \models \langle\langle \text{owns}, \text{j}, \text{Y};\ 1\rangle\rangle];\ 0\rangle\rangle$

We have not yet discussed veridicality of the support relation for such negative infons, but the implications of what has been said above are clear: s supports the infon $\langle\langle \text{Exist}, P, Q;\ 0\rangle\rangle$ if there is *no* overlap in extension between P and Q; more explicitly if there is no object $b \in \text{Ind}(\text{Sit}(s))$ such that $s_r \models \langle\langle \text{car}, b;\ 1\rangle\rangle$ and $\models_{\text{Sit}(s)} \langle\langle \text{owns}, \text{j}, b;\ 1\rangle\rangle$. Alternatively, we may take the dual condition: for every object $b \in \text{Ind}(\text{Sit}(s))$ such that $s_r \models \langle\langle \text{car}, b;\ 1\rangle\rangle$ and $\models_{\text{Sit}(s)} \langle\langle \text{owns}, \text{j}, b;\ 0\rangle\rangle$.

It should be kept in mind in this connection that the analysis we have proposed here does *not* entail that an utterance of (10) can only be true if there is no car anywhere in the world that is owned by John. The resource situation s_r could restrict the cars that (10) excludes from being owned by John in any one of a number of ways.

For instance, there might be uses of (10) in which the resource situation restricts the range of the existential quantifier to cars in the United Kingdom; when used this way (10) asserts that there is no car in Britain which John owns. If it happens nevertheless that he owns a car in the US—say, one which he left with friends upon his permanent return to Europe a couple of years earlier—this would not count against the statement being true. (Admittedly, with the verb *own*, such restricted uses appear marginal.)

The role of resource situations in the semantics of quantified utterances holds a particular significance in the context of the juxtaposition of situation semantics and DRT that is our general concern in this paper. For this is one of the points on which the two theories suggest distinct mechanisms for dealing with the same phenomenon. The treatment of contextual restriction of quantificational domains within DRT is something that is treated in connection with the analysis of plurals by Kamp and Reyle (forthcoming), Chapter 4.

5 Conclusion

Except for the issue concerning the treatment of indefinites, the analyses of negation that we have presented could be seen as independent of DRT since they might arise if one tried to provide a situation semantics for predicate logic or some fragment of English with negation in the conservative style that we explored. Thus the main conclusion that we draw concerning the relationship between DRT and situation semantics is that if we are to maintain the 'indefinite as variable' idea of DRT (or classical situation semantics) and use a partial semantics in the style of situation semantics, then it seems that we have either to give up the notion of persistence and with it the notion that all negative sentences in natural language correspond to the presence of negative information as opposed to the lack of positive information or we may have to countenance the possibility that certain negative DRSs do not express "local" information in that they only describe situations which support negative facts about a whole universe of individuals. However, if we return to Montague's proposal that indefinites correspond to generalized quantifiers then we may have a partial semantics that allows "local" negation which is persistent.

It is difficult to make this into a general result about partial semantics for quantification and negation. However, it seems to us that it holds true for some of the standard tools available in DRT and situation semantics. It remains an open question whether there is not some variant of the 'indefinite as variable' analysis or of partial semantics that would allow us to have the best of both worlds.

An interesting suggestion for such a variant was made by the referee of this paper. The idea would be to use a quantifier relation **exist** which has just one argument role for a property or relation of any number of arguments. Intuitively the relation **exist** would hold just in case the relation has a non-empty extension. A DRS would then correspond to such an existential infon where the relation abstracts over parameters corresponding to the domain of the DRS. A conjunction of infons corresponding to the conditions of the DRS would provide the body of the relation. There are two ways in which we could begin to implement this suggestion. We could say that a DRS of the form

$$\boxed{\begin{array}{c} X_1, \ldots, X_n \\ C_1 \\ \vdots \\ C_m \end{array}}$$

describes a situation s iff

$$s \models \langle\langle \text{exist}, [X_1, \ldots, X_n \mid s \models C_1 \wedge \ldots \wedge C_m]; 1 \rangle\rangle$$

Alternatively we could say that this DRS describes a situation s iff

$$s \models \langle\langle \text{exist}, [X_1, \ldots, X_n \mid \models_{\text{Sit}(s)} C_1 \wedge \ldots \wedge C_m]; 1 \rangle\rangle$$

A problem with this approach seems to be that we need the second of the two alternatives for negative cases and the first alternative for positive cases. Thus we might want to require that the DRS (11) describes a situation s just in case

$$s \models \langle\langle \text{exist}, [\text{X} \mid \models_{\text{Sit}(s)} \langle\langle \text{car}, \text{X}; 1 \rangle\rangle \wedge \langle\langle \text{own}, \text{j}, \text{X}; 1 \rangle\rangle]; 0 \rangle\rangle$$ [10]

However, we would want the positive DRS (6) to describe a situation s according to the first alternative, i.e., iff

$$s \models \langle\langle \text{exist}, [\text{X} \mid s \models \langle\langle \text{car}, \text{X}; 1 \rangle\rangle \wedge \langle\langle \text{own}, \text{j}, \text{X}; 1 \rangle\rangle]; 1 \rangle\rangle$$

unless we were to give up the locality of any infons corresponding to the individual conditions of a DRS. Nevertheless, it seems like this suggestion might be an important direction in which to go, not least because it moves us closer to providing a situation theoretic object corresponding to a DRS (namely the quantified infon with relation **exist**). The idea would thus get us closer to the second approach mentioned in the introduction to this paper, that of modeling DRSs as situation theoretic objects. However, as with the discussion of properties above, it has the disadvantage of relying on complex infonic structure to deal with simple DRS conditions.

We hope at least that the discussion in this paper shows that it would be dangerous to assume that an appropriate partial semantics for indefinites as

[10] Or perhaps something which makes the embedded structure explicit like

$$\begin{aligned} & s \models \langle\langle \text{exist}, T_y; 1 \rangle\rangle \quad \text{where} \\ & \quad T_y = [\text{Y} \mid \models_{\text{Sit}(s)} \langle\langle =, \text{Y}, \text{j}; 1 \rangle\rangle \wedge \langle\langle \text{exist}, T_x; 0 \rangle\rangle] \\ & \quad T_x = [\text{X} \mid \models_{\text{Sit}(s)} \langle\langle \text{car}, \text{X}; 1 \rangle\rangle \wedge \langle\langle \text{own}, \text{j}, \text{X}; 1 \rangle\rangle] \end{aligned}$$

free variables can be obtained in a straightforward manner—an assumption that was perhaps made in classical situation semantics as put forward by Barwise and Perry 1983.

References

Barwise, J., and J. Etchemendy. 1990. Information, Infons, and Inference. In Cooper et al. 1990.

Barwise, J., and J. Perry. 1983. *Situations and Attitudes.* Cambridge, MA: MIT Press.

Chierchia, G. 1991. Anaphora and Dynamic Logic. In *Quantification and Anaphora I.* DYANA Deliverable R2.2.A, ed. M. Stokhof, J. Groenendijk, and D. Beaver. Edinburgh University: Centre for Cognitive Science.

Cooper, R. P. 1991a. *Classification-Based Phrase Structure Grammar: an Extended Revised Version of HPSG.* PhD thesis, University of Edinburgh.

Cooper, R. P. 1991b. Persistence and Structural Determination. This volume.

Cooper, R. n.d. Introduction to Situation Semantics. In preparation.

Cooper, R. 1989. Information and Grammar. Research Paper 438, Department of AI, University of Edinburgh.

Cooper, R. 1991. Three Lectures on Situation Theoretic Grammar. In *Natural Language Processing: EAIA 90 Proceedings.* Lecture Notes in Artificial Intelligence, no. 476, ed. M. Filgueiras, L. Damas, N. Moreira, and A. P. Tomás, 101–140. EAIA, Springer-Verlag.

Cooper, R., K. Mukai, and J. Perry (ed.). 1990. *Situation Theory and Its Applications,* vol. 1. CSLI Lecture Notes Number 22. Stanford: CSLI Publications.

Evans, G. 1980. Pronouns. *Linguistic Inquiry* 11(2):337–362.

Fenstad, J. E., P.-K. Halvorsen, T. Langholm, and J. van Benthem. 1987. *Situations, Language and Logic.* Dordrecht: Reidel.

Filgueiras, M., L. Damas, N. Moreira, and A. P. Tomás (ed.). 1991. *Natural Language Processing: EAIA 90 Proceedings.* Lecture Notes in Artificial Intelligence no. 476. Springer Verlag.

Gawron, J. M., and S. Peters. 1990. *Anaphora and Quantification in Situation Semantics.* CSLI Lecture Notes Number 19. Stanford: CSLI Publications.

Groenendijk, G., T. Janssen, and M. Stokhof (ed.). 1981. *Formal Methods in the Study of Language.* Amsterdam: Mathematisch Centrum.

Groenendijk, G., and M. Stokhof. 1989. Dynamic Montaque Grammar: A First Sketch. Prepublication Series X-89-04, ITLI.

Heim, I. 1990. E-Type Pronouns and Donkey Anaphora. *Linguistics and Philosophy* 13(2):137–177.

Kadmon, N. 1987. *On Unique and Non-Unique Reference and Asymmetric Quantification.* PhD thesis, University of Massachusetts, Amherst.

Kadmon, N. 1990. Uniqueness. *Linguistics and Philosophy* 13(3):273–324.

Kamp, H. 1975. Two Theories About Adjectives. In *Formal Semantics of Natural Languages,* ed. E. Keenan. Cambridge: Cambridge University Press.

Kamp, H. 1981. A Theory of Truth and Semantic Representation. In *Formal Methods in the Study of Language*, ed. G. Groenendijk, T. Janssen, and M. Stokhof. Amsterdam: Mathematisch Centrum.

Kamp, H., and U. Reyle. n.d. From Discourse to Logic. Forthcoming from Reidel.

Kleene, S. 1952. *Introduction to Metamathematics*. Princeton, NJ: D. van Nostrand.

Muskens, R. 1989. *Meaning and Partiality*. Academisch Proefschrift, University of Amsterdam.

Neale, S. 1990. Descriptive Pronouns and Donkey Anaphora. *Journal of Philosophy* 87(3):113–150.

Sem, H. 1987. Discourse Representation Theory, Situation Schemata and Situation Semantics: A Comparison. Cosmos Report 2, Department of Mathematics, University of Oslo.

Stokhof, M., J. Groenendijk, and D. Beaver (ed.). 1991. *Quantification and Anaphora I*. DYANA Deliverable R2.2.A. Edinburgh University: Centre for Cognitive Science.

Westerståhl, D. 1990. Parametric Types and Propositions in First-Order Situation Theory. In Cooper et al. 1990.