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SEMANTICS AND PROPERTY THEORY

1. Desiderata for a Theory of Properties

The nature of properties, relations and propositions has always been at the heart of philosophical debate. Among other things, they have played a central role in theories of intensionality, belief, universals and in the analysis of the attitudes. In fact, it does not seem unwarranted to claim that most of the entities that populate philosophical debates are ultimately analyzable through constructs which crucially rely upon properties and propositions.

The aim of this paper is to develop a theory of properties, relations and propositions which will support, in a strong sense, the semantics of natural language. By that we mean that a semantics built on such a theory of properties should mesh well with (what is known about) syntax, help explaining why predicative expressions in English and other languages behave the way they do, and constitute, on this score, an improvement over purely set-theoretic semantics (such as, e.g., Montague's).

The idea that semantics provides a fundamental testing ground for a property theory is based on the assumption that properties are the semantic counterparts of natural language predicative expressions. So, for example, the sentence *John runs* says of John that he has or instantiates the property of running. This much seems uncontroversial. If we take it seriously, however, it seems to follow that the behavior of predicative expressions in natural language should constitute a primary source of evidence as to the nature of properties. This of course does not imply that other sources of evidence should be discarded. Nor does it imply that we take properties to exist just as semantic values, shadows of predicative expressions. But we think that the richness of predicative constructions in natural languages can shed significant light on the nature of properties, since the bulk of our pretheoretical intuitions about the latter seems to stem from the former.

The present paper is organized as follows. In the rest of this introduction we shall outline some general desiderata that we think a theory of properties should meet. In Section 2 we will present the syntax and semantics of a multi-sorted first order theory of properties. In Section 3

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we discuss the roles of types (versus sorts) in semantics, as a preliminary to developing a semantic application of our theory. In Section 4, we develop a grammar of English based on our multisorted property theory. Finally, in Section 5, we discuss some aspects of the property theoretic semantics developed in Section 4 and compare it with other approaches.

1.1. *Closure Under the Logical Connectives and Quantifiers*

One important aspect of the behavior of natural language predicative expressions concerns the apparent fact that such expressions are closed with respect to the logical connectives. Using various devices (such as verb-phrase conjunction and disjunction or relative clause formation) we can form predicative expressions of indefinite complexity. So, for example, whatever prompts us to say that the meaning of *John runs* is built by attributing a property to an individual, should also apply to *John runs and juggles simultaneously* or *John plays the violin or listens to the radio*. The first desideratum of our theory is a simple statement of this observation:

(1) The class of properties is closed with respect to the logical connectives

This view is quite traditional. In most, if not all formal theories of properties a similar desideratum is adopted. We shall spell out the exact content of this requirement shortly.

1.2. *Intensionality*

The second plank in our theory concerns difficulties which arise in the traditional analysis of intensional notions. Such difficulties can be observed with particular perspicuity if one considers a possible world analysis of such notions. According to the proponents of such a view, intensional notions can be analysed using possible worlds: properties are represented as functions from worlds into sets and propositions as functions from worlds into truth-values. Various elaborations and refinements of this simple idea have generated a series of by now classical theories of modal and intensional matters. These have been integrated into a program of systematic elaboration of the semantics of natural languages carried on most prominently within what has become known as Montague semantics.

This approach has been quite successful. Moreover, good arguments have been given in favour of analysing propositions, at some level, as sets of worlds, in spite of apparent evidence to the contrary (e.g. Stalnaker, 1985). However most researchers admit that such an analysis just cannot stand alone.

As far as properties are concerned, the view that they can be analyzed as functions from worlds into sets is at odds with the following intuition:

(2) Two properties can be logically equivalent without being identical entities.

For example, given what *buy* and *sell* mean, it is necessarily the case that something is sold iff it is bought. Should it follow from this that being bought and being sold are the same property? We think not. This point has been made by many others (e.g. Thomason (1980), Bealer (1982), Jubien (1985)). We believe that the intensional character of properties and propositions (or, as we prefer to say, "information units") should be taken at face value. While the notion of possible world is a fundamental one, marrying it with classical set theory to generate properties results in an insufficiently intensional notion of property.

1.3. *Self-predication*

A third and perhaps more controversial desideratum that we wish to maintain is that, unlike sets, in the traditional Zermelo-Fraenkel formalization, properties are not well-founded. That is

(3) Properties can be truly predicated of themselves.

Various arguments have been proffered in favour of (3). For example, in Parsons (1979) we find the following argument:

(4) Everything has the property of being autoidentical
———————————————————————
The property of being autoidentical has the property of being autoidentical.

If the argument is valid, as it intuitively seems, being autoidentical is a property that is truly predicable of itself. Other cases of self attribution of properties seem to arise in the analysis of iterated or mutual belief (see e.g. Cresswell (1985)), the semantics of perception (Barwise and Perry (1983)) and in the analysis of certain kinds of gerunds and other nominalization phenomena in natural language (Chierchia (1982, 1985)).

In general, there might be good reasons according to certain notions of set (e.g. the iterative conception – see Boolos (1971)), for demanding that sets cannot belong to themselves. But we see no reason to impose such a requirement on properties. Indeed we have sketched some reasons not to do so.

To develop a useful theory which meets desiderata (1) and (3) is not a trivial task – one immediately encounters a property which holds of everything that does not hold of itself. The development of a theory which meets such desiderata thus faces problems of various kinds. From our perspective we are presented with a twofold task. On the one hand, we require a theory of properties rich enough to offer a semantic analysis of any predicative expressions in natural language, including those which encapsulate the various versions of Russell's property. This is a fairly complex descriptive goal. Secondly, intertwined with such a goal, there is a normative or prescriptive task still. For, while we have clear intuitions about simple clauses (e.g. x has the property of running and chewing gum iff x has the property of running and x has the property of chewing gum), we do not have sharp intuitions when something like Russell's property is thrust upon us. Does such a property hold of itself or not? Dealing with such shaky intuitions, one has little choice; one can only let the theory decide the matter. In this regard, a theory of properties faces difficulties similar to those faced by a theory of truth in connection with the so-called semantic paradoxes.

1.4. *A "Fregean" Perspective*

Here is one of the many possible ways in which one can go about designing a theory of properties that meets the desiderata in (1)–(3). One can say that properties have two roles or exist in two guises. On the one hand they are intrinsically "incomplete" or "unsaturated" structures. An act of predication is the "completion" or "saturation" of these structures. The result of such an act is a proposition or, as we prefer to say, an information unit. Qua unsaturated structures, properties are not individuals and cannot saturate other properties. We will call these unsaturated structures "information unit functions" (by analogy with the concept of "propositional function").

On the other hand, properties also have an individual nature and as such can play the role of subjects in acts of predication. One can represent this by positing individuals that are systematically correlated with information unit functions. In other words, information unit functions have images among the individuals. When we use an information unit function as a subject in an act of predication (i.e. when we nominalize it) we purport to refer to the individual correlate of such function.

Perhaps, this can be made clearer in terms of a natural language example. Consider *runs* as in *John runs*. *Runs* is something that cannot stand by itself. It is an incomplete structure. We would say that its semantic value is an information unit function. However *runs* is morphologically related to *running* as in *running is fun*. *Running* is a noun phrase, just like *John*. And like the latter, we take it, it denotes an individual: the individual correlate of the information unit function associated with *runs*.

This view of properties is inspired by Frege's (1892) distinction between "concepts" and "objects" and therefore, we call it "Fregean".[1] Its importance in developing formal theories of properties has been emphasized recently in Cocchiarella's work (see e.g. Cocchiarella (1985)).

As pointed out above, there are other approaches one can take. For example, one can take properties to be simply a special sort of individuals. Such individuals can be predicated of other individuals by resorting to a predication relation, call it π. "x has property y" or, perhaps, "xy's" would be expressed as "$\pi(x, y)$". Several theories of the latter kind, based on a predication relation π, have been developed (see e.g. Aczel (1980), Bealer (1982) and Jubien (1985)). Looking at natural language from this perspective, it would seem that something like *John runs* should be represented as $\pi(j, \text{run})$. And something like *running is fun* might be represented as $\pi(\text{run}, \text{fun})$. This seems to suggest that in spite of the apparent diversity in syntactic roles of *runs* versus *running*, these expressions denote the same type of semantic object, namely the type of individuals. Perhaps, they even denote the same individual. On this view, the different morphological shapes of the two expressions in question simply marks which slot of the predication relation the property "run" happens to occupy.

Prima facie, the two rough pictures that we have sketched appear to embody rather different conceptions of what properties are. In fact, the theories that have been previously proposed as a formal explication of these views appear to be quite different (compare, for example, Cocchiarella (1985) versus Bealer (1982)). We think that natural language semantics strongly supports what we call the "Fregean" perspective over the other view and a detailed argument to this extent will be provided in Section 5.2. Accordingly, our theory is designed to embody the "Fregean" view.

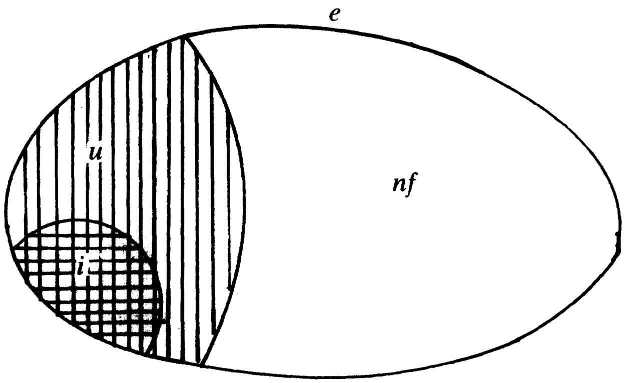
2. A THEORY OF PROPERTIES, RELATIONS AND PROPOSITIONS

The theory that we are going to present (which we shall call PT_1) has several direct sources. For the axiomatic part, it is based on Gilmore (1974) and Feferman (1984). Its model theory stems directly from the work of Aczel (1980), Herzberger (1982) and Gupta (1982). A thorough discussion of its more technical aspects can be found in Turner (1987a, b).

2.1. *The Syntax of PT_1*

The language of PT_1 is a multisorted first-order language[2] with four basic sorts: *u*, *nf*, *i*, *e*. *u* is the sort of "urelements", or basic individuals. *nf* is the sort of nominalized functions, *i* is the sort of information units, and *e* is the sort of individuals (which includes urelements, nominalized functions and information units). So *e* (which is a mnemonic for "entity") is the universal sort. We assume, furthermore, that information units are urelements. This can be pictured as follows:

(1)



The only complex sort of the language is $\langle e, e\rangle$, the sort of functions from individuals to individuals. The language contains the λ-operator, a nominalization operator '$^\cap$' that turns functions into individuals (nominalized functions) and a predication operator '$^\cup$' that turns nominalized functions (back) into functions.

We now define recursively, for any sort α, the set ME_α of meaningful expressions of sort α. We assume that if $\alpha = e$, i, u, or nf, Var_α is a denumerable set of variables of sort α. If α is any sort, $Cons_\alpha$ is a set of constants of sort α (i.e., we don't have variables of sort $\langle e, e\rangle$).

(2)i. $Var_\alpha, Cons_\alpha \subseteq ME_\alpha$.

ii. If $t \in ME_e$ and $x \in Var_e$, $\lambda x[t] \in ME_{\langle e, e\rangle}$.

iii. If $t \in ME_{nf}$, $^\cup t \in ME_{\langle e, e\rangle}$.

iv. If $f \in ME_{\langle e, e\rangle}$, $^\cap f \in ME_{nf}$.

v. if $f \in \mathrm{ME}_{\langle e, e\rangle}$ and $t \in \mathrm{ME}_e$, $f(t) \in \mathrm{ME}_e$.
vi. $\mathrm{ME}_i \subseteq \mathrm{ME}_u$; ME_u, $\mathrm{ME}_{\mathrm{nf}} \subseteq \mathrm{ME}_e$.
vii. If $t \in \mathrm{ME}_e$, ${}^{\dagger}t \in \mathrm{ME}_i$
viii. If ψ, $\phi \in \mathrm{ME}_i$, t, $t' \in \mathrm{ME}_e$, and $x \in \mathrm{Var}_\alpha$, for any basic sort α, then $(t = t')$, $\neg\psi$, $(\psi \vee \phi)$, $(\psi \,\&\, \phi)$, $\exists x(\psi)$, $\forall x(\psi)$, $(\psi \rightarrow \phi)$, $(\psi \leftrightarrow \phi)$ are all in ME_i.

We adopt the standard definitions of bondage and freedom for variables. We write $\alpha(t/x)$ for the result of substituting t for x in α. The basic device that forms information units is the operator '$\dagger$'. This operator applies to any member of ME_e. It can be thought of as a truth-predicate. '${}^{\dagger}t$' asserts the truth of t. The language maintains that we can attribute truth to anything. Intuitively, attributing '$\dagger$' to information units will amount to claiming their truth, while attributing it to things like, say, my cat (i.e. to say "my cat is true") is going to result in an information unit that will be necessarily false.

Perhaps it is useful to give an example of a few well formed expressions of various sorts. $x_{n,r}$ is the nth variable of sort r and $c_{n,r}$ is the nth constant of sort r. To enhance readability, subscripts and parentheses will be omitted when no confusion is likely to arise.

(3)

$x_e = x_{\mathrm{nf}}$	i
$\neg(x_e = x_{\mathrm{nf}}) = x_i$	i
$c_{1,\langle e,e\rangle}(\neg(x_e = x_{\mathrm{nf}}))$	e
${}^{\dagger}c_{1,\langle e,e\rangle}(\neg(x_e = x_{\mathrm{nf}}))$	i
$\lambda x_e[{}^{\dagger}c_{1,\langle e,e\rangle}(\neg(x_e = x_{\mathrm{nf}}))]$	$\langle e, e\rangle$
${}^{\cap}\lambda x_e[{}^{\dagger}c_{1,\langle e,e\rangle}(\neg(x_e = x_{\mathrm{nf}}))]$	e
$\lambda x_{1,e}[{}^{\cap}\lambda x_{2,e}[\exists x_{\mathrm{nf}}(x_{1,e} = x_{\mathrm{nf}} \,\&\, {}^{\dagger\cup}x_{\mathrm{nf}}(x_{2,e}))]]$	$\langle e, e\rangle$
$\lambda x_e[x_e = x_e]$	$\langle e, e\rangle$
$\lambda x_e[\exists x_{\mathrm{nf}}(x_{\mathrm{nf}} = x_e \,\&\, \neg{}^{\dagger\cup}x_{\mathrm{nf}}(x_{\mathrm{nf}}))]$	$\langle e, e\rangle$,

The antepenultimate expression in (3) shows how the language allows for multiple abstraction.[3] Such an expression is a function that applied to a y gives us an object that applied to z returns an information unit. Such an information unit would be, intuitively true just in case y is a property that z has. Thus the function in question is another way to express predication. The penultimate expression expresses a universal property and the last expression in (3) expresses, essentially, Russell's property.

2.2. *The Axiomatic Theory*

The theory has two main components. The first governs abstraction and application. The principles that we adopt concerning abstraction and application are simply the standard axioms of the λ-calculus. In particular we assume that full λ-conversion holds:

(1) $\lambda x[t](t') = t(t'/x)$

The second component concerns the logic proper and, in the present setting, actually takes the form of a theory of truth. In what follows, ψ and ϕ range over information units.[4]

(2)i. $^{\dagger}\psi$, where ψ is a tautology
ii. $\psi \rightarrow {^{\dagger}\psi}$, ψ atomic i.e. of the form $^{\dagger}\beta(\alpha)$ (S4)
iii. $^{\dagger}\psi \rightarrow \psi$ (T)
iv. $(\forall x\, {^{\dagger}\psi} \rightarrow {^{\dagger}(\forall x \psi)})$ (Barcan)
v. $(^{\dagger}\psi \;\&\; {^{\dagger}(\psi \rightarrow \phi)}) \rightarrow {^{\dagger}\phi}$ (IMP)
vi. $^{\dagger}(\neg {^{\dagger}\psi}) \leftrightarrow {^{\dagger\dagger}\neg\psi}$

The guiding idea underlying this axiom system is that truth arises from a revision process, along the lines suggested in Herzberger (1982) and Gupta (1982). One starts out by evaluating simple formulae in a base model. Formulae containing the truth predicate are evaluated in stages: one evaluates $^{\dagger}\psi$ in a model M_n, by looking at the value of ψ in M_{n-1}. Formulae that contain vicious occurrences of the truth predicate will indefinitely oscillate in truth value. However, at a certain ordinal all the sentences that eventually stabilize in truth value do so. These are the models that establish the consistency of the theory. The axioms in (3) characterize the formulae that are valid in every "stable" model. The logic of predication (i.e. the logic of information unit functions) is then simply lifted from (3) via the λ-operator.

One can gain further insight as to the working of the system by looking at what happens when, say, we apply Russell's property to itself:

(3) $^{\dagger}\lambda x_e[\exists x_{\rm nf}(x_{\rm nf} = x_e \;\&\; \neg {^{\dagger\cup}x_{\rm nf}}(x_{\rm nf}))]$
$({^{\cap}\lambda x_e}[\exists x_{\rm nf}(x_{\rm nf} = x_e \;\&\; \neg {^{\dagger\cup}x_{\rm nf}}(x_{\rm nf}))])$

In virtue of (1), (3) is identical with

(4) $^{\dagger}\exists x_{\rm nf}(x_{\rm nf} = {^{\cap}\lambda x_e}[\exists x_{\rm nf}(x_{\rm nf} = x_e \;\&\; \neg {^{\dagger\cup}x_{\rm nf}}(x_{\rm nf}))]$
$\;\&\; \neg {^{\dagger\cup}x_{\rm nf}}(x_{\rm nf}))$

which by elementary tautologous transformations is equivalent to

(5) $^{\dagger}\neg{^{\dagger}\lambda x_e}[\exists x_{\rm nf}(x_{\rm nf} = x_e \;\&\; \neg {^{\dagger\cup}x_{\rm nf}}(x_{\rm nf}))]({^{\cap}\lambda x_e}[\exists x_{\rm nf}(x_{\rm nf} = x_e \;\&$
$\neg {^{\dagger\cup}x_{\rm nf}}(x_{\rm nf}))]$

But now, from (6) no paradox can be derived. To make things more readable, let us abbreviate $\lambda x_e[\exists x_{\rm nf}(x_{\rm nf} = x_e \wedge \neg {^{\dagger\cup}x_{\rm nf}}(x_{\rm nf}))]$ as RP (for

Russell's property) so that (5) becomes:

(6) $\quad {}^{\dagger}\neg{}^{\dagger}\mathrm{RP}({}^{\cap}\mathrm{RP})$.

Notice that we cannot yet "push negation over" by means of the negation axiom (2vi), and get ${}^{\dagger\dagger}\neg\mathrm{RP}({}^{\cap}\mathrm{RP})$, for the result would be ill-formed. However, from (6) by axiom (2iii) we can get:

(7) $\quad \neg{}^{\dagger}\underline{\mathrm{RP}({}^{\cap}\mathrm{RP})}$.

Now, the underlined part of (7) is identical to (1). Hence, by repeating the steps in (3)–(6), from (7) we get:

(8) $\quad \neg{}^{\dagger}\neg{}^{\dagger}\mathrm{RP}({}^{\cap}\mathrm{RP})$.

By iterating again the process, we obtain:

(9) $\quad \neg{}^{\dagger}\neg{}^{\dagger}\neg{}^{\dagger}\mathrm{RP}({}^{\cap}\mathrm{RP})$.

At this point we can apply the negation axiom (2vi) to (9) (with respect to the underlined part) and derive:

(10) $\quad \neg{}^{\dagger\dagger}\neg\neg{}^{\dagger}\mathrm{RP}({}^{\cap}\mathrm{RP})$

Double negation cancels out:

(11) $\quad \neg{}^{\dagger\dagger\dagger}\mathrm{RP}({}^{\cap}\mathrm{RP})$

Two of the truth-operators can go, since the ${}^{\dagger}\mathrm{RP}({}^{\cap}\mathrm{RP})$ is atomic, and we go back to (7):

(12) $\quad \neg{}^{\dagger}\mathrm{RP}({}^{\cap}\mathrm{RP})$

It follows, then, by standard arguments that both (7) and (8) are theorems of PT_1. Hence, ${}^{\dagger}\mathrm{RP}({}^{\cap}\mathrm{RP})$ and ${}^{\dagger}\neg{}^{\dagger}\mathrm{RP}({}^{\cap}\mathrm{RP})$ must both be false. The truth-operator screens out the paradoxes by enabling us to mimic three-valued logic from within a classical setting.

2.3. *The Semantics of PT_1*

A PT_1 frame is a structure of the $F = \langle O, \mathbf{I}, \mathbf{P}, S, \Delta, T\rangle$, where

(1)(i) $O = \langle E, [E \to E], \gamma, \delta\rangle$, where E is a non empty set, $[E \to E]$ is some set of functions from E to E and $\delta\colon E \to [E \to E]$, $\gamma\colon [E \to E] \to E$ such that $\delta(\gamma(f)) = f$. (O is a model of the λ-calculus.)

(ii) $\mathbf{I} = \langle I, \cap, \neg, \cap_r, \equiv\rangle$ is an algebra of information units, where $r = i$, u, nf, or e, I is a non empty set, $\cap\colon IXI \to I$, $\neg\colon I \to I$. $\equiv\colon E \times E \to I$ (intuitively, intensional identity) and $\cap_r\colon (E_r \to I) \to I$, where $r \in \{i, e, \mathrm{nf}, u\}$ and $E_e = E$, $E_{\mathrm{nf}} =$

$\{e \in E: \exists f \in [E \to E]$ such that $\gamma(f) = e\}$, $E_u = E_e - E_{nf}$, and $E_i = I \subseteq E_u$.

(iii) $\mathbf{P} = \langle P, \sqcap, \sqsupset, \bigwedge_r, =, 1, 0\rangle$ is a boolean algebra of propositions

(iv) $T: \mathbf{I} \to \mathbf{P}$ is a homomorphism, i.e.

$T(i \cap i') = T(i) \sqcap T(i')$

$T(\neg i) = \sqsupset T(i)$

$T(e \equiv e') = e = e'$

$T(\bigcap_r f) = \bigwedge_r \lambda e T(f(e))$

$T(\Delta(e)) = S(e)$, where Δ: $E \to I$ and S: $E \to P$. (Intuitively, Δ is the truth operator and S provides an "extension" for it)

A PT_1-interpretation is an ordered pair $M = \langle F, a\rangle$, where F is a PT_1-frame and a is an interpretation function which, for any sort r, assigns elements of E_r to members of Cons_r. (We assume, in particular, that if $\alpha \in \text{Cons}_{\langle e,e\rangle}$, $a(\alpha) \in [E \to E]$). Furthermore, we assume that g is an assignment to variables such that if $x \in \text{Var}_r$, $g(x) \in E_r$. The function $g(e/x)$ is identical to g except perhaps that $g(e/x)(x) = e$. In what follows, we shall omit all references to M in the recursive definition of the function $[\![\ ]\!]^{M,g}$, that assigns a value to all the ME_r, r any sort.

(2)(i) if $x \in \text{Var}_r$, $[\![x]\!]^g = g(x)$; if $\alpha \in \text{Cons}_r$, $[\![\alpha]\!]^g = a(\alpha)$.

(i) $[\![\lambda x t]\!]^g = \lambda e.[\![t]\!]^{g(e/x)}$

(iii) $[\![{}^{\cup}t]\!]^g = \delta([\![t]\!]^g)$

(iv) $[\![{}^{\cap}t]\!]^g = \gamma([\![t]\!]^g)$

(v) $[\![f(t)]\!]^g = [\![f]\!]^g([\![t]\!]^g)$

(vi) $[\![{}^{\dagger}t]\!]^g = \Delta([\![t]\!]^g)$

(vii) $[\![t = t']\!]^g = [\![t]\!]^g \equiv [\![t']\!]^g$

(viii) $[\![\neg\psi]\!]^g = \neg[\![\psi]\!]^g$

(ix) $[\![\psi \,\&\, \phi]\!]^g = [\![\psi]\!]^g \cap [\![\phi]\!]^g$

(x) $[\![\forall x_r \psi]\!]^g = \bigcap_r \lambda e \in E_r [\![\psi]\!]^{g(e/x_r)}$

Observe that the semantics for PT_1 is fully compositional. Observe also that for the definition to be well-founded each $\lambda e.[\![t]\!]^{g(e/x)}$ has to be a member of $[E \to E]$. The closure of $[E \to E]$ under such function has to form part of the notion of model. This can be avoided using various algebraic closure conditions, but the above is preferred here for the sake of intuitiveness.

We say that a member of ME_i, ψ is true in M with respect to g iff $T([\![\psi]\!]^g) = 1$. We say that M is a PT_1-model iff all the axioms of PT_1 are true in M. A formula ψ is PT_1-valid iff it is true in every PT_1-model.

The definition of a PT_1-model is impredicative. We think that this is a necessary consequence of the fact that the notion of property is so fundamental that it can't be reduced to anything beyond the principles that govern predication. An analogy with set theory might help. What a set is is determined by the axioms of set theory. Sets cannot be completely modelled in a way that doesn't ultimately rely on those very axioms. The same, we think, is true of properties. From this perspective, set theoretic models of property-theories can be technically useful tools (e.g. to show consistency) and, to up to a point, valuable heuristics into the "intended" interpretation. But only up to a point, for properties just are not set-theoretic constructs.

2.4. *Meeting the Desiderata*

It is easy to see that the present theory does meet the desiderata outlined in Section 1. The construction of functions, and in particular, the formation of information unit functions is closed under the logical connectives. The logic of complex functions is determined, ultimately by the logic of '†'. Nominalized forms inherit the structure of the functions they are derived from. Thus, for example one can define a meet operator on nominalized forms as follows:

(1) $$x_{\mathrm{nf}} \sqcap y_{\mathrm{nf}} =_{\mathrm{df}} {}^{\cap}\lambda x_e[{}^{\dagger\cup} x_{\mathrm{nf}}(x_e) \wedge {}^{\dagger\cup} y_{\mathrm{nf}}(x_e)]$$

Similarly for the other connectives and quantifiers. Thus while the choice of property-correlates is left to a certain extent open, their logical behavior is determined by the correlation with information unit functions as characterized by the theory.

This leaves one free to think of property-correlates in various ways. One could conceive them nominalistically as just the predicative expressions themselves, or platonistically as real, independently given objects. We like to think of certain property-correlates (e.g. being liquid) as natural causal structures, part of the "furniture of the world". Other property-correlates (like being liquid or not being green) we think are constructs derived from the former through our capacity for concept-formation, of which our property-theory, one might submit, represents a "module".

The present theory sanctions very strong forms of self-predication, which was our third desideratum. For example, there is a universal property[5] and Parsons' argument can straightforwardly be proven valid.

Concerning the second desideratum of Section 1, the source of intensionality lies within information units. Information units are highly intensional structures and their identity conditions are left open. Functions and their individual counterparts inherit their intensional character from information units. A very rich variety of alternatives is open to us in this connection. Let us mention a few.

Information units can be regarded as "structured meanings" along the lines proposed in Cresswell (1985), who has proposed a theory of the attitudes based on them. His idea is related to Carnap's notion of "intensional isomorphism". Roughly put, one interprets sentences as denoting structures that are made up of the meanings of their basic components and mimic directly the way these meanings are "syntactically" composed. Imagine taking the syntactic analysis tree of a sentence (or, perhaps of the representation of the sentence into some logical form), chopping off the leaves (which, in syntactic trees, are just symbols) and replacing them with their semantic values. The resulting objects (something like syntactic trees rooted into "real" things, rather than into symbols) will be structured meanings; and attitudes, like believing, can be analyzed as relations involving these objects. Cresswell argues at some length for the advantages of an approach along these lines that he claims, among other things, goes around the problem of logical omniscience, while at the same time incorporating a simple theory of de re (and de se) belief.

Cresswell, however, points also out a rather serious foundational problem that his approach runs into in connection with iterated belief (1985, p. 85 ff). In rough terms, what happens is that the semantics of something like "John believes that Mary believes that it rains" involves applying relations to themselves, for John stands in the believe-relation with a structured meaning one of whose components is the believe-relation itself. No explicit solution to this problem is offered. And we think that no really satisfactory one is forthcoming, if one believes that properties are just set theoretic constructs. This faith is bound to generate problems of this sort.

On the present approach, it appears to be quite straightforward to construe information units as "structured meanings". In one of the models that the theory admits (being constructed out of models for the λ-calculus) information units are interpreted as the formulae themselves. Structured meanings appear to be simple variants of the latter models, obtained by replacing symbols with their semantic values. Moreover, the logic of our theory does accommodate self-predication in a very general way and the problem of iterated attitudes will simply not arise.

Other possibilities that come to mind is to regard information units as something like the situation types of Barwise and Perry (1983). Prima facie, it doesn't seem hard to develop the notions proposed by Barwise and Perry (1983) and subsequent work, using the rich and simple logic of our property-theory, although we haven't tried this out in detail. By explicit admission of their authors, the version of situation semantics developed in Barwise and Perry (1983) faces serious foundational problems (see Barwise and Perry 1985). In Barwise and Perry (1983) the formal basis of the situation-theoretic apparatus was taken to be Kripke-Platek set theory. In more recent work, that has been replaced by Aczel's theory of non well-founded sets (see Aczel 1986). We think using more directly property-theoretic frameworks such as Aczel's Frege structures or the present theory (which is closely related to the latter) might help.

Many other options are open. We don't feel ready to choose among them and prefer to leave the issue open. We think that the above considerations, loose as they may be, do suffice in providing some preliminary evidence in favour of the semantic potential of a property-theory like the one developed here.

We now turn to a more detailed discussion of semantic issues raised by this approach.

3. Types in Semantics

Our PT_1 is a multisorted first-order theory. Most if not all current (formal) semantic theories for natural language (in particular, all of those that stem from Montague's work) make heavy use of higher order strongly typed theories. Thus, using PT_1 for semantic purposes will require some discussion of the respective roles of types and sorts in semantics, for purposes of comparison.

Perhaps, it might be useful to start the discussion by individuating some of the roles that type theory has played and plays in semantics. We see two fundamental such roles.

On the one hand, type theory is a theory of predication. As a theory of predication, type theory appears to be built on the following assumptions.

(1)a. Properties are of an essentially different logical type than their arguments (i.e. the things they are true of).

b. There is no genuine form of self-predication.

c. One cannot refer to the totality of properties (and, consequently, one cannot refer to all there is)

The theory of properties that we have sketched accepts (1a) while rejecting (1b, c).

Perhaps, the fact that our theory rejects (1b) requires some clarification. Strictly speaking, in PT_1, as in standard type theory, no property really applies to itself. But properties (or rather information unit functions) have isomorphic images in the domain of individuals and self-application (or self-predication) is the application of an information-unit function to its own individual image. This enables us to claim that, up to isomorphism, we do have genuine self-predication. We do not go all the way, though, in *identifying* information-unit functions with their isomorphic images, for that would obliterate point (1a), namely the existence of a semantic difference between properties in their predicative role and properties in their individual role, a difference that we think is useful to maintain.

Whatever one thinks of our approach to self-predication, it should be uncontroversial that PT_1 embodies a different theory of predication from the one embodied by standard type-theory.

A second major role of type theory in semantics is that of providing a way of classifying semantic domains. In doing semantics, we associate symbols of different syntactic categories with objects drawn from different domains. Type theory offers a systematic way of classifying the various domains of objects that might be needed for semantic purposes.

It seems undeniable that some systematic way of classifying domains in semantics is going to be necessary, whichever framework one adopts at the foundation. It might be useful, in this connection, to individuate how such "classificatory" uses of type theory are actually manifested. For, one might expect that an analogue of them should somehow be available in any general alternative to a type-theoretic (or standard set-theoretic)[6] semantics. We shall discuss briefly four such ways, that appear to be common to most Montague inspired semantic research.

3.1. *Generalized Quantifiers.*

In working out a compositional semantics we need often to posit certain abstract entities as the semantic values of certain constituents. A prime example is the category NP. It has been argued in many places that NP's ought to be interpreted as generalized quantifiers. (The first place where, as far as we know, this was argued for is Montague (1970), even though he did not use the term "generalized quantifier"). Generalized quantifiers are, essentially, sets of properties (or sets of sets) and can be represented as exemplified in (2).

(2) every man′ a. $= \lambda P \forall x[\text{man}'(x) \rightarrow P\{x\}]$ (in Montague's IL)
b. $= \{X\colon \text{man}' \subseteq X\}$ (in set-theoretic notation)

where *every man′* indicates the translation of the English NP *every man* into the (meta)language used for semantic purposes. Thus, for example, (2b) associates with every man the set of all those X's such that the extension of the man-property (i.e. the set of men) is a subset of X. We can then capture the contribution of NP's to truth-conditions along the following lines. A sentence like *every man runs* can be said to be true (using the notation in (2b)) iff the extension of the run-property is a member of the generalized quantifier associated with *ever man*.[7]

The motivation for analyzing NP's along the lines just sketched is quite extensive and we cannot discuss it here in any detail (see e.g. Barwise and Cooper, 1981). We think that any semantic theory should incorporate a theory of generalized quantification at some level. A fragment of type theory (or of standardly typed set-theories) provides a simple and manageable way of doing so.

Montague, in fact, pushed this line even further by proposing that intensional generalized quantifiers can also be used to represent the objects of desires, thoughts and, more generally, the relata of any (NP-taking) intensional verb. Montague's well-known analysis of intensional verbs is illustrated in (3a) and contrasted with the analysis of an extensional verb in (3b).

(3)a. John seeks a unicorn $\Rightarrow$ $\text{seek}'(j, {}^\wedge\lambda P \exists y[\text{unicorn}'(y) \wedge P\{y\}])$
b. John kicks a unicorn $\Rightarrow$ $\exists y[\text{unicorn}'(y) \wedge \text{kick}'(j, y)]$

This analysis might appear, perhaps, obscure and complicated. However, Bennett (1976), Dowty, Wall and Peters (1981) and Cooper (1983) have argued that it does seem to capture in a compositional fashion all the empirical properties that intensional verbs seem to have. Even though recent works in philosophical logic have pointed towards various alternatives to Montague's analysis, they have not precipitated yet (as far as we can tell) a compositional semantics for natural language that is able to deal with this hard problem with equal success. It seems desirable to us that any general alternative to Montague semantics be able to either improve on such an analysis or, at least, preserve it. Again, type theory provides a useful way of distinguishing (and classifying) extensional versus intensional verbs.

3.2. *Syntactic versus Semantic Categories.*

The categorial structure of natural languages is quite rich. A quite widespread working hypothesis among generative linguists is that the syntactic categories attested in the languages of the worlds constitute a systematically specifiable, probably finite, and perhaps small set.

But however tightly specifiable and however small the set of syntactic categories in the languages of the world might turn out to be, it certainly is more richly structured than the categories of a standard first order theory. A question that one would like to ask is: why? Where does the richness of the categorial structure of natural language come from?

Syntactic categories express patterns of regularities among expressions.

Some such patterns might have a purely syntactic explanation. In fact, if one adopts the "modular" view defended by Chomsky and others, it is to be expected that part of the richness of syntactic categorial systems is autonomously generated by syntactic principles. However, this does not in the least undermine the possibility that subsystems of the systems of syntactic categories may reflect a way of classifying semantic domains that we, as speakers, may be endowed with. In other words, some syntactic category might be the direct encoding of semantic categories. If this is so, it seems likely (given the relative richness of syntactic categorial systems) that we are going to need a way of classifying semantic domains more articulated than the one embodied in unaugmented first order logic.

Again, type theory comes to mind. In fact, it seems to us that most versions of Montague inspired semantics embody precisely the following claim: some syntactic categories are based on ways of classifying semantic domains, others arise out purely syntactic considerations.[8] One would think that any general alternative to Montague semantics should take a stand on this issue.

3.3. *Syntactic Generalizations*.

The point made in connection with syntactic categories can be, in fact, generalized to all syntactic phenomena. Of the syntactic regularities that one can detect in the languages of the world some, maybe most, can and must be accounted for in purely syntactic terms. However, this does not, by any mean, rule out that some syntactic generalizations might have ultimately a semantic explanation.

Now, what can semantic explanations be based on? An a priori reasonable candidate is something like a type mismatch of some kind, e.g. trying to apply a function to an argument in the wrong domain.

A more concrete example might make things clearer. A generalization due to Visser states that a control verbs passivize only if the understood subject of the infinitive is the matrix object, as illustrated in (4).

(4)a. John persuaded Mary to leave
b. Mary was persuaded to leave
c. John promised Mary to leave
d. *Mary was promised to leave

In (4a) the matrix object is the understood subject of the infinitive and we have a well-formed passive counterpart; in (4c) the matrix subject is the understood subject of the infinitive and passive is ungrammatical. Some authors (Bach 1980, Gazdar, et al. 1985) have proposed that the reasons for this pattern (which is indeed quite general) might be semantic. In particular, they have proposed that the semantic operation associated with passive is of the wrong logical type to apply to relations of the same logical type as *promise*. A series of independent considerations are argued to require that promise-type verbs have the logical type $\langle Ty(\mathrm{NP}), \langle Ty(\mathrm{VP}), Ty(\mathrm{VP})\rangle\rangle$ (where, $Ty(A)$ is the semantic type associated with category A), while persuade-type verbs have the type $\langle Ty(\mathrm{VP}), \langle Ty(\mathrm{NP}), Ty(\mathrm{VP})\rangle\rangle$. Passive is argued to be defined, universally, on relations of the latter type.

We cannot get into much detail here, nor are we interested in defending this particular account of Visser's generalization. We bring it up because we think it constitutes a non untypical attempt to come up with semantic accounts of facts that seem to lack convincing syntactic accounts. The structure of most such purported explanations appears to involve the way in which semantic objects are classified. This appears to constitute yet another issue with which a theory that seeks to improve on Montague's use of semantic types should be confronted with.

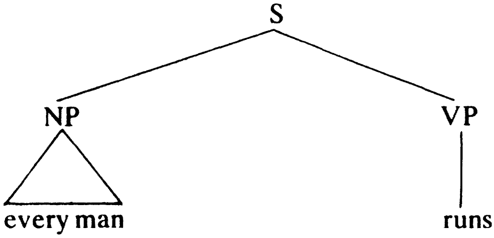
3.4. *The Syntax-Semantics Map*

In Sections 3.2 and 3.3 we have pointed out that classificatory principles for semantic domains (such as those that type theory provides) seem to play a role (or have been claimed to play a role) in accounting for the nature of syntactic categories as well as for the nature of certain observable syntactic patterns. We can go further. The set up of semantic domains can be used to characterize the relation between syntax and semantics in general.

A compositional semantics requires that each syntactic rule (at the relevant level of syntax) be matched by a corresponding semantic rule. However, everything else being equal, one would prefer not to have to specify for any given grammar the pairing of syntactic rules with the corresponding semantic one, on a case-by-case basis. One would like such a pairing to follow from general principles.

The semantic make up of expressions (i.e. their logical type) might help in trying to individuate such principles and channel, as it were, the interpretive procedure. Perhaps, this point can be best appreciated by looking at a simple example. Consider:

(5)



Let *Ty* be, again, the function that specifies the logical type associated with each syntactic category. The type of NP's is that of generalized quantifiers. In Montague's notation this means that $Ty(\text{NP}) = \langle\langle e, t\rangle, t\rangle$, where e is the type of basic entities and t is the type of truth-values.[9] Then we can take the type of *runs* to be either $\langle e, t\rangle$ (i.e. characteristic functions over the set of entities) or that of functions from generalized quantifiers into truth-values. In either case, there will be exactly one function and exactly one argument which represent the meanings of the lower nodes of the syntactic tree in (5). Thus, functional application will be the obvious way to obtain the semantic value of the mother (i.e. the value of the whole S) given the semantic value of the daughters; and the directionality of functional application will be recoverable from the types associated with the syntactic categories.

This strategy, suitably generalized, can constitute the core of semantic interpretive procedure for the grammar. The basic semantic rule is simply functional application and its specific mode of application in each case can be read off the syntactic categories of the daughters in a local subtree, by relying on a general association between syntactic categories and semantic types, along the lines discussed in connection with (5). Rule specific stipulation becomes largely unnecessary.[10]

Suppose, on the other hand that the semantic values of different constituents are drawn from one and the same unstructured semantic domain. Then it would seem that the above strategy is not viable, for we couldn't use semantic types to channel interpretation. We would have to stipulate in each case explicitly the operation to be performed on the daughters of a local subtree to compute the value of the mother. This illustrates yet another way in which type theory appears to have a crucial empirical impact on semantics.

3.5. *Wrap-up*

We have pointed out at the beginning of this section that our PT_1 embodies a theory of predication very different from the one embodied in type-theory (or in standard set-theories). In the introduction we have given some general reasons for rejecting a type-theoretic approach to predication in natural language (and later we will consider further specific linguistic arguments to that extent). At the same time, we have pointed out the need for general classificatory criteria for semantic domains, which is one of the things that type-theory is very useful for. The problem, then, is how to get the latter without the former. We would like to maintain the type theoretic distinctions that are semantically fruitful, but at the same time we would like to implant them on a non-type theoretic approach to properties and predication.

A priori, there are two general strategies to try out. The first might be to capitalize on the richness of our property-theoretic domain. In such a domain (using the correlates of information-unit functions) we can represent properties and relations of indefinite complexity (similarly to what happens to sets in the domain of set-theory). Thus, we can articulate our property-theoretic domain in subdomains, classify them using a suitable system of sorts and do semantics using these subdomains.

Alternatively, we could start out with our property-theoretic domain and build, externally to it, the types of function spaces we need, using standard type theoretic techniques. So instead of building function spaces out of an unstructured domain of primitive entities (like Montague did), we would build the function spaces we need starting with a property-theoretic domain at the bottom.

It is not easy to tease apart these two approaches, on purely a priori considerations. It is not even clear, a priori, whether these approaches are indeed distinct, for it is well-known that type-theory can be recast as a first-order multi-sorted theory (i.e. one can go back and forth from types to sorts and vice versa).

Although we have no final solution to this complex problem, we think that the choices that one makes do have empirical consequences in semantics. We will try to illustrate this by highlighting some of the points where the above options appear to make a difference in actually spelling out a Montague-style English fragment based on our property theory in the next section.

In fact, it will be seen that the two strategies that we are discussing are more like extremes of a continuum rather than a dichotomic alternative. In particular, the approach we will adopt casts some of the relevant distinctions as "horizontal" subdivisions internal to the domain of individuals while others are characterized in a "vertical" manner by building function spaces externally to our property theoretic domain.

4. A FRAGMENT OF ENGLISH

The purpose of the following fragment is to illustrate our general framework and show how straightforwardly it inherits all the positive features of classical Montague semantics. For ease of comparison, and to avoid adding further idiosyncratic notation on top of what one is bound to introduce in building a new semantic theory, we try to keep as close as possible to Montague's original format. This should not be taken to imply necessarily our adherence to Montague's original approach to syntax.

We begin by developing a version of PT_1 with modal and temporal operators and with a more articulated sortal system. We call the resulting formal system PT_2.

4.1. PT_2: *a Modal Extension of* PT_1

We say that our *basic* sorts are the same as those of PT_1 (namely: e, u, nf, and i), plus pw and Q. Intuitively, pw is going to be the sort of possible worlds (i.e. propositions in the traditional sense). Q is going to be the sort of generalized quantifiers. The complex sorts are going to be defined in terms of the following recursive schema:

(1) $\langle a_1\langle, \ldots, \langle a_n, b\rangle \ldots\rangle$, where, for $1 \leq i \leq n$, a_i and b are any of the basic sorts.

What this means is that we are going to have essentially curried n-place functions whose n inputs are drawn from any of the basic sorts and whose output also is something of a basic sort. We think that this is all we need.

We assume that for any sort r, Cons_r is a possibly non empty set of constants of sort r. If $r = e$, i, nf, pw or u, Var_r is a set of variable of sort r. Thus, we are only going to allow variables of a non functional sort. This means that technically our system is still going to be a first order theory. The formation rules are a straightforward extension of those of PT_1

(2)i. $\text{Var}_\alpha, \text{Cons}_\alpha \subseteq \text{ME}_\alpha$.

ii. If $t \in \text{ME}_e - \text{ME}_{\text{pw}}$ and $x \in \text{Var}_e$, $\lambda x[t] \in \text{ME}_{\langle e, e\rangle}$.

iii. If $t \in \text{ME}_{\text{nf}}$, ${}^{\cup}t \in \text{ME}_{\langle e,e\rangle}$ and ${}^{\dagger\cup}t \in \text{ME}_{\langle e,i\rangle}$.

iv. If $f \in \text{ME}_{\langle e,e\rangle}$, ${}^{\cap}f \in \text{ME}_{\text{nf}}$.

v. If $f \in \text{ME}_{\langle a,b\rangle}$ and $t \in \text{ME}_a$, $f(t) \in \text{ME}_b$.

vi. ME_i, $\text{ME}_{\text{pw}} \subseteq \text{ME}_u$, ME_u, $\text{ME}_{\text{nf}} \subseteq \text{ME}_e$, $\text{ME}_Q \subseteq \text{ME}_{\langle e,i\rangle} \subseteq \text{ME}_{\langle e, e\rangle}$.

vii. If $t \in \text{ME}_e$, ${}^{\dagger}t \in \text{ME}_i$

viii. If ψ, $\phi \in \text{ME}_i$, t, $t' \in \text{ME}_e$, and $x \in \text{Var}_\alpha$, for any basic sort α, then $(t = t')$, $\neg\psi$, $(\psi \vee \phi)$, $(\psi \,\&\, \phi)$, $\exists x(\psi)$, $\forall x(\psi)$, $(\psi \rightarrow \phi)$, $(\psi \leftrightarrow \phi)$, $\Box\psi$, $\Diamond\psi$, $\mathbf{H}\psi$, $\mathbf{W}\psi$ are all in ME_i.

ix. If $\psi \in \text{ME}_i$, ${}^{\wedge}\psi \in \text{ME}_{\text{pw}}$.

Let us see what the new features of PT_2 are with respect to PT_1, aside from the addition of temporal and modal operators. First, we note that scope of the nominalization operator '${}^{\cap}$' has been generalized to expressions of sort $\langle e, i\rangle$. (This follows from clause (2vi) that requires that $\text{ME}_{\langle e, i\rangle} \subseteq \text{ME}_{\langle e,e\rangle}$). Second, we note that we introduce '${}^{\dagger\cup}$' as a new predication operator that creates information unit functions. We also introduce an analogue of Montague's "cap" operator, '${}^{\wedge}$' that maps information units into propositions (sets of worlds). Proposition-denoting expressions are taken to be singular terms, since we assume in (2vi) that $\mathrm{ME}_{\mathrm{pw}} \subseteq \mathrm{ME}_u \subseteq \mathrm{ME}_e$. Clause (2ii) prevents us from forming functions from individuals into sets of worlds, which are not going to be needed in the grammar to be developed. If found desirable, such functions could be added to our system. But we must prevent them from being nominalized, for there are too many of them. Finally, we extend functional application in the obvious way and we treat generalized quantifiers as a subsort of information unit functions.

We now proceed to specify the semantics for PT_2. A PT_2 frame $F = \langle O, \mathbf{I}, \mathbf{P}, S, \Delta, T\rangle$, is identical to a PT_1 frame except for the following conditions:

(3)i. $\mathbf{P}$ is the boolean algebra generated by $\mathcal{P}(W \times J)$, where W is a set of worlds and J is a set of instants ordered by $<$.

ii. $\mathbf{I}$ contains three additional operators $f_\Box$, $f_\mathbf{W}$, $f_\mathbf{H}$ all in $[I \rightarrow I]$ such that for any $i \in I$

a. $T(f_\Box(i)) = W \times J$, if $T(i) = W \times J$ and $T(f_\Box(i)) = \emptyset$, otherwise

b. $T(f_\mathbf{W}(i)) = \{\langle w, j\rangle: \exists j' \in J, j < j' \text{ and } \langle w, j'\rangle \in T(i)\}$

c. $T(f_\mathbf{H}(i)) = \{\langle w, j\rangle: \exists j' \in J, j' < j \text{ and } \langle w, j'\rangle \in T(i)\}$

iii. $P \subseteq E_u$.

We extend next the definition of E_r (the domain of things of sort r), for any sort r in the obvious way.

(4)a. If $a, b \in \{e, i, \mathrm{nf}, u\}$, then E_a is as (1ii) of Section 2.3, namely, $E_e = E$, $E_{\mathrm{nf}} = \{e \in E: \exists f \in [E \rightarrow E] \text{ such that } \gamma(f) = e\}$, $E_u = E_e - E_{\mathrm{nf}}$, $E_{\mathrm{pw}} = \mathcal{P}(W \times J) \subseteq E_u$, and $E_i = I \subseteq E_u$); $E_{\langle e, i\rangle} = \{f \in [E \rightarrow E]: \forall e \in E, f(e) \in E_i\}$; $E_Q = \{f \in E_{\langle e, i\rangle}: f \text{ is conservative}\}$ (we say that f is conservative iff there is some $e \in E_{\mathrm{nf}}$ such that for all $e' \in E$, $T(f(e)) = T(f(e \cap e')$ – see Barwise and Cooper (1981), Keenan and Stavi (1986)).

b. $E_{\langle a, b\rangle} = E_b^{E}a$, otherwise.

A PT_2 interpretation M is a pair of the form $\langle F, a\rangle$, where for any $\alpha \in \mathrm{Cons}_r$, $a(\alpha) \in E_r$. A value assignment g maps Var_r into E_r. In specifying the value function $[\![\ ]\!]^{M,g}$, we omit reference to the interpretation M and only provide the clauses that are different with respect to PT_1 (as specified in (2), Section 2.3).

(5)i. $[\![{}^{\dagger\cup} t]\!]^g = \lambda e \in E.\, \Delta(\delta([\![t]\!]^g))(e)$

ii. $[\![\Box\psi]\!]^g = f_\Box([\![\psi]\!]^g)$

iii. $[\![\mathbf{W}\psi]\!]^g = f_\mathbf{W}([\![\psi]\!]^g)$

iii. $[\![\mathbf{H}\psi]\!]^g = f_{\mathbf{H}}([\![\psi]\!]^g)$
iv. $[\![{}^\wedge\psi]\!]^g = T([\![\psi]\!]^g)$

The definition of PT_2 validity and entailment are straightforward modifications of PT_1 validity and entailment.

Perhaps the best way to justify our additions to PT_1 is by seeing them at work in a sample English grammar. As usual, we are going to use PT_2 as the language in terms of which the meaning of various constituents is compositionally represented.

4.2. *The Grammar of the Fragment*

Instead of presenting first all of the syntax and then later all of the semantics of the fragment we will present syntactic and semantic rules in tandem in the hope of enhancing readability.

4.2.1. *Syntactic Categories.* Following Montague (for the reasons pointed out in the introduction to this section), we adopt a categorial notation:

(5)i. $e_\alpha, i_\alpha \in \mathrm{CAT}$
ii. if $A, B \in \mathrm{CAT}$, $A/_\alpha B \in \mathrm{CAT}$

where α is an admissable feature bundle.

An expression of category $A/_\alpha B$ combines with a B to give an A. We leave it open what exactly counts as an admissable feature bundle. We will be introducing features rather loosely as needed for syntactic purposes, without spelling out exactly what they are, for that would take us too far afield. If, desired each feature bundle could be replaced with Montague's "multiple slash" notation. Or one could adopt one of the current theories of features such as those developed, e.g. in Bach (1983), Gazdar et al. (1985) or Shieber (1986).

We list, next, the categories that we are actually going to use along with samples of lexical entries. For each category A, B_A is the set of lexical entries of category A

B_N = {John, Mary, he$_n$, someone, everything, dog, man, woman, park...}
where $N = e_{[+N,-V,\pm C]}$
dog, man etc. are [+N, −V, +C], and other nominals are [+N, −V, −C];
we abbreviate $e_{[+N,-V,-C]}$ as NP and $e_{[+N,-V,+C]}$ as CN
B_{ADJ} = {red, drunk, ...}, where ADJ = $e_{[+N,+V]}$
$B_{PP} = \emptyset$, where PP (Prepositional Phrase) = $e_{[-N,-V]}$
B_{IV} = {run, walk, talk, ...}, where IV = $e_{[-N,+V]}$

$B_S = \emptyset$, where $S = i_{[-\text{COMP}]}$
$B_{S'} = \emptyset$, $S' = i_{[+\text{COMP}]}$
$B_{VP} = \emptyset$, where $VP = S/NP$
$B_{IV'} = \emptyset$, where $IV' = IV_{[to]}$
B_{Det} = {the, a, some, . . . }, where Det = NP/CN
B_{ADS} = {necessarily, possibly, . . . } where ADS = S/S
B_{ADV} = {slowly, rudely, . . . } where ADV = IV/IV
B_{P1} = {in, with, . . . } where P1 = PP/NP
B_{TV} = {be$_1$, kiss, seek, . . . }, where TV = IV/NP
$B_{IV/S'}$ = {believe, know, . . . }
$B_{IV/IV'}$ = {try, want, . . . }
$B_{TV/IV'}$ = {force, believe, . . . }
B_{TTV} = {give, send, . . . }, where TTV = TV/NP
B_{ADN} = {former}, where ADN = CN/CN
$B_{IV'/IV}$ = {to}
$B_{S'/S}$ = {that$_1$, that$_2$}
$B_{IV/PRED}$ = {be$_2$}, where PRED $\in$ {ADJ, PP}

4.2.2. *The Category-Type Correspondence*. We will depart from Montague's original format on one count, namely we will adopt the approach developed in Partee and Rooth (1983), for it strikes us as an improvement over Montague's theory that is particularly straightforward to implement. According to Partee and Rooth (1983) each syntactic category is associated not with just one type but with a restricted range of types. Thus a particular expression can have a meaning in more than one semantic domain. Generally, such an expression is associated with just one meaning in the lexicon. Its other possible meanings are derived in the contexts where they are needed by means of general type-shifting principles. Hopefully, this will become clearer as we go along.

The category-type correspondence is provided in terms of the following recursively specified (multi-valued) function k:

(6)i. $k(i_\alpha) = i$; if $\alpha = [+N, -V, -C]$, $k(e_\alpha) = Z$, where $Z = e$ or $Z = Q$; $k(e_\alpha) = \text{nf}$, otherwise.
ii. $k(A/_\alpha B) = \langle k(B), k(A)\rangle$

What makes this function multivalued is the fact that any syntactic category of the form A/NP is associated with two semantic sorts, namely $\langle Q, k(A)\rangle$ and $\langle e, k(A)\rangle$. This will entail that expressions of that category are allowed to have two sorts of meanings, typically a lexically specified one and one derivable from the lexical one by sort-shifting.

4.2.3. *Lexical Meanings*. In general, a lexical entry β of category A is going to be translated as a constant β' of PT_2 of sort $k(A)$. If, α is of category A/NP, we are going to assume that α' is of sort $\langle e, k(A)\rangle$, unless otherwise specified. In other words, NP-taking expressions are going to be lexically associated with individual-taking functions, in the default case. The following further conventions apply:

(7)i. John$' = j$, where $j \in \text{Cons}_u$ (similarly for other proper names)

ii. $\text{he}'_n = x_{e,n}$ (sometimes, we will write x_n for $x_{e,n}$. In general, sortal specifications will be ommitted only when no confusion is likely to arise).

iii. someone$'$, everything$' \in \text{Cons}_Q$. In particular, we adopt the following postulates:
$\text{someone}' = \lambda x_e \exists z_{\text{nf}} [x_e = z_{\text{nf}} \wedge \exists y_e [{}^{\dagger\cup}\text{person}'(y_e) \wedge {}^{\dagger\cup} z_{\text{nf}}(y_e)]]$
(in general, we shall write $\lambda x_{\text{nf}} \psi$ as a short form for $\lambda x_e \exists z_{\text{nf}}[z_{\text{nf}} = x_e \wedge \psi])$
$\text{everything}' = \lambda x_{\text{nf}} \forall y_e [{}^{\dagger\cup} x_{\text{nf}}(y_e)]$

iv. a$'$, the$'$, every$', \ldots \in \text{Cons}_{\langle \text{nf}, Q\rangle}$. In particular, the following postulates are assumed:
$\forall z_{\text{nf}}[{}^{\cap}\text{a}'(z_{\text{nf}}) = {}^{\cap}\lambda x_{\text{nf}} \exists y_e [{}^{\dagger\cup} z_{\text{nf}}(y_e) \wedge {}^{\dagger\cup} x_{\text{nf}}(y_e)]]$
$\forall w_{\text{nf}}[{}^{\cap}\text{the}'(w_{\text{nf}}) = {}^{\cap}\lambda x_{\text{nf}} \exists y_e [{}^{\dagger\cup} w_{\text{nf}}(y_e)$
$\wedge \forall z_e [{}^{\dagger\cup} w_{\text{nf}}(z_e) \leftrightarrow z_e = y_e] \wedge {}^{\dagger\cup} x_{\text{nf}}(y_e)]]$
$\forall z_{\text{nf}}[{}^{\cap}\text{every}'(z_{\text{nf}}) = {}^{\cap}\lambda x_{\text{nf}} \forall y_e [{}^{\dagger\cup} z_{\text{nf}}(y_e) \rightarrow {}^{\dagger\cup} x_{\text{nf}}(y_e)]]$

v. be'_1, seek$' \in \text{Cons}_{\langle Q, \text{nf}\rangle}$, similarly for other intensional verbs. In particular, for every $\beta \in \text{ME}_Q$, $\text{be}'_1(\beta) = {}^{\cap}\lambda y_e[\beta({}^{\cap}\lambda x_e[x_e = y_e])]$ (this is essentially, Montague's treatment of the copula).

vi. $\forall x_i[\text{necessarily}(x_i) = \Box x_i]$
$\forall x_i[\text{possibly}(x_i) = \Diamond x_i]$.

vii. $\forall x_{\text{nf}}[\text{be}'_2(x_{\text{nf}}) = \text{to}'(x_{\text{nf}}) = x_{\text{nf}}]$

viii. $\text{that}'_1 \in \text{Cons}_{\langle i, i\rangle}$; $\forall x_i[\text{that}'_1(x_i) = x_i]$ (i.e. *that*$'_1$ is an identity map. Consequently, that$_1$-clauses are going to denote information units)
$\text{that}'_2 \in \text{Cons}_{\langle i, u\rangle}$; $\forall x_i[\text{that}'_2(x_i) = {}^{\wedge}x_i]$ (i.e. *that*$'_2$ maps information units into sets of worlds. Consequently, that$_2$-clauses are going to denote sets of worlds).

Perhaps, the only feature of the approach developed so far that needs an immediate comment concerns the treatment of English predicative expressions: verbs, common nouns, etc. Traditionally, they are analyzed as predicates. In our theory, the intuitive notion of "predicate" is formally reconstructed in two forms: as information unit functions and as their nominalized counterparts. Hence, we have a choice here, as to how to represent natural language predicates. It would be possible to analyze them as information units functions. So, for example, we could assign to *run*, etc. the sort $\langle e, i\rangle$. This would have a number of consequences. For example, VP-adverbials are standardly analyzed as functions from predicates into predicates. Consequently, in the present notation, they would be of sort $\langle\langle e, i\rangle, \langle e, i\rangle\rangle$. This means that we would have to introduce in PT_1 sorts "higher" than those that we have got so far. This can be done. However, we can also adopt the alternative strategy, which is to analyze all predicative expressions as nominalized functions. They will later be turned into information unit function by the operator '$^{\dagger\cup}$', which is taken to be the semantic value of inflectional features (more on this later). This enables us to analyze adverbs as functions of sort $\langle \text{nf}, \text{nf}\rangle$, and consequently to maintain a simpler sortal structure. We will see in Sections 5.2.3 and 5.3 that the present analysis of predicative expressions has further consequences of interest.

Notice that the sort of transitive and ditransitive verbs is then determined by our choice concerning the sort of intransitive verbs. Thus, for example, (extensional) transitive verbs are analyzed as functions from entities into nominalized functions, ditransitive verbs as functions from individuals into functions from individuals into nominalized functions, etc.

Perhaps, it is also appropriate to recall, at this point, that functions of the form, say $\langle \text{nf}, \text{nf}\rangle$ (i.e. adverbials) as well as complex functions of sort $\langle a, \langle b, c\rangle\rangle$ are not directly nominalizable. This might be desirable, for in general adverbs and, say, transitive or ditransitive verbs as such do not appear to be nominalizable in English (as well as in many other languages).[11] However, it is possible to indirectly define entities in the domain of PT_1 that could be regarded as individual counterparts of these non directly nominalizable functions. For example, the individual that would correspond to the semantic value of *give* could be represented as $^{\cap}\lambda x^{\cap}\lambda y[\text{give}'(x)(y)]$. Abstract objects of this kind, although, in some sense, representable in $PT_{1,2}$, require for their implementation a number of stipulations that go beyond those directly incorporated into the basic structure of $PT_{1,2}$ (e.g. '$^{\cap}$' applied directly to *give*′ is undefined; '$^{\cup}$' applied to $^{\cap}\lambda x^{\cap}\lambda y[give'(x)(y)]$ would not yield back *give*′, etc.).

Thus we can adopt the strategy, familiar from much linguistic research, of regarding the semantic structure of PT_2 as providing us with a markedness scale concerning the type of meanings we should expect to find in natural languages. The constructions that can be directly represented in PT_2, in its present form, are unmarked, those that require stipulations beyond those that are directly built into PT_2 are more marked. Thus nominalization of adverbs, determiners, and other complex functions is expected to occur only in limited and special circumstances. This seems roughly correct, at least as a first approximation (see also Chierchia (1984, 1985) for further relevant discussion).

Whether the specific hypothesis that we are building into the sortal structure of PT_2 is correct or not, the above considerations point towards kinds of issues might be relevant in assessing the empirical viability of a theory of semantic domains.

4.2.4. *Syntactic and Semantic Rules*. We now define P_A (i.e. the set of well-formed expressions of category A) recursively, and simultaneously provide the interpretive rule that corresponds to each syntactic rule.

We first have to specify the base of the recursion:

(8) For any $A \in \text{Cat}$, $B_A \subseteq P_A$

The real core of the present grammar is constituted by the following rule of categorial cancellation:

(9) If $\alpha \in P_{A/B}$ and $\beta \in P_B$, $F_1(\alpha, \beta) \in P_A$, where:
if $A/B = \text{VP}$, $F_1(\alpha, \beta) = \beta\alpha$
if $A/B = \text{TV}$ and $\alpha = \gamma\delta$, $F_1(\alpha, \beta) = \gamma\beta\delta$
otherwise, $F_1(\alpha, \beta) = \alpha\beta$

The interpretive rule associated with categorial cancellation is going to be, obviously, functional application. Here is where the two types associated with nominal categories become relevant: for we might have, for example, an extensional transitive verb (which will be of sort $\langle e, \text{nf}\rangle$) combining with a quantified NP (which will be of sort Q). The problem is how should such a combination take place. Partee and Rooth (1983) suggest using, in these cases, a type-shifting mechanism. In our framework their mechanism becomes a recursively defined operator $[\ ]_Q$ that maps functions of sort $\langle e, a\rangle$ into functions of sort $\langle Q, a\rangle$. The syntax and semantics of $[\ ]_Q$ is as follows:

(10) if $\alpha \in \text{ME}_{\langle e, a\rangle}$ where $a = i$ or $a = \langle e, \ldots \langle e, \text{nf}\rangle \ldots\rangle$, $[\alpha]_Q \in \text{ME}_{\langle Q, a\rangle}$;
if $\alpha \in \text{ME}_{\langle e, i\rangle}$, $[\alpha]_Q(\beta) = \beta({}^{\cap}\alpha)$
if $\alpha \in \text{ME}_{\langle e, \ldots \langle e, \text{nf}\rangle \ldots\rangle}$, then
$[\alpha]_Q(\beta)(t_1) \ldots (t_n) = {}^{\cap}\lambda y[\beta({}^{\cap}\lambda x[{}^{\cup}[\alpha(x)(t_1) \ldots (t_n)](y)]]$

This sort-shifting operation could be generalized in various ways, but we do not need to get into such possible generalizations here.

Perhaps, the best way to understand how (10) works, especially for readers not familiar with Partee and Rooth (1983) is to look at the examples provided in the appendix.

Given (10) we can define the semantic counterpart of (9), i.e. categorial cancellation, as follows:

(11) If $\alpha \in P_{A/B}$ and $\beta \in P_B$, $F_1(\alpha, \beta)$ translates as $\alpha'(\beta')$, if defined, as $[\alpha']_Q(\beta')$, otherwise.

In a categorial framework, the pair of rules in (9) and (11) are generally taken to constitute a universal template (modulo language particular settings of case marking options and word order parameters) that determines the central aspects of grammar.

Our grammar will also contain some category-shifting processes that, for our purposes, can be cast as follows:

(12)a. If $\alpha \in P_{\mathrm{ADJ}}$, $F_2(\alpha) \in P_{\mathrm{CN/CN}}$, if $\alpha \in P_{\mathrm{PP}}$, $F_2(\alpha) \in P_{\mathrm{ADV}}$, where F_2 is the identity map.

b. If $\alpha \in P_{\mathrm{ADJ}} \cup P_{\mathrm{PP}}$, $F_2(\alpha)' = \lambda x[\alpha' \cap x]$ (i.e. $= \lambda x[{}^{\cap}\lambda y[{}^{\dagger\cup}\alpha'(y) \wedge {}^{\dagger\cup}x(y)]]$ – cf. (1) in Section 2.4)

We also introduce Montague-style rules of quantification and relativization:

(13) If $\alpha \in P_{\mathrm{NP}}$, $\psi \in P_{\mathrm{S}}$ and ψ contains an occurrence of he_n, $F_{3,n}(\alpha, \psi) \in P_{\mathrm{S}}$, where $F_{3,n}(\alpha, \psi) = \psi'$, ψ' the result of replacing the first occurrence of he_n in ψ with α, and substituting all subsequent occurrences of he_n with forms that agree in gender with α.

(14) If $\alpha \in P_{\mathrm{NP}}$ and $\psi \in P_{\mathrm{S}}$, $F_{3,n}(\alpha, \psi)' = \alpha'({}^{\cap}\lambda x_n \psi')$, if defined; $\lambda x_n \psi'(\alpha')$, otherwise.

These rules are adopted just because of their familiarity. Many alternatives are possible (and, indeed, desirable). Notice that the slight departure from Montague's original format in (14) is due to the fact that some NP's (e.g. proper names) are not directly interpreted as generalized quantifiers (although, the addition a sort-shifting rule that turns them into generalized quantifiers would be straightforward).

In the same vein, we provide the following rule of relativization:

(15) If $\alpha \in P_{\mathrm{CN}}$, $\psi \in P_{\mathrm{S}}$ and ψ contains at least an occurrence of he_n, $F_{4,n}(\alpha, \psi) \in P_{\mathrm{CN}}$, where $F_{4,n}(\alpha, \psi) = \alpha$ that ψ', where ψ' is obtained from ψ by deleting the first occurrence of he_n and replacing all subsequent occurrences with suitably inflected forms.

(16) If $\alpha \in P_{\mathrm{CN}}$, $\psi \in P_{\mathrm{S}}$, $F_{4,n}(\alpha, \psi)' = [\alpha \cap {}^{\cap}\lambda x_n \psi']$

These rules do not (and are not meant to) incorporate any treatment of island, ECP or across-the-board extraction phenomena.

Finally, we add a number of morphosyntactic rules:

(17) If $\alpha \in P_{\mathrm{IV}}$, $\mathrm{INFL}(\alpha) \in P_{\mathrm{VP}}$, where $\mathrm{INFL}(\alpha)$ is the result of changing the infinitival form of the main verb occurrence in α to its inflected indicative (3rd pers. sing.) form.

(18) If $\alpha \in P_{VP}$, $\text{INFL}(\alpha)' = {}^{\dagger\cup}\alpha$

(19) If $\psi \in P_S$ and the main verb occurrence in ψ is the simple present, then $\text{PAST}(\psi)$, $\text{FUT}(\psi) \in P_S$, where $\text{PAST}(\psi)$ is the result of changing the main verb occurrence in ψ to its future form, and analogously for $\text{PAST}(\psi)$.

(20) If $\psi \in P_S$, $\text{PAST}(\psi)' = \mathbf{H}\psi'$ and $\text{FUT}(\psi)' = \mathbf{W}\psi'$

(21) If $\psi \in P_S$ and the main verb occurrence in ψ is non negative, then $\text{NEG}(\psi) \in P_S$, where $\text{NEG}(\psi)$ is the result of replacing the main verb occurrence in ψ with its negative form.

(22) If $\psi \in P_S$, $\text{NEG}(\psi)' = \neg\psi'$

This concludes our exposition of a sample grammar based on PT_2. If the reader feels the need to get more familiar with its workings, s/he might want to work through some of examples provided in the appendix.

5. Some consequences

In the present section we are going to discuss some features of the sample grammar developed in Section 4. First we are going to consider some general characteristics of our overall approach, with special emphasis on the status of types versus sorts. Then we are going to discuss more specifically our grammar of predicative constructions and the role played in it by our "Fregean" perspective.

5.1. *Generalia*

The fragment in Section 3 is a slight extension of Montague's PTQ. This, essentially provides us with an injective map from classical Montague semantics into our property-theoretic semantics that shows how all positive features of the former can be lifted into the latter without introducing any extra complication. Furthermore, all the proposed extensions and revisions of classical Montague semantics (e.g. Dowty's treatment of tense and aspect, Carlson's treatment of bare plurals, Bach and Partee's treatment of anaphora, quantifier storage techniques, etc.) can also be straightforwardly implemented. Our adoption of the Partee and Rooth approach to sort-shifting is a simple illustration of the latter claim. Nothing is lost in the new framework.

Several things are gained. Let us consider some of them.

5.2.1. PT_2 is a fairly simple theory of intensional objects, that sets the basis for interesting theories of the attitudes. The fragment in Section 4 will assign to (1) the readings given in (2) and (3) respectively.

(1) John believes that Mary likes Sue

(2) believe′(j, like′(m, s))

(3) believe′(j, ^like′(m, s))

(We are using here, for ease of readability, the standard notation for relations rather than Montague's "curried" notation).

(3) states that the belief-relation holds between John and the worlds where Mary likes Sue. One can easily specify this further along the lines discussed by proponents of the possible worlds approach, e.g. by saying that (3) obtains just in case in every world compatible with John's beliefs, Mary likes Sue. On this construal, (3) will entail that John believes all the logical consequences of the proposition *Mary likes Sue*, which can be argued to capture the sense in which belief is a disposition to act, as discussed, e.g., in Stalnaker (1985). On the reading in (2), on the other hand, belief is cast as a relation of John to an information unit, which, arguably, captures the sense in which belief is a disposition to manipulate logical structures in deliberation and reasoning. We have briefly discussed in Section 2.4 some possible approaches to information units (a particularly promising one being the "structured meaning" idea), but we have to leave the details of this for some other occasion.

What we have here is in many ways a gross oversimplification. For example, our grammar treats (1) as ambiguous in a dichotomic way between (2) and (3). However, this semantic distinction should presumably be graded (i.e. (2) and (3) should be more like the extremes of a continuum) and appears to be context-dependent in ways which we are not capturing. While much further research is needed on this score, we think that something like the readings in (2) and (3) should be part of any principled solution to the problem of mental attitudes and we know of no other semantics which incorporates them both as smoothly within a unified framework.

5.2.2. Our basic domain of individuals enables us to quantificationally refer to anything (we have a universal sort e). We can prove in PT_2 that there are universal properties and we can straightforwardly account for the validity of Parsons' argument given in Section 1.3. We can express Russell's property. We have a way of expressing an extremely powerful truth predicate (via the operator '†'). Type theory and "typed" set theories, like Zermelo-Fraenkel, have none of these characteristics. On the face of it, natural language seems to have all of them. Thus PT_2 appears to be closer to natural language than these other approaches.

5.2.3. The theory of semantic domains built into our PT_2 semantics is simpler and more constrained than Montague's. In particular, our theory is designed to incorporate the following claims:

(1) only (1-place) functions (into *e* or into *i*) are nominalizable.
(2) only nominalized functions can be quantified over. There is no direct quantification over functions as such (of whatever sort).

We have already discussed (1) in Section 4.2.2; we shall discuss (2) in connection with our overall treatment of predication.

In particular, notice that functions are sorted in terms of their adicity and in terms of the sort of their arguments and that there are no functions that take other functions as their arguments, with the exception of intensional verbs (which are of sort $\langle Q, \mathrm{nf}\rangle$). We could have avoided that, since it is possible to represent generalized quantifiers inside our domain of individuals. But what happens then is the following. Take an extensional verb like *show up'*. If the generalized quantifier *some student'* is construed as a subsort of sort *e*, then $^{\cup}$*show up'* will be defined for it. This seems to predict that, say, the English sentence *some student hasn't shown up* will have a (true) reading represented by $\neg^{\dagger\cup}$*show up'*(*some student'*) which says that the property of being a property that some student has did not show up. Although we can somehow express this in English, as we just did, the English sentence *some student hasn't shown up* does not seem to have such a reading. Saying that *some student'* is not in the domain of $^{\cup}$*show up'* is one way of accounting for that, and it is the simplest we could think of. But better ways of dealing with these matters might well be found.

Our use of the term "sort" rather than "type" follows the tradition of reserving the former to horizontal partitions internal to the domain of individuals. Since our overall strategy has been to exploit the rich structure of our domain of individuals as much as we could and to limit the construction of function spaces external to our domain as much as we could, use of the term "sort" seemed appropriate. But the substantive issue does not lie in this terminological choice but in the theory of semantic domains that one adopts. We have tried to provide some preliminary reasons why the theory of semantic domains built into PT_2 is better designed to fit natural language semantics than Montague's. Other arguments will be considered in the next section.

We think that our strategy and the bulk of our choices has a certain amount of motivation which is independent of the particular theory of semantic domains that we have been discussing. We want a theory that enables us to make sense of self predication. This means that in some sense properties must be construable as individuals, which immediately leads one to construct a richer domain of individuals. The more powerful the property-theory, the richer the domain of individuals will be. In any first-order theory, functions over this set of individuals will be straightforwardly definable, and they will inherit whatever sortal structure the set of individuals has. But given that functions can be represented inside the domain of individuals, higher-order function spaces are generally not needed.

So, we think it is fair to conclude that general motivations internal to our property-theoretic concerns, do tend to lead to a theory of domains that supports natural language semantics better than standard type-theory (and its set-theoretic variants). This seems to remain true even if many aspects of the particular version of theory that we are adopting here clearly need further work.

5.3. *Reference to properties in natural language*

There various ways of referring to entities in natural language. Some such ways are quantificational, such as, for example, (1).

(1)a. John reads *every thing that Mary reads*
b. John reads *the thing that Mary reads*
c. John reads *whatever Mary reads*

Our grammar generates (1a, b) and assigns them the readings given in (2a, b) respectively.

(2)a. $\forall x[[\text{thing}'(x) \wedge \text{read}'(m, x)] \rightarrow \text{read}'(j, x)]$
b. $\exists x[\text{thing}'(x) \wedge \text{read}'(m, x) \wedge \forall y[\text{thing}'(y) \wedge \text{read}'(m, y)] \rightarrow x = y] \wedge \text{read}'(j, x)]$

To accomodate the free relative (1c), which intuitively appears to have a universal quantificational force, is quite straightforward. An easy way to do it would be in terms of the following pairs of rules:

(3)a. If $\psi \in P_S$ and ψ contains an occurrence of *he*$_n$, then $F_{5,n}(\psi) \in P_{NP}$, where $F_{5,n}(\psi) = \text{whatever } \psi'$ where ψ' is derived from ψ by deleting the first occurrence of *he*$_n$ and changing all subsequent occurrences to *it*.
b. If $\psi \in P_S$, $F_{5,n}(\psi)' = \lambda y_{nf} \forall x_n[\psi' \rightarrow {}^{\dagger\cup}y(x_n)]$

This pair of rules – especially the syntax – are of course rough approximations. See Cooper (1983) for relevant discussion of free relatives. Now on the basis of (3), (1c) would get the following logical form:

(4) $\forall x[\text{read}'(m, x) \rightarrow \text{read}'(j, x)]$

Given this analysis of (1a–c), any of the sentences in (1a–c) in conjunction with (5a) will entail (5b).

(5)a. Mary reads Principia
b. John reads Principia

That is, (5b) will follow from any of (1a–c) together with (5a), which appears to be intuitively correct. And a wide variety of similar inference patterns could be easily constructed.

Consider now the argument in (6).

(6)a. John tries *everything that Mary tries*
b. John tries *the same thing that Mary tries*
c. John tries *whatever Mary tries*
d. Mary tries {reading Principia / to read Principia}
e. John tries {reading Principia / to read Principia}[12]

It is intuitively clear that (6e) follows from any of (6a–c) in conjunction with (6d). And this is exactly what our grammar predicts. For it will assign to, say, (6c, d, e) the readings given in (7a, b, c) respectively:

(7)a. $\forall x[\text{try}'(m, x) \rightarrow \text{try}'(j, x)]$
b. $\text{try}'(m, \text{read}'(\text{principia}'))$
c. $\text{try}'(j, \text{read}'(\text{principia}'))$

where *read*′(*Principia*′) in (7b, c) is a nominalized property.

Thus on the basis of the simple apparatus needed to account for the elementary inferences involving (1) and (5), our grammar predicts the validity of arguments like the one in (6). What is crucial in obtaining this result is that properties be individuals and that infinitives and gerunds denote properties.

These results are more surprising than what it might, at first sight, appear, for the following reasons. An alternative conceivable semantics for infinitives and gerunds is to regard them as propositional creatures of some sort (information units, event-types or some other structure that "has a subject"). The reason why this is reasonable lies in the fact that infinitives and gerunds are generally understood as if they had a subject. For example, (6d) means something like "Mary tries to bring about a situation where Mary's reading Principia occurs". One way of accounting for this is by building it directly into the semantics of infinitives and gerunds, so that the truth conditional import of (6d) could be represented as something like (8).

(8) $\text{try}'(m, \text{read}'(m, \text{Principia}'))$

In fact, this propositional view of infinitives and gerunds appears to be held currently by a majority of generative linguists. What the validity of the argument in (6) suggests is that this view is probably wrong, for if (8) is the meaning of (6d) and (7a) the meaning of (6a), then what (6a) and (6d) should entail is something like:

(9)a. try′(*j*, read′(*m*, Principia′))
b. John tries to bring about a situation where Mary's reading Principia occurs.

But this is just not true. In conclusion, it would seem, prima facie, that on any variety of propositional analysis of infinitives and gerunds the validity of reasoning patterns such as those in (6) will be a total mystery.

One way of rescuing a propositional analysis of infinitives and gerunds would be to tinker with the interpretation of the italicized NP's in (6a–c) versus (1a–c). One might try to argue that, say, the italicized NP in (1a) really means every thing that Mary reads, while the italicized NP in (6a) could not literally mean every thing that Mary tries, but would have to mean something like every attribute that Mary tries to have. But while facts could be described this way, why should precisely this reading arise in precisely these cases would again remain a mystery.

These considerations would seem to confirm the hypothesis that infinitives and gerunds denote properties, as it accounts so naturally for the inference pattern in question.

A further consequence of the above considerations concerns the status of the italicized NP's in (6a–c). Such NP's will be (quantificational) ways of referring to properties. Their syntactic and semantic structure appears to be identical with the structure of the italicized NP's in (1a–c). Unless strong arguments to the contrary are offered, this suggests that they ought to be analyzed in just the same way, as on the present approach.

But this would not be possible on a type-theoretic approach. Within such an approach, the usual move in analysing, say, *read* versus *try* is to lift the type of *try*, so that it can take properties of individuals as one of its arguments. This entails that the type of the italicized NP's in (1a–c) and the type of the italicized NP's in (6a–c) will have to be different. In fact, it is not hard to see that this leads to an infinite multiplication of the types that each category is associated with (e.g. prepositions will have to be ranked differently on the basis of the type of the NP that they combine with, etc.), throughout the grammar. The most explicit analysis along these lines can be found in Parsons (1979) who provides a way to manage this infinite spread of "floating" types.[13]

Facts are further complicated by items that can take both "ordinary" NP's and gerunds (or infinitives), such as, say, *be fun*:

(10)a. John is fun
b. reading principia is fun
c. being fun is fun

To capture the relatedness of (10a) and (10b) on a type-theoretic approach (such as Parsons's) is hard. To capture (10c) in a way that meshes well with an overall plausible theory of gerunds appears to be close to impossible.

The strategy adopted here in analyzing, say, *read* versus *try* is the reverse of the standard type-theoretic approach. Instead of lifting the type of *try* with respect to the type of *read*, we lower the type of the argument of *try* as to make it of the same type as the argument of *read*. All the problems we have mentioned thus disappear; and, as far as we can tell, no new problem arises.

The above discussion overall supports in a strong way, we think, any semantics that treats properties as individuals. However, it does not seem to have any direct bearing concerning the "Fregean" view that properties also have an "unsaturated" character that must be kept separate from their individual character. We now turn to some evidence that we believe bears upon the latter issue.

Consider the descriptive generalization given in (11a) and illustrated in (11b, c).

(11)a. Finite VP's never occur as arguments of other VP's
b. *John forces Mary leaves
c. *John tries leaves

Many of the languages of the worlds (also outside of the Indoeuropean family) display a syntactic and morphological contrast in the verbal domain between finite and infinitival VP's. In any such language, as far as we know, there is no known exception to the generalization in (11): sentences like (11b, c) just never seem to arise. Why? Is there some specific property of language makes it behave this way?

On the present "Fregean" approach a simple hypothesis suggests itself. Finite VP's are information unit functions. As such they cannot be arguments of other information unit functions. They have, however, individual correlates that can occur in argument position. The latter are realized as infinitival VP's.

In slightly different terms, we can say that the distinction between properties as unsaturated structures and properties as saturated objects is a fundamental one in a theory like ours. If that theory underlies the semantic framework of natural language, one might expect such a distinction to manifest itself in some overt distributional and/or morphological pattern. For wouldn't it be strange, if such a semantic distinction is so pervasive, for it to go unmarked in language after language? We think so. Take, for example, another fundamental semantic distinction, the one between propositions and properties. Would it not be surprising if no language had distinct *syntactic* categories in which such semantic distinction is realized? Strange indeed. On the present theory, the distinction between information unit functions and individuals is as central as the distinction between information unit functions and information units (i.e. propositions). Consequently, it seems reasonable to expect both such distinctions to be, somehow, syntactically "visible".

We think that this expectation is warranted: the semantic distinction between propositional (information unit) functions and their individual correlates is realized in the distinction between finite and non finite VP's (at least, for the (many) languages that have such a distinction). The distributional characteristics of finite versus infinitival VP's (of which the one in (11a) is a central example) fall right into place, from this perspective.[14]

Let us contrast, now, the "Fregean" perspective with a non Fregean one, where properties are just treated as individuals. The theory developed, e.g., in Bealer (1982) is a good example in this connection. What would have such a theory to say about the generalization in (11a)? Nothing at all. From such a perspective, the pattern in (11), must have a syntactic account, as Bealer (1983, pp. 85 ff.) explicitly points out.[15] In fact, Bealer explicitly criticizes Frege for assuming the subject-predicate contrast has a semantic basis.

Now, Bealer's point might well be correct: the reason why paradigms such as the one in (11) are so widespread might be syntactic in nature. But suppose, for the sake of argument, that this is not so. Suppose, that is, that there is no independent syntactic principle from which the behavior of predicative expressions that we are considering could be derived. The following situation would, then, arise. Putting type-theory aside, we have two ways of developing theories of properties and predication. One maintains that there are propositional functions and embeds them in the domain of individuals. The other treats properties as being just individuals and regards predication as a special distinguished relation (presumably, a special individual, if relations are individuals as well). The former provides an account of the paradigm in (11) and the latter does not, as we have seen. We can thus conclude that *if* the paradigm in (11) (i.e. the finite/infinitival contrast) lacks a principled syntactic account, *then* (everything else being equal) the "Fregean" approach is to be preferred to the non Fregean one, as it provides some explanation for a phenomenon that otherwise would have none.

We conclude by providing some reasons for doubting that an autonomous syntactic explanation for (11) and related generalizations is likely to be very enlightening.[16] Luckily, we don't have to go through the usual exercise of building up straw man theories and then demolishing them. The generalization in (11) has, of course, been often noted and various purely syntactic ways of dealing with it have been proposed in virtually every current syntactic theory. So we can briefly look up (without any pretense of exhaustiveness) simply what such proposals have to say as far as explaining (11) goes and consider how they fare with respect to our semantic proposal.

If we look at non transformational theories, then perhaps Generalized Phrase Structure Grammar (GPSG), as developed in, e.g., Gazdar et al. (1985) is not unrepresentative of the way in which such theories have dealt so far with the particular issue of the distribution of inflectional affixes (that characterizes the finite/non finite contrast in English). As far as we can tell in Gazdar et al. (1985) there just is no account for the paradigm in (11). This can perhaps best be seen by looking at the list of rules for the grammar that they develop (p. 247). Each individual rule that introduces VP's in complement position explicitly stipulates that such VP has to be non finite. Their grammar would be no more complicated if the distribution of the feature INF (for infinitival) in complement VP's were random. If this is the whole story, the fact that in any language that has the finite/non finite contrast, non finiteness is used to mark VP's occurring in complement (i.e. argument) position would appear to be purely accidental, as far as syntax goes.[17]

A much more articulated approach to the issue at hand can be found within current transformational theories such as the one developed in, e.g., the Government and Binding (GB) framework of Chomsky (1981) and related work. The GB theory analyzes infinitives (and gerunds) as being syntactically clauses with a phonologically null pronominal subject, usually represented as PRO. So, for example, (12a) is analized syntactically as (12b).

(12)a. to leave

b. [$_S$PRO -INFL to leave]

Where -INFL (or -AGR, for "agreement") is an abstract feature that marks non finiteness. Within this theory the problem of accounting for (11) becomes the problem of accounting for the distribution of PRO. The standard solution to this problem is to say that +INFL assigns case to the subject, while -INFL does not, and that PRO must occur in caseless position.

The details of this account need not concern us here. What we would like to point out in this connection is first that our semantic account is not incompatible with the overall GB view and second that in effect the GB framework would benefit significantly from incorporating it.

Our idea is that finite VP's are functions (and hence cannot occur in argument position) while non finite VP's are individuals (and hence must occur in argument position). From this perspective we could simplify the GB theory of case by reducing it essentially to:

(13) functions assign case

The fact that +INFL (or +AGR) is a case assigner would then follow from what inflected (i.e. finite) VP's in general *mean*. The distribution of PRO (whose interpretation, under the present analysis would involve an abstraction operator, like λ)[18] could then be derived just like before. This is desirable since presumably what contributions INFL makes to meaning needs to be specified on any theory. What we are suggesting is that this specification by itself should suffice to derive the case assigning properties of finite versus non finite VP's (and consequently the distribution of PRO).

But there is more to our semantic account. Even if most infinitives within GB are analyzed as in (12), very strong arguments (internal to the GB theory) have been given to analyze certain infinitival constructions as bare (i.e. subjectless) VP's. A very strong case to this extent has been made recently by Burzio (1986) concerning certain causative constructions in Romance. He argues extensively that the syntactic structure of (14a) is (14b).

(14)a. Maria fa riparare la macchina (da Giovanni)
Maria has the car repaired (by Giovanni)
b. Maria $[_{VP}$ $[_{V}$fa$]$ $[_{VP}$ riparare la macchina (da Giovanni)$]]$

where the causative verb subcategorizes directly for VP (rather than for S). Now, even if such constructions are expected to have a marked status within the GB theory, still the point can be made that the generalization in (11) applies to them as well. We know of no case where the subcategorized VP is inflected. It is far from clear that the original purely syntactic explanation in terms of case the assigning properties of +INFL would extend to these cases where a bare VP is selected. Our semantically based modification of such explanation, on the other hand, clearly does. Nothing special needs to be said about the cases in (14): finite VP's cannot be subcategorized for because they are of the wrong logical type for being arguments.

These considerations are of course preliminary and the proper assessment of these matters would require much more extensive discussion than the one that we have been able to present here. However, what we have done does constitute enough of an argument to the extent that even the best developed syntactic theory of the phenomena in (11) that we know of would benefit significantly from a principled incorporation of the "Fregean" semantics for predication that we have developed. A non Fregean theory of properties and predication appears to have nothing to offer to such theory on this score.

Our conclusion is tentative but non the less bold: a "Fregean" approach to properties and predication meshes better with what we currently know about natural language syntax than a non Fregean approach.

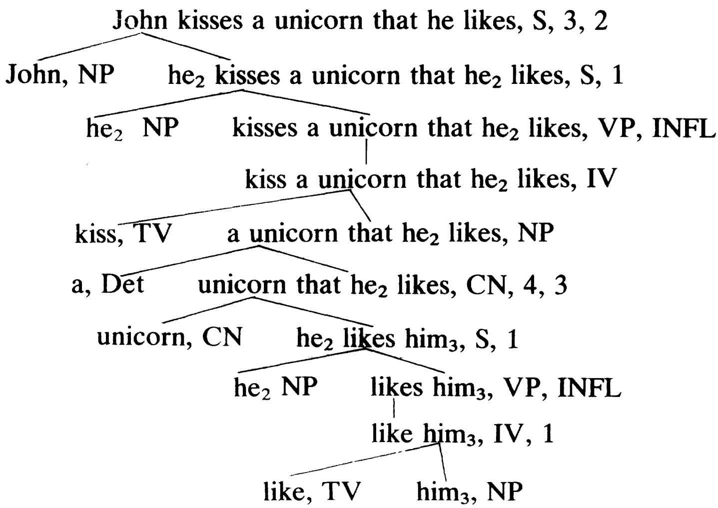
5.3. *Final Remarks.*

We have developed a first-order property theory and argued for its semantic effectiveness. Many problems are left open and most of the topics that we have dealt with are in need of much more work. However, we hope to have illustrated on the one hand what kind of empirical semantic issues can be relevant in designing a property-theory and on the other hand what kind of tremendous potential property-theories with certain characteristics have for the proper assessment of central issues in semantics and philosophy of language.

APPENDIX: SOME EXAMPLES

1. John kisses a unicorn that he likes

(1) Analysis tree



(2) unreduced translation:
$\lambda x_2[^{\dagger\cup}[\text{kiss}']_Q\ (\text{a}'(\text{unicorn}' \sqcap {}^{\cap}\lambda x_3[^{\dagger\cup}\text{like}'(x_3)(x_2)]))(x_2)](j)$

(3) reductions

a. $^{\dagger\cup}[\text{kiss}']_Q(\text{a}'(\text{unicorn}' \sqcap {}^{\cap}\lambda x_3[^{\dagger\cup}\text{like}'(x_3)(j)]))(j)$ λ-red.

b. $^{\dagger\cup\cap}\lambda y[\text{a}'(\text{unicorn}' \sqcap {}^{\cap}\lambda x_3[^{\dagger\cup}\text{like}'(x_3)(j)])({}^{\cap}\lambda x[^{\cup}\text{kiss}'(x)(y)])](j)$ definition of $[\ ]_Q$

c. $^{\dagger}\lambda y[\text{a}'(\text{unicorn}' \sqcap {}^{\cap}\lambda x_3[^{\dagger\cup}\text{like}'(x_3)(j)])({}^{\cap}\lambda x[^{\cup}\text{kiss}'(x)(y)])](j)$ $^{\cup\cap}$-canc.

d. $^{\dagger}\text{a}'(\text{unicorn}' \sqcap {}^{\cap}\lambda x_3[^{\dagger\cup}\text{like}'(x_3)(j)])({}^{\cap}\lambda x[^{\cup}\text{kiss}'(x)(j)])$ λ-red.

e. $\lambda y_{\text{nf}}\exists z_e[^{\dagger\cup}[\text{unicorn}' \sqcap {}^{\cap}\lambda x_3[^{\dagger\cup}\text{like}'(x_3)(j)]](z_e) \wedge {}^{\dagger\cup}y_{\text{nf}}(z_e)]({}^{\cap}\lambda x[^{\cup}\text{kiss}'(x)(j)])$ axiom on *a*′

f. $\exists z_e[^{\dagger\cup}[\text{unicorn}' \sqcap {}^{\cap}\lambda x_3[^{\dagger\cup}\text{like}'(x_3)(j)]](z_e) \wedge {}^{\dagger\cup\cap}\lambda x[^{\cup}\text{kiss}'(x)(j)](z_e)]$ λ-red.,

g. $\exists z_e[^{\dagger\cup}[\text{unicorn}' \sqcap {}^{\cap}\lambda x_3[^{\dagger\cup}\text{like}'(x_3)(j)]](z_e) \wedge {}^{\dagger\cup}\text{kiss}'(z_e)(j)]$ λ-red. $^{\cup\cap}$-canc.

h. $\exists z_e[^{\dagger\cup\cap}\lambda y[^{\dagger\cup}\text{unicorn}'(y) \wedge {}^{\dagger\cup}\text{like}'(y)(j)](z_e) \wedge {}^{\dagger\cup}\text{kiss}'(z_e)(j)]$ def. of $\sqcap$

i. $\exists z_e[^{\dagger}[^{\dagger\cup}\text{unicorn}'(z_e) \wedge {}^{\dagger\cup}\text{like}'(z_e)(j)] \wedge {}^{\dagger\cup}\text{kiss}'(z_e)(j)]$ λ-conv., $^{\cup\cap}$-canc.

j. $\exists z_e[^{\dagger\cup}\text{unicorn}'(z_e) \wedge {}^{\dagger\cup}\text{like}'(z_e)(j) \wedge {}^{\dagger\cup}\text{kiss}'(z_e)(j)]$ axioms on †.

II. Further examples (only reduced translations are provided).

(1)a. Mary seeks a unicorn

b. $^{\dagger\cup}\text{seek}'(\text{a}'(\text{unicorn}'))(\boldsymbol{m})$

(2)a. John tried to talk

b. $\mathbf{H}\ ^{\dagger\cup}\text{try}'(\text{talk}')(j)$

(3)a. John believes that Mary will protest

b. $^{\dagger\cup}\text{believe}'(\mathbf{W}^{\dagger\cup}\ \text{protest}'(\boldsymbol{m}))(j)$

c. $^{\dagger\cup}\text{believe}'(^{\wedge}\mathbf{W}^{\dagger\cup}\text{protest}'(\boldsymbol{m}))(j)$

On reading (c), (a) will entail:

d. $^{\dagger\cup}\text{believe}'(^{\wedge}[\mathbf{W}^{\dagger\cup}\text{protest}'(\boldsymbol{m}) \wedge [^{\dagger\cup}\text{talk}'(b) \vee \neg^{\dagger\cup}\text{talk}'(\text{b})]])(j)$

(4) Let autoidentical′ $= {}^{\cap}\lambda x_e[x_e = x_e]$

a. being autoidentical is autoidentical

b. ${}^{\cap}\lambda x_e[x_e = x_e] = {}^{\cap}\lambda x_e[x_e = x_e]$

Notes

* We would like to thank Barbara Partee for patiently inducing us to talk to one another at a time where perhaps we thought that that wasn't so urgent and for much good advice

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[1] Please note the scare quotes. We do not necessarily regard the view of properties just sketched as a philologically correct reconstruction of Frege's notion of property.

[2] Actually, PT_1 can be developed within a totally unsorted, first-order language – see Turner (1987a, b). We introduce at the outset a minimum of sorting to facilitate the transition to the extension of PT_1 that we will use for semantic purposes.

[3] This provides us with one way of handling relations. If one wanted to have relational constants one would need to add either further sorts (as we will do in Section 4) or a pairing construction – see Turner (1987a).

[4] This is the theory of Turner (1987a).

[5] In fact, there are many. E.g. $\lambda x_e[(x_e = x_e) \& \psi]$, where ψ is any tautology.

[6] By standard set-theory, we mean any set-theory that like Zermelo-Fraenkel's one has an axiom of foundation.

[7] Alternatively, we could lift the meaning of run′ to run* = {Q: Q is a generalized quantifier and run′ $\in Q$} and say that every man runs iff every man′ $\in$ run*. This would allow one to treat verbs as being uniformly "the functions". See Bach (1980), Keenan and Faltz (1985) for discussion.

[8] The degree of strength of this claim varies across various authors. An interesting discussion of the role of type theory in this perspective can be found in Schmerling (1983).

[9] Montague adopts the functional theory of simple types where sets are represented by their characteristic functions and every relation is "curried". In the example in the text, we are also putting aside intensions.

[10] See e.g. Gazdar et al. (1985) for more discussion of this point.

[11] The only case we know of that could be arguably regarded as nominalization of transitive verbs is represented by equational contexts of the form *to love is to exault*, where we seem to be equating, intuitively, two relations. The case, however, is controversial. See Dowty (1985) and Higginbotham (1986) for relevant discussion.

[12] For the present purposes we assume that gerunds are syntactically NP's (unlike infinitives) and semantically denote nominalized functions (like infinitives). The present argument goes through whatever the syntactic analysis of infinitives and gerunds is.

The introduction of gerunds in the grammar is totally straightforward, and we will not do it explicitly. Notice also that to say that gerunds and infinitives both denote properties does not commit us in any way to claiming that they have identical meanings.

[13] See Chierchia 1984 for a more detailed discussion of Parsons' theory.

[14] One of the anonymous referees reminded us of a generalization which appears to be parallel to (11), illustrated in (a).

(a)i. clauses can occur in argument position only if they have a complementizer.
ii. That John went is funny
iii. *John went is funny

Our approach, as it stands does not capture the paradigm in (a). It is not completely clear to us that it should. What is at stake in (11) is the finite/non finite contrast, while in (a) it is the presence versus absence of complementizers. The two issues overlap but do not, prima facie, coincide. Anyway, if it turned out that (a) really is related to (11), then we could say that information units (i.e. propositions) are not individuals but have individual correlates, just like functions. The complementizer might be, then, what maps information units into their individual correlates (and this is why it is needed in (iii)). This view would be particularly natural under the common assumption that propositions are, in fact, 0-place propositional *functions*. This position is articulated further in Chierchia (1984).

[15] One of the anonymous referees suggests that (11) might have a pragmatic account, i.e. that the facts in (11) do not follow from any syntactic or semantic principle. The exceptionless character of the paradigm in (11) strongly argues against such view. Pragmatic principles can be overridden, without causing ungrammaticality. Syntactic and semantic ones cannot. (Which is not to deny that many syntactic and semantic principles can have a pragmatic source).

[16] This attempt has been made more extensively in Chierchia (1984, 1985).

[17] In fact, a criticism along these lines to VP-analyses of infinitives can be found, in a more articulated form, in Koster and May (1982).

[18] Let us tentatively suggest, for the sake of concreteness, that a structure of the form, say, $[_S$PRO to leave$]$ is interpreted as $^{\cap}\lambda x[^{\dagger\cup}\text{leave}'(x)]$.

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