A Guide to Dynamic Semantics

Paul Dekker

ILLC/Department of Philosophy
University of Amsterdam
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1 Introduction

In this article we give an introduction to the idea and workings of dynamic semantics. We start with an overview of its historical background and motivation in this introductory section. An in-depth description of a paradigm version of dynamic semantics, *Dynamic Predicate Logic*, is given in section 2. In section 3 we discuss some applications of the dynamic kind of interpretation to illustrate how it can be taken to neatly account for a vast number of empirical phenomena. In section 4 more radical extensions of the basic paradigm are discussed, all of them systematically incorporating previously deemed pragmatic aspects of meaning in the interpretational system. Finally, a discussion of some more general, philosophical and theoretical, issues surrounding dynamic semantics can be found in section 5.

1.1 Theoretical Background

What is dynamic semantics. Some people claim it embodies a radical new view of meaning, departing from the main logical paradigm as it has been prominent in most of the previous century. Meaning, or so it is said, is not some object, or some Platonic entity, but it is something that changes information states. A very simple-minded way of putting the idea is that people uses languages, they have cognitive states, and what language does is change these states. "Natural languages are programming languages for minds", it has been said. Others build on the assumption that natural language and its interpretation is not just concerned with describing an independently given world, but that there are lots of others things relevant in the interpretation of discourse, and lots of other functions of language than a merely descriptive one. Eventually, or so it is claimed, a theory of meaning of natural language must therefore extend the standardly given descriptive or referential semantics, and seek to incorporate such arguably pragmatic aspects of interpretation.

No matter how one may think of it, various developments in the theoretical approach to meaning have conspired to the development and appeal

of what is called a 'dynamic' semantics nowadays, this to such an extent and success that a retrospective evaluation and critical assessment of an established paradigm is in place. Dynamic semantics can be seen to find its roots in the philosophy of language and epistemology; in cognitive and psychological models of meaning; in practical and computational accounts of interpretation; and in theory internal problems and autonomous developments in the formal semantics of natural language. In this introduction we would first like to say a few words on the first three kinds of roots, and then take off from the fourth.

Quite a while before the development of a tradition of formal semantics in theoretical linguistics, several aspects of meaning later picked up in dynamic semantic frameworks already presented themselves as major themes in the philosophy of language and epistemology. From the early twentieth century, the interplay between language, meaning, knowledge and belief became one of the main themes in the writings of, among many others, Gottlob Frege, Bertrand Russell, Ludwig Wittgenstein, and Rudolf Carnap. The notions and their central role in philosophy, logic, and methodology, played an important part in their writings, centering around the notion of truth as a central concept. A common theme was the contextuality (or egocentricity, not subjectivity) of these notions, and in a sense this theme broadened its scope when these notions got studied in their actual guise: their use. Ludwig Wittgenstein, most notably, eventually focused on the embeddedness of language, knowledge and meaning in the forms of life and being. Related philosophers, like Peter Strawson, John Langshaw Austin, Herbert Paul Grice and John Rogers Searle more in particular engaged with the question what kind of activity language is, and what actions it allows us to perform. From this, it was only a small step to conceive of language as a form of goal-directed behavior, a substantial part of which can be studied in terms of the changes in the context in which it is used, which, like we said, is one of the targets of dynamic semantics.

In the eighties of the previous century, dynamic logics have been developed in the area of computer science. Dynamic logics enable one to reason about computer programs, and to prove, e.g., correctness, or termination conditions. (Prominent investigators are Vaughan Pratt, David Harel.) These logics can be taken to describe, in an abstract manner, transformations of computer states induced, for instance, by runs of a program. Abstracting from all kinds of concrete properties of these states, and of the execution of these programs, the programs are associated with relations on states, which characterize so-called input and output states of runs of the program. This perspective on programming languages has been transplanted on natural language in dynamic semantics, in which the sentences of a language are also conceived of as state transformers. The meanings of indicative (descriptive) sentences then is spelled out, not in terms of their truth or truth conditions, but in terms of their intended effect, or their application and execution conditions. In later, more pragmatic and communication oriented extensions of dynamic semantics, also tools and concepts

of theoretical computer science are being used which have been developed in the area of (artificial or virtual) agent theory and communicating robots, see, e.g., the groundbreaking (Halpern et al. 1995).

With the 'dynamic turn' information states start to play a key role, and certain theoretical conceptions of these have also, of course, figured prominently in theoretical psychology and cognitive science. Certainly the more cognitively oriented views on meaning, like those of, e.g., Jerry Fodor, George Lakoff, and Ray Jackendoff are directed at characterizing meaning in terms of mental languages, mentalese, or internalized languages of thought. Present day versions of cognitively oriented semantic systems of interpretation acknowledge that meaning is a matter of construal and conventionalization and that, hence, the composition of meaning requires one to seriously take pragmatic aspects like context and intention into account. Obviously these and previous developments have led to the idea that in interpretation, natural language utterances have to be mapped on something like an internal language, and it is precisely this metaphor that has inspired Hans Kamp, one of the predecessors of dynamic semantics, to his discourse representation theory in the early eighties of the previous century. Before we give a, concise, sketch of Hans Kamp's original program, we first adduce some more language internal motivation for a dynamic account of interpretation in the next section.

1.2 The Linguistic Impetus

A variety of linguistic observations, not all of which are treated in detail in this overview article, point to the need of something like a dynamic semantics for natural language or a dynamic account of interpretation. Mostly employed are examples with anaphoric pronouns, definite noun phrases and presuppositions. Consider:

(1) A dog enters the garden. It is barking.
(1′) ?It is barking. A dog enters the garden.

(2) If a cat is hungry it usually meows.
(2′) ?It usually meows if a cat is hungry.

In both the conjunctive variant and the conditional one, a pronoun appears well-behaved if it is preceded by a noun phrase, an indefinite one here, which may serve as its *ante*cedent. Turning things around produces an odd discourse, or at least one in which the pronoun has to be resolved differently. This phenomenon is often rephrased by the locution that the indefinite noun phrase may set up a discourse referent which can be referred back to by a subsequent pronoun.

The next example employs definite descriptions:

(3) Mike has children. Mikes sons are blues and his daughters are soul.
(3′) Mikes sons are blues and his daughters are soul. Mike has children.

Once we have introduced Mike's children, we are entitled to talk about his sons and daughters, but if we already have talked about Mike's sons and daughters

it doesn't make sense to say he has children.[1] Apparently, asserting certain things may make it appropriate or inappropriate to assert other things, in other words, it changes the relevant context for them. Very much the same thing can be observed in the following pair of examples:

(4) Rebecca married Thomas. She regrets that she married him.
(4′) Rebecca regrets that she married Thomas. ?She married him.

The following two pairs of examples have to do with discourse relations.

(5) Bob left. Conny started to cry.
(5′) Conny started to cry. Bob left.

Most people are inclined to judge the first as implicating that Conny is weak-hearted, while the second seems to implicate that John is a rude jerk. Surprisingly, the two examples only differ in the order of the two coordinated sentences. If the two reported events are ordered as they are presented in (5), Bob's leaving seems by default to precede, and cause, Conny's crying; if they are reported as presented in (5′), Conny appears to have cried first, and then, and probably therefore, Bob left. It is absolutely not difficult to read the examples so that they get the other reading. The main point is that *some* relation between the two events gets assumed and that the interpretation of the two sentences must allows for such an (ordered) connection.

Something similar goes on in the following pair of examples.

(6) Max turned off the light. The room was pitch dark.
(6′) ?The room was pitch dark. Max turned off the light.

Upon a natural, temporally ordered, interpretation, example (6) first relates of Max switching the light off, and relative to that, as a result most probably, the room was pitch dark. Example (6′) first presents the interpreter with a state of the room being pitch dark, and then has Max turning off the light, however odd this may seem. Again, in both examples, we find two sentences, which report corelated facts. It does not appear to be sufficient to simply state that both facts obtain, for a certain connection has to be inferred.

The following examples have to do with discourse acts.

(7) I tell you your wife is cheating on you; now you know it.
(7′) Now you know your wife is cheating on you; I tell you.

The first is a perfectly coherent (but hard) thing to say. The, second, in the circumstances in which the first is fine, is queer, if not straightout false. For a similar reason, the following sentence may be true, when uttered, but in a sense a successsful assertion of it cannot be successfully iterated:

(8) Phoebe is waiting for your door, and you don't know it!

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1. Or it should be a conclusion "So, Mike has children," or to say something pressing with it, like: "Well, you know, that's what it means, 'having children'!" or: "They're real children!"

Apparently, saying something may affect a change in the context so that what is said, which was true when uttered first, turns out false afterwards.[2]

The last examples are conditionals, in which, arguably, the antecedent (or *if*-) clause affects the interpretation or evaluation of the consequent clause (often a *then*-clause). To begin with, a sentence "If A then B" seems be true in exactly the same situations as those in which "A only if B" and "If not B then not A" are, at least the three are equivalent in standard sentential logic. Now consider the perfectly acceptable, and most probably true, sentence from James McCawley, 1974:

(9) If butter is heated it melts.

Compare this sentence with the hardly acceptable sentence:

(9′) ?Butter is heated only if it melts.

(9″) ?If it doesn't melt butter isn't heated.

It seems that the first sentence causes the interpreter to focus on situations in which butter is heated, and let him see that in those situations, butter generally melts, as a consequence. In the other two sentences the melting seems to be presented as something like a necessary cause, which it isn't of course, and that may make these sentences awkward. Notice that the described dependencies may be the same or similar, but that the perspective is set up in different ways.

The fact that a conditional's antecedent may provide the ground for the consequent or main-clause also shows from the classical dynamic example:

(10) If a farmer owns a donkey he (normally) beats it.

When asked "Who beats what?", there seems to be no definite answer, other than a conditional one, viz.: "The farmer who owns a donkey, and the donkey that that farmer owns, in situations in which a farmer owns a donkey." Clearly, the answer can only be given relative to such possible situations as they are set up by the antecedent clause. Something similar goes on in the following example:

(11) If a linguist solicits she gets the job.

Again, when asked who gets the job the answer may be the linguist, if any, if she solicits. In this case, however, one may rightly ask what happens if two or more linguists solicit. Most probably the matter is undecided: at least one of them will get the job, but it remains unclear which one. It seems that in this case the situation set up by the antecedent is one in which a linguist solicits and which somehow ignores the cases in which more linguists do.

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2. In a light-hearted version of this examle there is a non-cooperative dynamic semanticist replying as follows:

(A) I haven't told you yet, but Jane is going out tonight.

(B) What haven't you told me yet?

(A) That Jane is going out tonight.

(B) But then you just told me!

Finally look at examples(12) and (12′).

(12) If Isabel is in the bathroom, Petra might be there, too.

(12′) If Isabel is in the bathroom and nobody else is, Petra might be there, too.

The first example is perfectly acceptable, whereas the second is up to inconsistent. From a standard logical perspective this is rather strange. For if Isabel is in the bathroom and nobody else is, then, logically speaking, Isabel is in the bathroom, so with example (12) we might want to conclude that Petra might be there, too. But we should not conclude this, because if there is nobody else, then neither is Petra. Somehow, again, the antecedent make us focus on situations in which Isabel is in the bathroom, and leave us ignorant on who else is there.

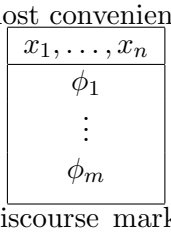
The above are a very limited number of examples which have been raised to show the need of a notion of dynamic interpretation. The idea then is that language depends on context, and that it changes the context, in discourse, but also in sentences themselves, like in conditional sentences. These two simple and obvious ideas may serve to explain that one cannot always swap two conjuncts, or reverse a conditional, or repeat a sentence. The examples above by the same token serve to indicate that 'context change' is a programmatic slogan only. In order to account for the relevant example the right notions of context have to be defined, and the ways in which language may change them.

1.3 Discourse Representation Theory

Hans Kamp's original paper (Kamp 1984) explicitly intended to bridge the apparent gap between formal logically oriented approaches to the semantics of natural language, and the cognitive modeling of reasoning and meaning from cognitive psychology. To this end, he employed (part of) the language of first order predicate logic as an essential ingredient in the interpretation of natural language. This representation language serves two main roles at the same time. On the one hand, it is used to state the contents, read: truth conditions, of natural language utterances, or rather of that of whole discourses. This, in almost the same way in which logical languages have been used to that purpose before. On the other hand, they form an essential ingredient in the process of interpretation, since already established representations of an ongoing discourse may be key to the understanding of parts which are as yet to come. They mimick, so to speak, the models the cognitive agents make of the discourse as it has been interpreted till a certain point, and which they make up and use in further processing. The ensuing architecture is aptly called *discourse representation theory* (*DRT*).

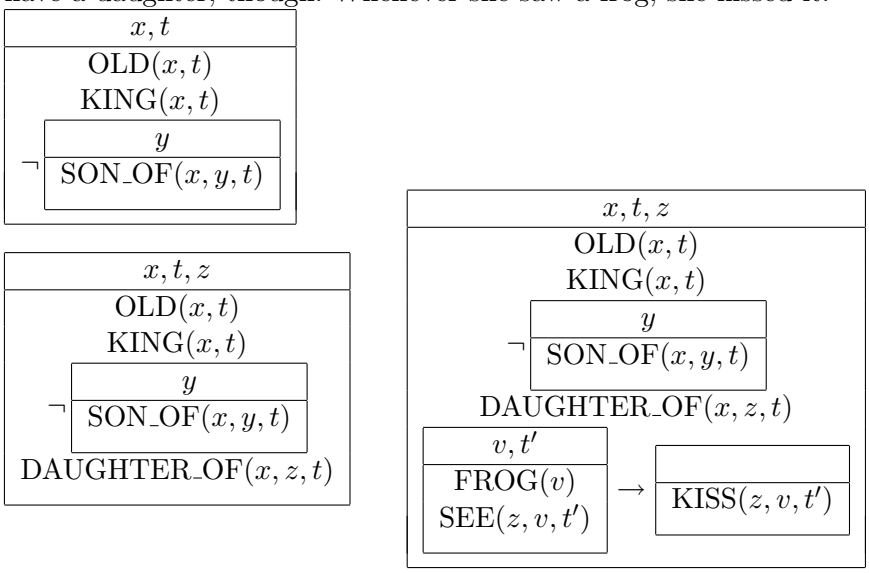
The language of *DRT*, the sentences of the language of discourse representation structures basically consists of, first a set of variables, or discourse markers, and, second, a set of conditions on these discourse markers. The set of discourse markers serves to represent the domain of discourse, the entities

which have been mentioned, introduced and at issue, at a certain point in the interpretation of a discourse. The conditions are there to ascribe properties to them, viz., the properties with which these discourse items have been dressed so far. Discourse representation structures, or *DRS*s, can be graphically displayed in a most convenient form as:

- 

The discourse markers, or variables, $x_1, \ldots, x_n$ make up the domain of this representation, and at the same time figure as labels for entities in the actual world. Truth-conditionally, such a *DRS* is equivalent with a predicate logical counterpart $\exists x_1 \ldots \exists x_n(\phi_1 \wedge \ \ldots \ \wedge \phi_m)$. Due to its recursive nature, conditions may themselves employ *DRS*s, so that if K_1 and K_2 are *DRS*s, then $\neg K_1$, $(K_1 \rightarrow K_2)$ and $(K_1 \vee K_2)$ are conditions in *DRS*s again. Thus, for instance, the *DRS*s in (14) form a way of representing the contents of a little fancy discourse like (13) at three stages in its interpretation:

(13) Once upon a time there was an old king, who didn't have a son. He did have a daughter, though. Whenever she saw a frog, she kissed it.

(14) 

These two *DRS*s represent the contents of the discourse in (14)—in a rudimentary form which we need not dwell upon here—after processing the first sentence, the first two sentences, and after processing the whole. Notice that the material contributed by the second and the third sentence gets *added to* (as a matter of fact: *in*) the representations that result from processing the first and the first two sentences. In this way, the pronouns *He* and *she* are appropriately related to the established domain of discourse. Notice that this way of constructing the representation for the whole discourse necessarily takes

place at the representational level. If we were to look at the truth conditions of the intermediate representations only, it would a mystery how the anaphoric relationships could get established.

We end this introductory section with some historical remarks on the treatment of indefinite anaphoric relationships and the study of discourse reference. The subject has gained prominence by, among many others, the logico-philosophical work of Peter Geach (Geach 1962) and Lauri Karttunen's seminal but relatively informal work on discourse reference (Karttunen 1968) in the sixties of the previous century. Hans Kamp and Irene Heim were the first, independently, to present a formal framework of interpretation for anaphoric phenomena, *DRT* and *File Change Semantics* (*FCS*) respectively, the first originally published in 1981, the second in 1982 (Kamp 1984; Heim 1989).[3]

After *DRT* had settled as one of the major semantic frameworks, the need for a more classical and arguably semantic approach developed, and this gave rise to the theories of interpretation of Peter Staudacher, first presented in 1986, and of Jon Barwise and Groenendijk and Stokhof, the last one of which gained most prominence (Staudacher 1987; Barwise 1987; Groenendijk and Stokhof 1991). A very substantial contribution has been presented by Pieter Seuren (Seuren 1985). These systems, and their off-spring, have generally been labeled as 'non-representational', 'compositional', and 'dynamic'. Many alternatives, notational variants, and extensions gained their way in the nineties of the previous century. Some were almost indistinguishable from Heim's own 'non-representational' formulation of her File Change Semantics. Some were tailored to find the algebraic, non-dynamic, analogue of these systems (Henk Zeevat); some were concerned with the true mathematical notion of a context (Kees Vermeulen and Albert Visser); some with its computational aspects and implementation (Jan van Eijck) (Zeevat 1989; Vermeulen and Visser 1996; van Eijck 2001). Most, however, were concerned with extensions, and application of the dynamic notion of interpretation to other phenomena, see sections 3 and 4 of this article.

Of course, in the nineties and in the present century, discourse representation theory remained as a highly attractive and successful framework. Simultaneously so-called E-type approaches and epsilon- or choice function approaches, which already existed before the dynamic turn, established themselves as appealing non-dynamic treatments of indefinite anaphora. (See, for instance, (Heim 1990; Barker 1997) and (Slater 2000; von Heusinger 2004.) However, although these approaches have established a lively tradition, they didn't gain the status of a rival framework, simply because they are tailored to giving a treatment of indefinites and pronouns in a standard framework of interpretation. See section 2 for a little more discussion.

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3. A bit misleadingly, both were classified as theories of discourse representation at the time, since Heim was not mainly concerned with discourse representation as such, but, eventually, with a compositional architecture of interpretation.

2 Dynamic Predicate Logic

2.1 Underlying Ideas

As indicated above, Dynamic Predicate Logic (henceforth: *DPL*, Groenendijk and Stokhof 1991), emerged as a reply to *DRT*'s representational treatment of anaphoric relationships. Implicit in *DRT*'s presentation and part of its appeal is the idea that a realistic account of interpretation should take into account the representations people make up of the contents of an ongoing discourse they are engaged in. Anaphora appeared to be a strong case in point. Intuition (together with Karttunens informal, but theoretical observations) strongly suggest that pronouns are used to refer to entities which have been mentioned in previous discourse. The interpretation of pronouns thus consists in establishing a relation of coreference with a term, which is (part of) a representation of an entity.

One of the main philosophical or methodological points of *DPL*—as a matter of fact this is something that is presented as a demonstrative proof—is that at least the phenomenon of anaphora, after all, does *not* motivate a representational architecture of interpretation. It is submitted that, as many people have realized, the treatment is problematic in standard architectures, like that of, e.g., Montague grammar, but this only shows that *some* modification of such architectures is required. Such a modification may consist in resorting to a representational formulation of the semantics as in *DRT*, but the adoption of a dynamic notion seems to serve the same purpose as well. In *DPL*, an arguably non-representational but dynamic account is presented of the basic data original *DRT* was developed for.

For methodological reasons the dynamics of *DPL* is restricted to the phenomenon of anaphora. As G&S says "It [*DPL*], too, restricts the dynamics of interpretation to that aspect of the meaning of sentences that concerns their potential to 'pass on' possible antecedents for subsequent anaphors, within and across sentence boundaries." (Groenendijk and Stokhof 1991) As we will see later on in this chapter, there is much more to the dynamics of interpretation than the 'on-line' interpretation of anaphoric relationships only. However, in order to get a firm conceptual grip on the immediate prerequisites and consequences of a dynamic style of interpretation, it is expedient to focus on one, structural, phenomenon only, and not to complicate matters too much in advance. Besides, as we seen above, the issue of a compositional and computational account of anaphoric relationships had already raised itself as a problem in the logico-linguistic community.

In *DPL*, then, the dynamics is concerned with information about things that may get introduced in a discourse, and which may serve as possible antecedents for subsequent anaphoric pronouns. This idea is fleshed out in a rather obvious way. As is usual linguistics, noun phrases (indefinite noun phrases and pronouns as well) are associated with indices, or variables, so as to be able to indicate cases of coreference and binding. The relevant information then is information about

the possible values of these variables, which may get changed and updated in discourse. Consider the following little discourse, with indices (variables) on the relevant noun phrases, and some 'check-points' for us to see what the relevant information is in Groenendijk and Stokhof's sense.

(15) $\checkmark_0$ Mary borrowed (a copy of *Naming and Necessity*)$_x$ from (a professor in linguistics)$_y$.$\checkmark_1$ The pages were covered with comments and exclamations.$\checkmark_2$ (He)$_y$ must have been studying (it)$_x$ intensively.$\checkmark_3$

Asumming this is the start of a discourse, at check-point 0 we have no information about the discourse whatsoever, so that all variables can have any value.[4] At check-point 1 a copy of *Naming and Necessity* has been introduced, with label x, and a professor in linguistics, with label y, and these are dressed with the information that Mary borrowed (the value of) x from (the value of) y. At check-point 2 more information is added about the value of x, it is a rather worn-out copy, and at check-point 3, finally, the supposition is added that (the value of) y studied (the value of) x intensively. The discourse, thus interpreted in a step by step manner, turns out true iff we can find such values of x and y, that is, iff in reality there is a copy of *Naming and Necesiity* with a lot of comments and exclamation marks of a professor in linguistics who had studied it intensively and from whom Mary borrowed it.

2.2 DPL Interpretation

The above, rather informal, observations have been implemented formally in the system of *DPL* in the following way. In our formulation we employ the format of (Groenendijk and Stokhof 1991) and define the notion $[\![\phi]\!]_M$, the interpretation of a (first order predicate logical) formula ϕ relative to an ordinary (first order predicate logical) model M, as a set of pairs of variable assignments, input – possible output assignments $\langle g, h\rangle$. The idea, as it is formulated, is that such a pair $\langle g, h\rangle$ is in the interpretation of ϕ relative to M iff upon input assignment g ϕ can be successfully interpreted and yield as a possible output assignment h.[5] Reference to M is omitted below if not needed.

We first give the language. A language L for dynamic predicate logic (henceforth *DPL*) is that of ordinary first order logic, based on sets C of individual constants c and sets $\mathcal{R}^n$ of relational constants R of arity n, and a denumerable set of variables V. The set of terms $T = C \cup V$ consists of the individual constants and variables of the language, atomic formulas $Rt_1 \ldots t_n$ are composed of n-ary predicates R and a sequence of n terms $t_1, \ldots, t_n$, or

4. In more-than-one issue systems it may have to be assumed that initially there is already somebody known as Mary and something known as *Naming and Necessity*.

5. We have chosen to follow Groenendijk and Stokhof's notation because it is mathematically the most transparent one. Notational alternatives of the same notion of interpretation can be obtained by writing $\langle g, h\rangle \in [\![\phi]\!]_M$ as $h \models_{M,g} \phi$ or as $g[\![\phi]\!]_M h$. The second notation here more closely resembles the standard satisfaction notation of ordinary static predicate logic; the third notation display the dynamic relational notion of interpretation more clearly. Of course, being notational variants, the differences are immaterial.

they are of the form $t_i = t_j$, stating the identity of (the values of) the terms t_i and t_j. The formulas of *DPL* are built up from atomic formulas using negation ($\neg$), existential and universal quantification ($\exists x$, $\forall y$), and conjunction ($\wedge$), disjunction ($\vee$), and (material) implication ($\rightarrow$).

Like we said the interpretation of *DPL* is defined relative to models M for L. A model $M = \langle D, V\rangle$ is a usual first order model with a domain of individuals D and an interpretation function V for the individual and relational constants of our language. The function V assigns an individual $V(c) \in D$ to the individual constants of L and a set of n-tuples of individuals $V(R^n) \subseteq D^n$ to its n-ary relational constants. In the interpretation of *DPL* we also use variable assignments f, g, h, k, l which assign individuals $f(x) \in D$ to the variables $x \in V$, so they are functions from V to D. The interpretation $[t]_{M,g}$ of a term t in a model M and relative to assignment g is $V(t)$ if t is an individual constant and $g(t)$ if t is a variable.

We use $g[x/d]$ for the variable assignment h that is like g except that it assigns d to x, so for all $y \in V$, if $x \neq y$ then $g[x/d](y) = g(y)$ and if $x = y$ then $g[x/d](y) = d$. We say $g[x]h$ iff assignment $h = g[x/d]$ for some individual d, and we state $g[X]h$ iff $X = \{x_1, \ldots, x_n\}$ and there are $k_1, \ldots, k_{n-1}$ such that $g[x_1]k_1$, ..., and $k_{n-1}[x_n]h$.[6] Using these notation devices we can state the semantics of *DPL* as follows:

Definition 1 (DPL Semantics)

- $[\![Rt_1 \ldots t_n]\!]_M = \{\langle g, h\rangle \mid g = h \text{ and } \langle [t_1]_{M,g}, \ldots, [t_n]_{M,g}\rangle \in V(R)\}$
  $[\![t_i = t_j]\!]_M = \{\langle g, h\rangle \mid g = h \text{ and } [t_i]_{M,g} = [t_j]_{M,g}\}$
  $[\![\neg\phi]\!]_M = \{\langle g, h\rangle \mid g = h \text{ and for no } k\text{: } \langle g, k\rangle \in [\![\phi]\!]_M\}$
  $[\![\exists x\phi]\!]_M = \{\langle g, h\rangle \mid \text{for some } k\text{: } g[x]k \text{ and } \langle k, h\rangle \in [\![\phi]\!]_M\}$
  $[\![\forall x\phi]\!]_M = \{\langle g, h\rangle \mid g = h \text{ and for all } k\text{: if } g[x]k$ then there is h: $\langle k, h\rangle \in [\![\phi]\!]_M\}$
  $[\![\phi \wedge \psi]\!]_M = \{\langle g, h\rangle \mid \text{for some } k$: $\langle g, k\rangle \in [\![\phi]\!]_M \text{ and } \langle k, h\rangle \in [\![\psi]\!]_M\}$
  $[\![\phi \vee \psi]\!]_M = \{\langle g, h\rangle \mid g = h \text{ and for some } k\text{: } \langle g, k\rangle \in [\![\phi]\!]_M$ or for some k: $\langle g, k\rangle \in [\![\psi]\!]_M\}$
  $[\![\phi \rightarrow \psi]\!]_M = \{\langle g, h\rangle \mid g = h \text{ and for all } k\text{: if } \langle g, k\rangle \in [\![\phi]\!]_M$ then there is h: $\langle k, h\rangle \in [\![\psi]\!]_M\}$

Except for existentially quantified formulas and conjunctions, input assignments g and output assignments h in the interpretation of a formula are guaranteed to be the same, if, that is, the model M and assignment g satisfy certain relatively standard conditions. That is, if an atomic formula like $Rt_1 \ldots t_n$ or $t_i = t_j$ is true relative to M and g then the input-output pair $\langle g, g\rangle$ is in the interpretation of such a formula. Intuitively this says that, if that test succeeds, g is accepted as possible input and that the interpretation of the formula does not

6. So, $g[X]h$ iff $g(x) = h(x)$ for all variables $x \notin X$, and $g[\emptyset]h$ iff $g = h$.

change anything in its output. And if the test fails then g is not accepted as possible input: in that case there is no assignment h such that $\langle g, h\rangle$ is in the interpretation of that formnula.

Exactly when this is the case, that is, when the conditions imposed by a formula ϕ upon M and g are not satisfied, then its negation *is* satisfied, and g is a possible input for $\neg\phi$ relative to M. In other words, if ϕ cannot be executed upon input g, then $\neg\phi$ can, and its interpretation will yield g again as output. In these cases, nothing really dynamic is going on. If relevant tests are satisfied in a context (relative to an assignment), then the context is accepted and remains unchanged.

This fact typically changes when it comes to existentially quantified formulas. According to the above definition, if we have some input assignment g, then the interpretation of $\exists x\phi$ requires us to try out any assignment k which differs from g only in its valuation of x, then see if it serves as an input for interpreting ϕ, and if it does and outputs h, then h is also a possible output for interpreting $\exists x\phi$ on input g. Notice that if x indeed, as in most examples, occurs free in ϕ, and ϕ imposes certain conditions on the valuation of x, then the output valuation of x, but not the input valuation, will have to satisfy these conditions. Somehow, something with the properties attributed to x is introduced by such a formula, and this something, also known as a discourse referent, is labeled with the variable x.[7] A conjunction does not change any context all by itself, but it does preserve, or rather compose, possible changes brought about by the combined conjuncts. That is to say, if ϕ accepts an input g and produce some possibly different output k, and if ψ accepts k as input and deliver h as possible output, then the conjunction $\phi \wedge \psi$ accepts g as possible input upon which h is a possible output. This implements the dynamic idea that the interpretation of $\phi \wedge \psi$ involves the interpretation of ϕ first and ψ next.

The remaining clauses in the definition are static again, if satisfied. They do not bring about changes in the assignments, and they are fairly easy to understand. A formula $\forall x\phi$ requires ϕ to be true relative to all (re-)valuations of x; a disjunction requires at least one of its disjunct to be satisfied. Only the interpretation of an implication is a bit more involved. An implication $\phi \rightarrow \psi$ is true (relative to M and g) iff relative to all ways of satisfying ϕ on input g in M, ψ is true as well. Since ψ here gets evaluated relative to outputs of interpreting ϕ, dynamic effects of ϕ may affect the interpretation of ψ. An implication, as it is said, is or can be 'internally dynamic'.[8] This concludes our exposition of *DPL*.

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7. This does not go without qualification though. It may happen that in ϕ itself something else may be introduced, also under the label x; we neglect this possibility whenever irrelevant.
8. But not 'externally dynamic', because if the (dynamic) test expressed by an implication is satisfied upon input g, the output will be g itself again.

2.3 DPL Illustrations

By way of illustration, let us first consider a simple example in detail, throughout neglecting reference to a model M.

(16) A farmer owned a donkey. It was unhappy. It didn't have a tail.
$\exists x(Fx \wedge \exists y(Dy \wedge Oxy)) \wedge (Uy \wedge \neg\exists z(Tz \wedge Hyz))$

Relative to input assignment g this will have as output assignment h if we can find assignments k and l such that k is a possible output of interpreting $\exists x(Fx \wedge \exists y(Dy \wedge Oxy))$ relative to g, and l a possible output of interpreting Uy relative to k, and h a possible output of interpreting $\neg\exists z(Tz \wedge Hyz)$ relative to l. Since the second formula is atomic, and the third a negation, we know that in that case $k = l$ and $l = h$. Assignment k (that is: h) is obtained from g by resetting the value of x so that $k(x) = h(x) \in I(F)$, and by next resetting the value of y so that $k(y) = h(y) \in I(D)$ and $\langle h(x), h(y)\rangle \in I(O)$. That is, $h(x)$ is a farmer who owns a donkey $h(y)$. Observe that for any farmer f and donkey d that f owns, there will be a corresponding assignment h': $g[\{x, y\}]h'$ and such that $h(x) = f$ and $h(y) = d$.

The second conjunct first tests whether y is unhappy, that is, whether $l(y) = k(y) = h(y) \in I(U)$. The third conjunct, a negation, tests whether assignment h cannot serve as input to satisfy the embedded formula $\exists z(Tz \wedge Hyz)$. This subformula is satisfied relative to h iff there is an assignment h' such that $h[z]h'$ and $h'(z) \in I(T)$ and $\langle h'(y), h'(z)\rangle \in I(H)$, that is, iff we can change h's valuation of z into anything that is a tail had by $h(y)$. The negation of the subformula tests whether we can *not* change the valuation of z in that way. Putting things together, $\langle g, h\rangle$ is in the interpretation of our example (16) iff $g[\{x, y\}]h$ and $h(x)$ is a farmer who owns a donkey $h(y)$ which is unhappy and does not have a tail. Observe, once more, that for any farmer f and unhappy tail-failing donkey d that f owns, there will be a corresponding assignment h': $g[\{x, y\}]h'$ and such that $h(x) = f$ and $h(y) = d$.

What we see in the example above is that a free variable y, for instance in the second conjunct, gets semantically related to, or effectively bound by, a preceding existential quantifier which does not have the variable in its syntactic scope. This is an example of a much more general fact about interpretation in *DPL*, which goes under the folkloric name of a 'donkey equivalence':

Observation 1 (Donkey Equivalences) For any formulas ϕ and ψ

- $(\exists x\phi \wedge \psi) \equiv \exists x(\phi \wedge \psi)$
  $(\exists x\phi \rightarrow \psi) \equiv \forall x(\phi \rightarrow \psi)$

These equivalences are classical, but for the fact that they do *not* come with the proviso that x not occur free in ψ. As a matter of fact, this is key to the understanding of *DPL* that free variables thus may get bound by previous existential quantifiers, and, as in the second case, with a strong (universal effect). The use of the second equivalence is exemplified by the following, canonical (whence the

folkloric name of the equivalences), examples:

(17) If a farmer owns a donkey, he beats it.
$(\exists x(Fx \wedge \exists y(Dy \wedge Oxy)) \rightarrow Bxy)$

(18) Every farmer beats every donkey he owns.
$\forall x(Fx \rightarrow \forall y((Dy \wedge Oxy) \rightarrow Bxy))$

These two sentences have generally been deemed equivalent, and so are the associated, natural, *DPL*-translations.[9]

There are some other equivalences generally valid in *DPL* that deserve our attention.

Observation 2 (Equivalences that Hold)

- $\neg\neg\neg\phi \equiv \neg\phi$ $\quad\quad$ $\forall x\phi \equiv \neg\exists x\neg\phi$
  $(\phi \vee \psi) \equiv \neg(\neg\phi \wedge \neg\psi)$ $\quad$ $(\phi \rightarrow \psi) \equiv \neg(\phi \wedge \neg\psi)$

These equivalences are all classical. The first is a (restricted) form of the law of double negation, and the other three show $\forall$, $\vee$ and $\rightarrow$ to be definable in terms of $\exists$, $\neg$ and $\wedge$ in a standard way.[10] As we have seen, however, $\neg$, and as a consequence $\forall$, $\vee$ and $\rightarrow$, are operators that introduce tests without any further dynamic impact. That is, if ϕ contains a quantifier with binding potential, this potential gets lost when it occurs under a negation, or under a universal quantifier, or in a disjunction or an implication. This can be motivated by the observation that the pronouns in the following examples do not seem to be resolved, or at least not bound by the indefinite which figures in the scope of one of these operators:

(19) Farley doesn't have car. It is red.

(20) Every man here owns a car. It is a mustang.

(21) Mary has a donkey or she doesn't have one. It brays.

These technical, and seemingly intuitive, observations have as a consequence that certain other classical equivalences do not hold in *DPL*:

Observation 3 (Equivalences that do Not Hold)

- $\neg\neg\phi \not\equiv \phi$ $\quad\quad$ $\exists x\phi \not\equiv \neg\forall x\neg\phi$
  $(\phi \wedge \psi) \not\equiv \neg(\neg\phi \vee \neg\psi)$ $\quad$ $(\phi \wedge \psi) \not\equiv \neg(\phi \rightarrow \neg\psi)$

The law of double negation does not hold in general, since a double negation, while it preserves the truth-conditional content of a formula, it undoes its dynamic effects. The other non-equivalences show that we cannot do without $\neg$

9. As a historical side-remark, Urs Egli, in 1979, proposed to add the above equivalences, by mere stipulation, to a standard system of interpretation, just in order to account for the anaphoric puzzles that plagued the literature. One of the merits of *DPL* is that its semantics generates these equivalences as true theorems.

10. Notice that, as a consequence of the above equivalences, $(\phi \vee \psi)$ is also equivalent with $(\neg\phi \rightarrow \psi)$.

and $\exists$ and $\wedge$. Any attempt to define them in terms of the other operators fails.[11]

2.4 Dynamic Consequences

Before we investigate some of the maybe most remarkable properties of a system of dynamic interpretation like that of *DPL*, it is useful to present (dynamic variants of) notions of truth and entailment:

Definition 2 (DPL Truth and Entailment)

- Formula ϕ is true relative to model M and assignment g (written as: $\models_{M,g} \phi$) iff there is an assignment h such that $h \models_{M,g} \phi$, i.e., iff there is an assignment h such that $\langle g, h\rangle \in [\![\phi]\!]_M$.
- A sequence of formulas $\phi_1 \ldots \phi_n$ (in that order) entail ψ (written as: $\phi_1, \ldots, \phi_n \models \psi$) iff relative to all models M and all assignments g_n, if there are assignments $g_0, \ldots g_{n-1}$ such that $\langle g_0, g_1\rangle \in [\![\phi_1]\!]_M$, $\ldots$, and $\langle g_{n-1}, g_n\rangle \in [\![\phi_n]\!]_M$ then $\models_{M,g_n} \psi$.

Truth relative to a model M and assignment g is defined in a relatively standard way. It is not just required that ϕ be satisfied, but that it can be satisfied, i.e., that there is some output assignment h in the interpretation of M relative to input assignment g. In a dynamic way of speaking, it says that the program ϕ can be executed relative to M and g, something which as a matter of fact means that the conditions are satisfied which ϕ imposes on M and g (or on the values g assigns to free variables in ϕ).

While the notion of truth can be seen as a mere adaptation of a standard notion of truth to a slightly more involved notion of interpretation (in terms of sets of *pairs* of assignments, rathers than sets of assignments simpliciter), the notion of entailment is inherently dynamic. According to the standard definition the conclusion of an entailment should be true whenever all the premises are. According to the definition of dynamic entailment it is required that whenever a whole sequence of premises, in that order, is satisfied, then the conclusion must be true as well, *relative to* the (or rather: any) output assignment resulting from the interpretation of the premises. Actually, this allows for binding relations between existentials occurring in the premises and free variables in the conclusion and this serves to justify two lines of reasoning found in the literature. Consider the following examples, with corresponding translation:

(22) If a man is from Rhodes, he is not from Athens.
Here is a man from Rhodes.
So he is not from Athens. (Heim)
$\exists x(Mx \wedge Rx) \rightarrow \neg Ax, \exists y(My \wedge Ry) \models \neg Ay$

(23) A: A man has just drunk a pint of sulphuric acid.
B: Nobody who drinks sulphuric acid lives through the day.

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11. Notice that also $\phi \rightarrow \psi$ is not equivalent with $\neg\phi \vee \psi$.

A: Very well then, he wont live through the day. (Geach)
$\exists x(Mx \wedge DPSAx), \neg\exists y(DPSAy \wedge LDy) \models \neg LDx$

The (simplified) entailments are valid in *DPL*.

As usual, a special case of entailment is one in which the sequence of premises is empty. A formula ψ is said to be valid ($\models \psi$) iff it is entailed by an empty sequence of premises, that is, iff $\models_{M,g} \phi$ relative to all models M and assignments g. The deduction theorem shows how $\rightarrow$ and $\models$ are connected:

Observation 4 (Deduction Theorem)

- An entailment $\phi_1, \ldots, \phi_n \models \psi$ holds iff $\phi_1, \ldots, \phi_{n-1} \models (\phi_n \rightarrow \psi)$ holds, iff $\models (\phi_1 \rightarrow \ldots (\phi_n \rightarrow \psi) \ldots)$ holds.

Acknowledging the strong interpretation of existentials in the antecedent of an implication, this shows that existentials in the premises of an entailment are also interpreted strongly, says, as *any* individual that satisfies the things existentially quantified over. For, schematically: $\exists x\phi \models \psi$ iff (deduction theorem) $\models (\exists x\phi \rightarrow \psi)$ iff (donkey equivalence) $\models \forall x(\phi \rightarrow \psi)$.

The notions of *DPL*-truth and *DPL*-entailment conveniently serve to illustrate *DPL*'s characteristic properties. In order to see this, let us first define what is called the normal binding form of a *DPL*-formula. The normal binding form ϕ^* of a *DPL*-formula ϕ is a formula fully equivalent with ϕ, but in which the semantic binding relations correspond exactly to the usual syntactic scope relations. It is defined as follows:

Definition 3 (DPL Normal Binding Form)

- $(Rt_1 \ldots t_n)^* = Rt_1 \ldots t_n$
  $(\neg\phi)^* = \neg(\phi)^*$
  $(\exists x\phi)^* = \exists x(\phi)^*$
- $(Rt_1 \ldots t_n \wedge \psi)^* = (Rt_1 \ldots t_n)^* \wedge (\psi)^*$
  $(\neg\phi \wedge \psi)^* = (\neg\phi)^* \wedge (\psi)^*$
  $((\exists x\phi) \wedge \psi)^* = (\exists x(\phi \wedge \psi))^*$
  $((\phi \wedge \psi) \wedge \chi)^* = (\phi \wedge (\psi \wedge \chi))^*$

The following two results are relatively easily established:

Observation 5 (DPL, Normal Bindings Forms, and PL)

- In all M, $[\![\phi]\!]_M = [\![\phi^*]\!]_M$.[12]
- $\models_{M,g} \phi^*$ in *DPL* iff $\models_{M,g} \phi^*$ in PL.[13]

12. For the first five clauses this follows by induction on the construction of ϕ and for the last two the equivalence in addition follows from the semantics of $\exists x$ and $\wedge$.
13. The proof proceeds again by induction on the construction of ϕ^*, together with the observation that in ϕ^* we find no subformulas of the form $\psi \wedge \chi$ where ψ is not atomic or a negated formula.

The first clause tells us that ϕ and ϕ^* are fully equivalent in *DPL*. The second tells us that normal binding forms ϕ^* have standard, static truth conditions. It follows that a normal binding form ϕ^* gives a *static, i.e., standard* account of the truth conditions of the formula ϕ under its *dynamic, i.e.,* DPL interpretation. So, whatever effects are obtained by the dynamic interpretation of a formula ϕ, these have been captured or formulated in a static way in the normal binding form of ϕ.

Armed with this observation we can establish what the difference between static and dynamic predicate logic precisely consists in. For, from a classical perspective the only 'surprising' clause in the definition of the normal binding form of a formula is the one dealing with a conjunction with an existentially quantified first conjunct. These observations thus imply that the only difference between *DPL* and static predicate logic is that it allows us to define the truth conditions of $\exists x(\phi \wedge \psi)$ in a dynamic way as $\exists x\phi \wedge \psi$, and, indeed, this was the goal initially envisaged by professor Egli.

Now we have established that *DPL* has successfully modified static predicate logic in that it (just) allows for dynamic binding of variables, it is time to reflect upon the consequences this move willingly or unwillingly has on the ensuing logic. An immediate consequence of this dynamification, for instance, is that conjunction is no longer commutative, that is, it is no longer in general the case that $\phi \wedge \psi$ and $\psi \wedge \phi$ are equivalent. Of course this can be expected from any account of the dynamics of interpretation. If formulas are both context dependent and capable of changing the context, then it matters, of course, whether we first interpret ϕ and then ψ, or the other way around.[14]

For basically the same reasons, formally and intuitively, the dynamic entailment relation is not monotone, not reflexive, and not transitive. An entailment may dynamically hold, because upon any way of satisfying the premises the conclusion holds. But then an additional premise may undo the required effects of the first.[15] Hence, the relation is not monotone. An essentially similar example shows entailment not to be reflexive: a formula may change a context in which it is satisfied into one in which it is not.[16] Finally, cutting out the middle term of a two step entailment may involve cutting out an essential—entailed but not executed—change in the context. Consider the following type of reasoning, after an example from Johan van Benthem:

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14. A somewhat stilted example is the conjunction of ϕ: *x is a boy who courts a girl*$_y$ (or $Bx \wedge \exists y(Gy \wedge Cxy)$), and ψ: *y is a girl who courts a boy*$_x$ (or $Gy \wedge \exists x(Bx \wedge Cyx)$). The conjunction $\phi \wedge \psi$ can be satisfied by two boys and one girl in a way that the conjunction $\psi \wedge \phi$ is not; and similarly $\psi \wedge \phi$ can be satisfied by two girls and one boy in a way in which $\phi \wedge \psi$ is not.

15. Compare the quasi-natural entailment: "Let x be even. So, x is even." with the quasi-natural non-entailment; "Let x be even. .... Now, let x be odd. So$^?$, x is even." In *DPL*, $\exists xEx \models Ex$, but $\exists xEx, \exists xOx \not\models Ex$.

16. In *DPL*, $(Ex \wedge \exists xOx) \not\models (Ex \wedge \exists xOx)$. A more natural example, but not formalized in *DPL*, is example (8) above.

(24) If Jane has a house, she has a garden and if Jane has a garden, she sprinkles it. Now Jane actually has a house. So[1] she has a garden, and, so[2] she sprinkles it.

This type of reasoning is fine, intuitively, and it is valid in *DPL*. However, if we cut out the first conclusion, the one headed by "So[1], ...", the result is odd, and certainly not valid. To conclude this section, it appears that, what seems to be a minimal change in the semantics of predicate logic, i.e., enabling a form of dynamic binding, has rather far-fetched consequences for the ensuing logic.

3 Dynamic Linguistic Applications

The scope of a system of dynamic interpretation has been broadened by extending the sorts of things dynamically talked about and quantified over, that is, by taking into account all kinds of things other than plain individuals, that tend to be introduced in discourses and dialogues, and that live and obtain at some sometimes more, sometimes less explicit levels of discussion and of a sometimes less, sometimes more abstract nature. The variety of things is in principle unlimited, as it may concern plurals objects, groups, masses, structured groups and masses, events, times and intervals, facts and propositions, situations, worlds, and what have you.

In this section we briefly review extensions of the domain of a dynamic system of interpretation that have been proposed in the literature. We will only scarcely raise the issue of whether the domains of discourse should really be taken to be populated by the whole diversity of entities conceivable in natural language metaphysics, simply because the very same questions pertain to the domain of natural language metaphysics itself.

3.1 Plurals and Anaphora

For a dynamic account of plurals and plural anaphora at least three issues present themselves, the first two of them directly pertaining to the task of providing an interpretation for plurals as such, and the other pertaining to the dynamic endeavour. Once we start dealing with plurals, the domain of discussion somehow has to include plural entities, and predications over plural entities. This automatically raises a couple of questions. Are these plural entities individuals themselves, or sets, or collectives, or groups? How do predicates apply to them, distributively or collectively? What does it mean to negate a property of a group? How do groups get related in relational structures, again in a distributive or collective way, or in a mix of these ways, or in a so-called cumulative way? These two types of question, one into the ontology of plurals and the other into their use in predicational structures, have to be faced by any account of plurals, and we will not dwell upon them here.

The third type of questions is more concerned with plural anaphora and their dynamic interpretation. Like other plural terms, plural pronouns may be

taken to refer to sets, and their actual interpretation may be guided by the same principles. An occurrence of the pronominal term *they* can be interpreted distributively ("each of them"), neutrally ("all of them"), or collectively ("they ... together"), like definite or indefinite noun phrases such as "the farmer" and "three students" can. The main difference could be taken to reside in the fact that indefinite and definite plurals relate to plurals entities in the way indefinite and definite singular ones relate to singular entities, also when it comes to the introduction of discourse referents, and their subsequent anaphoric retrieval. However, something more has to be said here.

In the first place, plural pronouns (and definite plural noun phrases) can be seen to pick up plural entities which have not as such been introduced in the discourse. Consider:

(25) Bob and Carol went to play bridge with Ted and Alice. They had a wonderful evening.

The plural form of the pronoun "they" indicates that it should not be taken to refer to either Bob, or Carol, or Ted, or Alice. It can, however, refer to the couple of Bob and Carol, which can be taken to constitute the plural subject of the first sentence, but also to the whole group of four, Bob, Carol, Ted and Alice.[17] Notice that this group of four as such has not been mentioned in the first line of example (25). Somehow this plural referent has to be constructed, or inferred, from the four individual persons that have been explicitly introduced. This process of forming plural discourse referents is called 'summation', after (Kamp and Reyle 1993).

Besides summation more can be at stake. Consider:

(26) Seven pupils and four teachers wrote five ballads and some rhymes. They performed them at an evening during the spring holiday.

Upon a rough, and certainly not wrong, reading, the sentence can be taken to introduce a set or group X of seven pupils and four teachers, and a set or group Y of five ballads and some rhymes, such that X wrote Y and X performed Y at a certain evening. Of course, the writing of Y by X can be given much more analysis. Maybe the intended reading is that the pupils wrote the ballads and the teachers the rhymes; may be all of the eleven individuals wrote all of the ballads and rhymes together; maybe each of the pupils wrote five ballads and each of the teachers some rhyme.

Likewise, the pronouns "they" and "them" can be taken to require further analysis as well, possibly depending on the particular kind of reading associated with the first sentence. Upon one, straightforward, reading, and maybe independent of the reading associated with the first sentence, all of the producers involved performed all of the products involved. Upon another, the performers, individually or group-wise, can be taken to have performed the ballads and rhymes *they wrote*. Upon this analysis, the truth conditions of the second

17. Maybe also to the group consisting of Bob, Carol and Ted, under certain circumstance unfortunate to Alice.

sentence are dependent on the analysis chosen for the first, so that the dynamics of interpreting the first sentence must, not only deliver just two plural discourse referents, but some internal relation between these referents as well. This requirement, discussed by various authors, to begin with (van den Berg 1990; Kamp and Reyle 1993), will be taken up again in the next subsection. For a more general overview of the issues having to with reference plural objects, see, for instance, (Does 1993; Lønning 1997).

3.2 Generalized Quantifiers

We distinguished three types of questions above with regard to a dynamic treatment of plurals. When it comes to generalized quantifiers, and if we neglect the issue of quantification over plural entities, the first two can be said to be settled quite well in the linguistic canon, and it is mainly the dynamic treatment of quantifiers that has led to an additional amount of debate.

Generalized quantifiers, or determiners, are usually taken to combine two meaningful elements, a nominal denotation and a verbal denotation, as in "Every boy smokes," and "Most cats dislike fish." The general form is $D(A)(B)$, where $D(A)$ is generally conceived of as a noun phrase (NP). Such a structure generates at least three potential loci of dynamic interaction: between material in the nominal part (A) and in the verbal (B) part; between the noun phrase ($D(A)$) and subsequent utterances; and between the verbal part, as it figures in the scope of noun phrase, and subsequent utterances. We look at each of the three loci in turn.

The first locus for dynamic interpretation has received most initial interest, because if we look at determiners which correspond to the first order classical four quantifiers, intuitions have seem to be settled, while intuitions widely drive apart when it comes to inherently second order quantifiers. The first fabulous four have their own natural rendering in first order predicate logic, and if this is interpreted dynamically, as in *DPL*, the results look fine. Consider the following three examples, with translation, and consecutive interpretation:

(27) A farmer who owns a donkey beats it. $(\exists x((Fx \wedge \exists y(Dy \wedge Oxy)) \wedge Bxy))$, i.e.: a farmer who owns a donkey beats a donkey he owns.

(28) No farmer who owns a donkey beats it. $(\neg\exists x((Fx \wedge \exists y(Dy \wedge Oxy)) \wedge Bxy))$, i.e.: no farmer who owns a donkey beats any donkey he owns.

(29) Every farmer who owns a donkey beats it. $(\forall x((Fx \wedge (\exists y(Dy \wedge Oxy)) \rightarrow Bxy))$, i.e.: every farmer who owns a donkey beats every donkey he owns.

However, such first order representations are not generally available when it comes to genuine second order quantifiers which express relations between sets. Consider a quantifier like *MOST*:

(30) Most farmers who own a donkey beat it.

Upon the received analysis, the quantifier expressed by *MOST*, upon its most prominent interpretation, is supposed to hold of two sets A and B, iff the

number of A's that are B exceeds the number of A's that are not. Deciding the number of A's is fairly easy, also when A is dynamically interpreted, but it may be difficult to establish the number of B's, for B contains a pronoun apparently anaphoric on material in A. This issue has raised a whole tradition of discussion of its own.

As a way out (Kamp and Reyle 1993; Chierchia 1992) have proposed that the general, schematic analysis of sentences like (30) should really be $D(A)(A\&B)$, so that example (30) can be taken to say that most farmers who own a donkey, own a donkey and beat it. By thus copying the nominal part A into the verbal part B, anaphoric relationships can be established there locally, and in the *DRT* or *DPL* way. However, it has been argued by several authors, including Chierchia himself, that for several determiners and in several contexts this delivers too weak truth conditions; in these cases, instead, one should take $D(A)(A \rightarrow B)$ as an analysis, thus raising the reading that most farmers who own a donkey beat every donkey they own. Despite a lot of discussions about which reading to favour when, further observations, and many alternatives, the matter unfortunately remains under dispute, theoretically as well as empirically. Maybe this is not without reason, though, for empirical findings from (Geurts 2002) suggest that the theoretical dilemma here corresponds to an actual interpretative crisis people face when confronted with the relevant examples.

When it comes to the second locus of dynamic interpretation in quantified structures the data seem to be more robust, although still allowing for a variety of implementations. The data here are mainly taken from (Kamp and Reyle 1993), and (Nouwen 2003), which gives a good overview of the relevant literature. In the first place, it must be clear that the dynamics of quantified noun phrases should not be modeled after that of the existential quantifier in *DPL*. For only very few determiners allow for schematic equivalences equating $D(A)(B)$ *and He/They* C with $D(A)(B$ *and* $C)$. The noun phrase $D(A)$ in quantified structures of the form $D(A)(B)$ may avail of an antecedent for subsequent anaphora, but its referent has to be set up. Here, various options are possible. The (discourse) referent may be the set of all things which are A, as in example (31), but this may be a case of noun anaphora as well.

(31) Only some men came to the meeting. They, i.e., the men, hate it.

Alternatively, the referent may be the set of all those who are A *and* B, as in:

(32) Quite a few men came to the meeting and they, i.e., the men who came, did have a good time.

This format seems to be the most generally available option, and it has been worked out in detail in (Kamp and Reyle 1993; van den Berg 1996; Nouwen 2007).[18] A formal, and fully general, generation of this kind of referent set is

18. It is already an old observation that we also find 'complement anaphora', where the quantified structure relates to a set of things which are A and *not* B:

costly, but feasible, no matter whether it be done in a representational format like that of *DRT*, or in a dynamic semantic fashion.

A good example of dynamic effects on the third location is (a variant of) one from (Nouwen 2007):

(34) Almost all students chose a book. Most of them wrote an essay about it.

The first sentence in this example can be taken to yield the set of students who chose a book, and this is the set of individuals "them" refers to. Assuming not everyone of them chose the same book, there is no singular referent figuring as the chosen book. At first sight, at best, one might think that the first sentence thus relates to, not the set of students who chose a book, but also to the set of books chosen by a student. However, this may not be sufficient. A natural interpretation of the second sentence of (34) has it that most of the students each wrote an essay about a book that each of them individually chose. Having merely the sets of choosing students and that of chosen books available, does not allow us to recover which student chose which book.

For this reason (Kamp and Reyle 1993; van den Berg 1996; Nouwen 2007) turn the relevant discourse referents for example (34) into some kind of relational structures. The discourse referents do not induce two sets of singular individuals, they are taken to induce a single set of pairs of individuals, again either in a representational format, or in terms of variable assignments. Formally this requires the relevant semantic contexts to be stated, not in terms of assignments of sets of individuals to variables, but in terms of sets of assignments of individuals to variables. (If you want, in stead of a sequence of sets of individuals as referents, a set of sequences of individuals is employed.)

An alternative for this approach acknowledges the dependencies between the interpretation of the various noun phrases, but accounts for them in a functional, rather than relational manner. For example, for the first sentence of example (34) a set of students who chose a book may be induced, but, because the chosen books depend on the chosing students, the dependent term "a book" does not relate to books itself, but to a function from the chosing students to the chosen books. When, in the second sentence, the set of chosing students is taken up again, this book-function can be employed so as to deliver, for each student the chosen book. Such an approach has been worked out and motivated in detail in (Dekker 2004; Dekker 2008). A related approach, with parametrized referent sets in stead of functions, has been presented in (Krifka 1996).[19]

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(33) Few men came to the meeting. They, i.e., those who didn't come, went to the beach instead.

See (Nouwen 2003) for more discussion.

19. The functional approach easily applies to a couple of old examples from the semantic literature.

(35) If a book is printed with Kluwer it has an index. It can always be found at the end. (after Irene Heim)

(36) Harvey courts a girl at every convention. She always comes to the banquet with him.

Already from these sketchy and incomplete remarks it may have become clear that the dynamic semantics of plural anaphora and generalized quantifiers quickly turns into a highly complicated matter. If a proposal to deal with these issues is stated in a general enough format, it has to take into account the interplay of a variety of plurals and quantifying noun phrases, interactions with the various readings (collective, distributive, etc.) of plurals, scope interactions, often interfering effects of topical and focal elements, and other structural phenomena in one go. Plenty of room for an indigestible number of ambiguities. It should be noticed, however, that these complications do not seem to pertain to the dynamic endeavour. The dynamics required for the issues discussed in the last two subsections simply consists in the establishing and picking up of discourse referents, or so that is the picture. That it may require a lot of pain-staking work to decide on and properly employ these discourse referents basically is another matter.

3.3 Tenses, Events and Modalities

Another area where the dynamics of interpretation has come to play a significant role is that of tense, events, and mood, or modalities. (Modalities will also be discussed, from another angle, in the next section.) A major difference between the phenomena dealt with here is that the involved tenses, events and mood are most generally *not* introduced explicitly in a discourse. In as far as the metaphor of the introduction and picking up of discourse referents can be maintained here, it often can be taken to involve implicit, and relatively indeterminate referents.

It is quite an old observation that tense realized on the verbs of natural language, not only relate to the temporal location of reported events relative to the time of utterance. In many ordinary discourse and narrations the temporal locations, or the reported events themselves, are ordered in specific ways. Consider:

(39) Conny switched off the light. The room was pitch dark.

The first interpretation of this sequence that comes to mind is one in which it says that Conny switched off the light and *then* it was pitch dark. Making this explicit shows that there is something akin to an anaphoric connection between the two sentences. The second sentence appears to communicate that *at, or after, that time*, it was pitch dark, and thus it refers back to the time when the light was switched off. Clearly a dynamic notion of interpretation can be

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(Lauri Karttunen)

(37) Most men had a gun, but only a few used it. (Gabriel Sandu)

(38) Mary believes there is a burglar in the house. She thinks he came in through the chimney. (Fred Landman)

In each of the second sentences the pronouns "it", "she", "it" and "he" can be understood as functionally depending on, in that order, Kluwer books (their index), conventions Harvey visits (the girls he courts there), men who have a gun (their gun), and worlds Mary conceives possible (and the burglars in her house there). It appears quite intuitive to account for these dependencies in terms of functional referents, rather than relational ones.

used here to interpret the first sentence as introducing a point of time where the light was switched off, and the second as referring back to it and reporting that after that point of time the room was pitch dark.

It need be said that discourse, nor mere narrative stories, not only present a sequence of times or events in the order in which they are reported. Consider:

(40) Conny opened the door. The room was pitch dark.

(41) Conny switched on the light. The room was pitch dark.

These two examples need not be understood as saying that *after* the event reported by the first sentence the room was pitch dark, but *at the time of* the event, as in (40, or even *before*, as in (41), so as to explain why Conny may have switched on the light. There is a vast literature on the different types of connections that can be established between the times and events which are related in discourse. In the first place, of course on the ontology and structure of tense and events, and in the second place on the (dynamic) mechanisms required to determine the specific relations they are said to participate in, cf., e.g., (Moens and Steedman 1988; Webber 1988; Webber et al. 2003; Lascarides and Asher 1993; Kamp et al. 200x). Needless to say, that, whatever the required ontologies and relations need to be, in any case the interpretation of sentences must provide the kind of structure so that subsequent sentences can appropriately attach to it. On the face of it, this constitutes a really dynamic endeavour.

We may mention here two lines of work in this direction which have been developed since the second half of the nineties. First, mainly in the framework of *DRT*, Bart Geurts and Anette Frank have developed the means to deal with the dynamics of all kinds of sentential structures, allowing (co-)reference to facts and propositions, and thus enabling an account of so-called modal subordination and related data like we find in:

(42) A wolf might enter the house. It would eat Leo. This would disturb him not in the least.

(43) Rosanne is sure that Mark doesn't have a car. She would have seen it. (Indeed I have never seen it.)

The challenge in these examples again resides in finding an adequate treatment of the pronouns. Example (42) first raises the possibility of a wolf entering the house, and next picks up on that possibility, together with its wolf, referred to by "it". What this wolf, finally, would do is something that would disturb Leo, it is claimed. According to example (43) Rosanne rules out the possibility that Mark has a car, because if he had had one, she would have seen *it*. See (Roberts 1989; Frank 1997; Geurts 1999) for empirical details and relevant theoretical discussion. Recently, these phenomena have been dealt with in a strictly more dynamic semantic fashion by, among others, Daniel Hardt, Matthew Stone and Adrian Brasoveanu, see, e.g., (Stone and Hardt 1999; Brasoveanu 2006).

Specific treatments of tense and events worth mentioning here employ computational logics to characterize dynamic aspectual properties of events. For instance, (Naumann 1995 employs dynamic logic to characterize aspectual

properties of verbs, conceiving of events as programs, and also (Fernando 2007) locates the dynamics in the presented situations and events, which are taken as strings of observations. See also (Gründer 2007), who applies these dynamic methods in a treatment of aspectual shifts.

3.4 Presuppositions and Anaphora

In linguistics, presuppositions are a kind of preconditions for linguistic items (expressions) or acts (utterances) to make sense. They are often taken to come as, among other things, conditions for terms to be referring, for predicates to be applicable, or for sentences to be true or false. Terms like proper names and definite descriptions are supposed to be referring to some in principle identifiable object; verbs and nouns carry presuppositions on the types of things they apply to, such as that of being existent, or animate, or rational; certain controlling verbs like 'stop' and 'regret' require certain activities to be going on, or certain facts to be obtaining, etc. And for a simple sentence like "The vice-president stopped jogging" to be either true or false, the vice president must be taken to exist, to have had the habit of jogging, and, therefore also to be the kind of thing capable of jogging.

A typical test for presuppositionhood is negation. A presupposition of a sentence is normally preserved when the sentence is put under a negation. Thus, from both "Don stopped smoking cannabis" and "Don didn't stop smoking cannabis" one can draw the conclusion that Don used to smoke cannabis. Both sentences can be taken to presuppose that Don smoked cannbis and then the sentences assert that he did, cq., did not, stop doing so. Similarly, it is a presupposition of the sentence "Frank went to Paris again" that Frank once went to Paris before, because this is an entailment of both that sentence and its negation: "Frank didn't go to Paris again" And both "Marc insulted the president of Trans-Danubia" and "Marc didn't insult the president of Trans-Danubia" both appear to entail that Trans-Danubia has a president.

This negation test can be extended with other types of operators, like modals ('maybe', 'possibly', 'must', 'should') or quantificational ones ('many students . . . ', 'few impressionists'), or attitudinals ('Max thinks that . . . ', 'Mary claims that . . . ', 'It is suggested that . . . '), or suppositionals ("if . . . ', 'suppose that . . . '). In most run-of-the-mill cases the presuppositions of a sentence or sentential expression is inherited by a compound expression in which that sentence figures in the scope of one of these operators. One of the most interesting discussions in linguistics is concerned with the types of cases in which presuppositions are not inherited by larger configurations, or in which they get modified. The two main theories of presupposition nowadays are the 'AB theory' and the 'satisfaction theory', both if which are arguably dynamic. In this section we briefly discuss the main tenets of the AB theory, and in section 3 we concisely present the ideas behind the satisfaction theory.

One of the main ideas of the AB theory of presupposition (the *A*ccommodation

and *B*inding theory, van der Sandt 1988; van der Sandt 1992; Geurts 1999) is that presuppositions have to be resolved, and that the mechanisms of presupposition resolution and of anaphora resolution are basically the same.[20] Presuppositions appear in a preliminary phase of interpretation, and at some intermediary level, as separate informational entities which have to be 'resolved' for the interpretation process to be completed. The intermediary level is taken to be that of *DRT*'s discourse representation structures. Ideally these presuppositions are bound by material in a contextually given representation, and this means they are resolved, and they as it were dissolve. It may also happen, though, that presuppositions are not automatically bound, and in this case they get 'accommodated'. As a matter of fact, they are like squatters, because presuppositions tend to accommodate themselves, by positing their content in a relevant part of a representation which makes them bound in the slot where they originally appeared. Let us consider one example.

(44) Sally believes that Harry didn't quit smoking cannabis.

The most deeply embedded sentence "Harry quit smoking cannabis" comes with the unresolved representation of the presupposition that Harry smoked cannabis. If we all know, and Sally as well, that Harry was a regular cannabis user, then the presupposition that he smoked cannabis is bound and resolved. This is reading (a). If we are not sure about Harry's use of drugs, but if it has been established that Sally believes he is a cannabis smoker, then the presupposition in the scope of Sally's reported beliefs is bound and resolved as well (reading b). It may be a bit awkward, but if Sally is already known to believe that Harry didn't ever smoke cannabis, then of course she can be taken to believe that he didn't quite doing so (reading c).

Nowhere in example (44) it is literally said or communicated that Harry did smoke cannabis, so if the preceding context of such an example does not supply a way of binding this presupposition, it has to accommodate itself. It may require some further contextual support, but one way for this presupposition to accommodate itself is right there where it is, thus bringing about a reading according to which Sally believes that Harry didn't quite smoking cannabis, if he did smoke cannabis in the first place. So Sally is taken to believe it is not the case that (i) Harry smoked cannabis and (ii) he stopped, a bit weaker than reading (c) above. A reading which requires maybe somewhat less effort, is one according to which Sally is taken to believe that Harry did smoke cannabis and didn't stop doing so. In this case, the presupposition accommodated itself in Sally beliefs, as one gets from reading (b) above. Probably the most usual interpretation is one where the presupposition accommodates itself at the main level, so that example (44) is taken to say that Harry used to smoke cannabis, and that according to Sally he didn't stop doing so, basically reading (a) again.

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20. Specifically, van der Sandt initially employed the treatment of anaphora as a paradigm for the treatment of presuppositions, whence the slogan 'presuppositions are anaphors'; Geurts and van der Sandt now agree that anaphora are a species of presupposition.

What inspired the AB theory most is that the mechanism of presupposition binding (and conversely that of accommodation) is structurally the same as that of anaphoric binding. The idea that presuppositions are anaphoric, or that anaphors are presuppositional, already indicates that their treatment is obviously a dynamic one. It is assumed that the interpretation of a discourse give rise to exactly the kind of contexts in which presuppositions are bound (ideally), or in which they are easily accommodable.[21]

The sketch of the AB theory so far given is of course far from complete. There is a lot of further literature on the formal details of and motivation for this approach, in which many linguistic data are covered. It may also be clear, that *DRT*'s representational level, employed by van der Sandt and Geurts, plays a key role in the resolution of presuppositions and (Kamp 2001), among others, has dealt with the computation and justification of these. Even so, for one who is interested in a notion of the meaning or interpretation of unresolved presuppositional structures, a many-dimensional system of intepretation is presented in (Dekker 2008) which can be seen as a semantic implementation of the AB theory.

4 Dynamic Pragmatic Extensions

In the introduction we already mentioned the view upon language as a tool that is actually employed as a means of communication or for other purposes. In the first two parts of this section we consider the descriptive use of language, that is, the use of indicative sentences in assertions. In the next two parts we consider other uses—interrogative, evidential and permissive uses—which have a specific realization in a variety of languages. The dynamic focus here lies on the kinds of acts—their preconditions, content, and (intended) effects—which can be performed with linguistic expressions, and which can be seen to constitute (part of) their meaning.

4.1 Common Grounds and Updates

In his ground breaking paper (Stalnaker 1978), Stalnaker characterized assertions, or the assertive use of indicative sentences, by means of four 'trusims', which he, in turn, fleshed out in a sketch of a formal model. The truisms are that assertions are made in a context (comprising at least a producer, or speaker, of a linguistic utterance, and an audience, or hearer), that they have content, that their content may depend on the context, and that assertions are made to

21. Notice, that on this picture the dynamics of information flow goes two ways. A preceding discourse must have set the stage for occurring presuppositions to be bound, or, by accommodation, presuppositions tell us what, with hindsight, the preceding discourse should have been, or how it should have been understood. So if one starts a conversation about a certain wedding, and somewhere in the beginning says "The rabbi was terribly late," one may assume, for instance, that the wedding originally talked about was a Jewish one.

influence or change the context. (Here one hears Stalnaker's dynamic outlook upon the matter.)

The type of context that is relevant concerns for instance what entities are referred to by a speaker, i.e., the thing a conversation is about, and the information which the interlocutors can be taken to share, on the basis of previously established mutual knowledge, but also on the basis of the information that has been exchanged in the conversation before the assertion was made. This is also why assertions can be seen to change the context. If an assertion is, explicitly, or silently, accepted by the interlocutors, its contents are added to the body of information that they are assumed to share.

Already this very rough and incomplete sketch of what assertions are intended to do inspires to some neat and simple, but non-trivial, formalization. First we have the *content of an assertion*, which, given a certain context, constitutes the information that is intended to be conveyed. Concentrating on assertions, this information is of a descriptive nature, and can be seen to chacaraterize 'the actual world' as being a certain way. The actual world is characterized by a set of possible ways the world might be, so that if the actual world is or were one of those ways, then the assertion would be true of that world, and vice versa. Formally, the content of an assertion is modeled by means of a set of possible worlds, those of which the assertion is true, and the objective of an assertion is to locate the actual world in that set. For a very simple propositional or predicate logical language a very simple possible worlds semantics can be provided which recursively defines such contents in a compositional way.

Next there is this 'stock of information' which the interlocutors can be taken to share, also known as the 'common ground'. Simplifying some non-trivial matters, this can also be modeled by means of a set of possible worlds: the set of possible ways the actual world should be for the shared body of information to be correct (of the actual world). If, then, an assertion is accepted in a conversation, so that its content are added to the common ground, a new common ground shows up which has it that the actual world should not only be as the previous common ground would have it, but it should also be like the assertion claims it to be. The worlds in the new common ground, thus, are those possibilities in the old common ground which are also in the content of the assertion. Formally, the new common ground is obtained by taken the set intersection of the old common ground with the contents of the assertion.

Stalnaker's observations arguably belong to the field of pragmatics, and so do those of (Grice 1975) about cooperative conversations. According to Grice, a rational and cooperative conversation should proceed according to a couple of maxims, one of which requires speakers to convey information which they have evidence for. Phrasing this in the picture Stalnaker has given, one might say that a speaker's own private information has to support the things he says, or at least, for the time being, the speaker has to pretend to have this kind of support. Conversely, a hearer can be expected to update his own private

information with the contents of assertions which have not been rejected, or at least, for the time being, pretend to do so. This suggests a transparent picture of some of the basics of information exchange.

Let us assume that a speaker's and a hearer's information state are also modeled by means of a set of possible worlds, those which he and she think might be the actual one, that is, if his or her information is correct.

Definition 4 (Cooperative Exchange)

- A speaker's information state σ supports the assertion of ϕ (written as: $\sigma \models \phi$) iff ϕ is true of the actual world according to σ (i.e., iff $\sigma \subseteq [\![\phi]\!]$).
- The update of a hearer's information τ with an assertion ϕ (written as $(\tau)[\![\phi]\!]$) is its intersection with the contents of ϕ (i.e., $(\tau)[\![\phi]\!] = \tau \cap [\![\phi]\!]$).

Pragmatically speaking, the notions of support and update may live an independent life. In principle, speakers may for themselves take care that the assertions they make are supported by their own information, and hearer may confine themselves with updating their own information, regardless of who says so. As a matter of fact, the two notions can each be defined independently in a compositional way. Nevertheless, they behave well together. Consider the following fact, which is easily established by set-theoretical means:

Observation 6 (Supported Update)

- If $\sigma \models \phi$ and $(\tau)[\![\phi]\!] = \tau'$ then $(\sigma \cap \tau) \subseteq (\sigma \cap \tau')$.

This fact is significant. It says that if speaker and hearer have correct information, as they can be taken to assume they have, then also the information is correct which they have after the hearer has updated her information state with the contents of an assertion supported by the speaker. Put in a colloquial way, if speaker and hearer correctly play the Gricean game of information exchange, then nothing gets spoiled. Notice that fact (6) itself is not so trivial in general. For one thing, it would (and should) not hold once the interlocutors start making assertions about the conversation itself, or about each other's information (as in example (7) above). For another, it is hard to phrase a similar and equally general observation in the framework of *DRT* or *DPL*, because these systems do not allow an obvious and independent definition of content and support. See (Aloni 1999) for more discussion, and (Dekker 2004) for a straightforward generalization of the above definition and fact to a system dealing with anaphoric relationships.[22]

The above understanding of assertions has nice and interesting implications for a treatment of presupposition. Stalnaker himself has cast his account already in terms of speaker's pragmatic *presuppositions* about the information the speaker

22. The key idea is that the notions of content, support and update get parametrized for information about the interpretation of terms used in a discourse, indefinites, pronouns, etc.

and his interlocutors take for granted. And it is in these terms that one can also look at linguistic presuppositions. If the presuppositions of a sentence or utterance consist of the things that are taken for granted for a proper understanding of that sentence, then it can be taken to be supported, not only by the information state of the speaker, but also by the common ground. That is to say, speakers can (and do) configure the information which they have support for in a part that they presume 'discourse old' or presupposed, and a part that is 'discourse new' or properly asserted. Hearers, in their turn, understand the presuppositional part as one that is contextually given, or at least as one that can be assumed to be so.

Notions of presupposition, and related phenomena like presupposition projection, have been worked out along these lines by, for instance, (Heim 1983; Beaver 1995; Chierchia 1995) in terms of what is labeled a satisfaction theory of presupposition. A most appealing aspect of this theory is that it comes with an automated satisfaction test. If a presupposition is something that is supposed to be given, then, in an update semantics of the kind sketched here, the presupposition should be supported by the hearer's state, or at least by the current common ground, and this notion of support is independently argued for. No separate notion of binding presuppositions is called for. Besides, in order to account for this intuition, presuppositions need not be assigned a special informational status, and get moved around, but in principle they have to be satisfied as is. Although the satisfaction theory of presupposition is akin in general spirit with the AB theory discussed in the previous section, the two theories make diverging predictions; for a discussion of the data, and required modifications of both theories, see, e.g., (Beaver 1995; Geurts 1996; van Rooij 2007; Schlenker 2007).

4.2 Conditional Interpretation

Among the descriptive types of sentences, conditional sentences may have received a traditionally most dynamic interpretation. It is commonplace that conditional sentences are not most adequately rendered by material implications, their look-alike from propositional logic. On the one hand conditional sentences appear to express something stronger than can be captured by a truth-functional definition, and intuitively the interpretation of a sentence like *If A then B* is not something corresponding to an independent assessment that A is false or B is true. A widely shared intuition about conditional sentences of that form really require an assessment of the truth, or something similar, of the consequent, on the supposition or establishment that the antecedent holds. As Frank Ramsey has put it in the thirties of the previous century, a question like *If A will B?* can be decided by looking at the question whether B holds after one, for the sake of the argument, has accepted A. If so, one is entitled to concluded *If A then B*, and if not so, it can be taken to follow that *If A then not B*.

In the framework sketched in the previous subsection these remarks can

be formalized by ruling that a true conditional *If A then B* is supported by a state s (written as: $s \models (\phi \rightarrow \psi)$), iff B is supported by the state that results from updating s with A (i.e., iff $(s)[\![\phi]\!] \models \psi$). This formulation appears to capture Ramsey's intuition, even though the formulation or the framework in which it is embedded, still needs further elaboration.[23]

Given the vast literature on conditionals (of a both philosophical, logical, linguistic as well as a computational nature) it is impossible to sketch the many ways in which these sentences can be interpreted. Already the Ramsey intuition directly allows for at least four more specific ways of dealing with conditional sentences of the form *If A then B*. The required updates with the antecedent may take the following forms:

If it so happens that A, ...

If I find out that A ...

If, contrary to fact, A were the case ...

If, contrary to what I know now, I were to find out that A ...

The four specifications of the update with the antecedent have substantially different effects. The choice for one of the interpretations, however specified in further detail, and the effects themselves, of course heavily depend on the temporal, modal, aspectual and intonational features of the sentences A and B involved, which would take us too far astray to discuss here. For the moment it suffices to observe that all four specifications are non-trivial as long as the interpretation of A can be taken to have dynamic aspects. For a recent overview of the various options, see, for instance, (Schulz 2007; Veltman 1996; Veltman 2005).

The dynamic conception of conditional sentences brings to bear, immediately it seems, on a couple of other dynamic aspects of their interpretation already discussed above, more specifically with respect to entailment, anaphora,and presupposition.

In the first place, if a conditional sentence gets interpreted in this dynamic fashion, and if a deduction theorem holds, we automatically see that a corresponding notion of entailment must be dynamic as well. For, once ϕ entails ψ (that is: $\phi \models \psi$) iff $\phi \Rightarrow \psi$ is valid, and $\Rightarrow$ is dynamic, then so must be $\models$. In a more comprehensive framework where we also have notions of update and support at our disposal, this says, informally, that ϕ entails ψ iff any update of any information s with ϕ always supports ψ (i.e., always: $(s)[\![\phi]\!] \models \psi$. This clearly reflects the dynamic of (deductive) reasoning. Once, upon the assumption that ϕ, we can conclude ψ, still under that assumption, then we may withdraw that assumption that ϕ and conclude that $\phi \Rightarrow \psi$. Notice that in such a deduction ψ is evaluated with the assumption ϕ still pending.

In the second place, the fact that the antecedents of conditional sentences

23. For one thing, if this operator, with this interpretation, is embedded in a language which itself is basically extensional, then, of course, the net effect of the operator by the end of the day is extensional as well; in that case: $s \models (\phi \Rightarrow \psi)$ iff $\forall w \in s$: $w \not\models \phi$ or $w \models \psi$.

contribute to setting up the context of evaluation for their consequent clauses, neatly accounts for the observed behavior or 'life-span' of discourse referents. If certain entities are, indeed temporarily, introduced by indefinites in the antecedent of a conditional sentence, they remain 'there' available for anaphoric pick up by means of pronouns in the consequent clause. This we find in the classical donkey sentence (10) above, repeated here:

(10) If a farmer owns a donkey he (normally) beats it.

As long as the antecedent assumption is 'in charge', 'the farmer' and 'the donkey' can be picked up, but this can not, or only by additional means, be done once this assumption has been dropped. The original work of Lauri Karttunen and subsequent investigations from Pieter Seuren contain many empirical observations about these conditional 'lifes' of discourse referents, and corresponding possibility of anaphoric take up (Karttunen 1971; Seuren 1985). The possibilities are also heavily influenced by the syntactic structure of more involved examples, see, for instance, (Chierchia 1995) for further details.

In the third place, the dynamic conception of conditionals *If A then B* brings to bear on the evaluation of presuppositions of the conditional's subsentences A and B. This must be obvious from the previous remarks together with the idea we find in the AB-theory of presupposition that presupposition is like anaphora, or anaphora is like presupposition. As van der Sandt and Geurts have demonstrated, presuppositions in the consequent clause C can be 'bound' by propositional material in the antecedent clause A. A particular example is (12) above, repeated here for convenience:

(12) If Isabel is in the bathroom, Petra might be there, too.

The presupposition from the consequent clause *Petra might be there, too*, that somebody else than Petra is in the bathroom, is satisfied, or bound, by the supposition given by the antecedent clause that Isabel is in the bathroom.[24] The same example, and the same kind of reasoning, can be used to show that a similar type of dynamics is at stake in the assessment of presuppositions in conditional sentences according to the satisfaction theory. With one caveat though. In the AB theory a presupposition P of the consequent clause B, if not bound by or accommodated in the antecedent clause A, is a presupposition of the whole structure *If A then B*. According to the basic tenets of the satisfaction theory, if such a presupposition P is not satisfied or accommodated, the pertaining presupposition of the whole conditional is not P, but *If A then P*. For more discussion on this issue, see the references quoted above.

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24. And as a matter of fact the additional supposition in (12′) that nobody else is there suffices to explain that, on these suppositions we cannot say that Petra might be there as well:

(12′) If Isabel is in the bathroom and nobody else is, Petra might be there, too.

4.3 Inquisitive Discourse and Dialogue

We have already indicated above that besides the descriptive use of language, there are many other typical kinds of usages, some of which are often systematically distinguished, even though they can be seen to be systematically related to the descriptive usage as well. A first typical type of usage is that of interrogatives, questions, that is.

Already at the outset of formal semantic theorizing about questions their *dynamic* role, their role in discourse or dialogue, has been obvious. While the meanings of indicative sentences can be characterized in terms of their truth conditions (qua satisfaction conditions), the meanings of interrogative senetences can be and have been characterized in terms of their answerhood conditions (qua satisfaction conditions, see Hamblin 1973; Karttunen 1977; Higginbotham and May 1981; Groenendijk and Stokhof 1984). This complies with the idea that one fully understands a question once one knows what, in which circumstances, counts as a full and complete answer to the question. Notice that, according to this picture, while truth conditions are directly, but not intrinsically, related to something more or less pragmatic like verification (in terms of verification), answerhood conditions are directly and intrinsically related to something essentially pragmatic: that of giving an answer to a question raised.

Adopting a dynamic theoretical perspective, discourses or dialogues can be described as games of stacking and answering 'questions under discussion' or as processes of 'raising and resolving issues'. Such processes are not unstructured: they are governed by structural rules which can be deemed linguistic (in a broad sense), and by very pragmatic principles of reasonable or rational coordination (Ginzburg 1995; Roberts 1996; Hulstijn 1997). A quite minimal way to do so proceeds by representing information as a set of possibilities, one of which is supposed to be actual at a certain stage of a discourse. The possibilities are grouped in sorts, so to speak, indicating that the current issue is, not which of the possibilities is the actual one, but which is the sort of the actual one, that is, in which sort of possibilities the actual world can be found.

Formally this can be taken to amount to taking information states as sets of sets of possibilities. Intuitively, such a state represents the world as being like one of those in a set of these sets, and it represents the current issue as the more specific question in which of these sets of possibilities the actual world can be found. When such a state (a set of sets) is updated with the information that p, for instance because someone asserts so, all of the sets of possibilities are updated with that information (and if such a set is inconsistent with that information it is excluded). The result is that the proposition p holds in all possibilities that remain, so that the actual world is indeed characterized as one in which p. The same state can also be updated with a new issue, whether q, for instance because someone asks so. In that case each of the sets of possibilities in the original state is divided in one set of possibilities in which q holds and one set of possibilities in which q doesn't hold. The net effect is that there is

no more information about the world, because the world is still represented as being like one of those in a set of sets, and the whole set of possibilities remains the same; but added to the issue to which *sort* the actual world belongs, the issue is added whether it is of a q or a non-q sort: in other words the sorting has become more fine-grained.

Such a limited set up as sketched already provides the basics for characterizing certain basic discourse and dialogue notions like that of a coherent and felicitous dialogue or for instance that of an optimal inquisitive discourse (see, e.g., Jäger 1996; Groenendijk 1999). For a dialogue to proceed coherently and felicitously, one may require assertions to be consistent with the current information state, but also informative: logically speaking it is of no use to to accept a state of inconsistent information or to assert what is already (commonly) known.[25] Questions can be required to be non-superfluous as well, so that one doesn't *raise* an issue which is already there.[26] A more specific requirement is, of course, that assertions address issues at stake. More specifically, they should, on the hand, tell you something about which sort the world is, so they should eliminate at least one of the sets (sorts) of possibilities; by the same token they should not be required to add unsolicited information.[27]

On the basis of these notions, and of a formulation of what it means for the partners in a dialogue to have their own information and questions, it is fairly straightforward to define what is an optimal outcome of a dialogue between these partners. Adopting Gricean ideas about what a cooperative discourse amounts to, one can say that in an optimal discourse, for as far as that is possible at all, the partner's questions eventually get answered on the basis of the information they jointly have, in an efficient and well-behaved manner. See (Aloni et al. 2007) for various approaches to flesh such insights out in more detail; see (Roberts 1996; Ginzburg 2008), for some alternative formulations. A general set up along these lines, and appropriate generalizations of it, may also prove suitable to formulate interesting notions of relevance, like those endorsed in relevance theory.

There is quite some literature about first order generalizations of the approach sketched here so as to include names and generalized quantifiers as well as *Wh*-questions (or 'constituent questions). There is an interesting trade off between these issues and a dynamic approach as an example from (Jäger 1996) may serve to show. Consider the two questions (45) and (46), and a subsequent respons with (47):

(45) Who is wise?
(46) Which Athenian is wise?
(47) Only Socrates is.

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25. Formally this amounts to requiring of an assertion of ϕ, relative to a state s, that the update with ϕ is not inconsistent and not trivial: $\emptyset \neq (s)[\![\phi]\!] \neq s$.
26. Formally this amounts to almost the same thing: $(s)[\![\phi?]\!] \neq s$.
27. Formally this amounts simply to requiring such an assertion to properly exclude, but not reformulate sorts: $(s)[\![\phi]\!] \subset s$.

When example (47) counts as a response to an utterance of (45), it can be taken to say that Socrates is the only wise person whatsoever. However, as a response to (46), the answer seems to be restricted to the Athenians, so that it appears to say that Socrates is the only wise Athenian. In other words, in such an example the *Wh*-phrase does not only serve to restrict the question which it heads, but also the answer which it gets, a particularly dynamic effect. See, again, (Aloni et al. 2007) for a treatment of the dynamic trade off between *Wh*-questions and (quantified) answers in such so-called 'topically restricted quantification'.

4.4 Evidentials and Permissives

While the field of formal pragmatics and speech act theory has grown independently of the development of dynamic semantics, it may come as no surprise that dynamically oriented semanticists have turned to other type of speech functions than question answering. In many cases interlocutors negotiate, not about truth, but about evidence, and a frequent use of language consists in commanding, forbidding and permitting certain actions of other agents.

The first type of use, that of evidentials, can be seen to be realized mainly lexically in Germanic langauges, and structurally, in terms of mood for instance, in other. Typical exponents of evidential uses are the epistemic modals *may* and *must* in English, as well as adverbials like *maybe*, *probably* and *evidently*. The first two sententials operators *may* and *must* neatly seem to fit in the dynamic paradigm, as the first can be used to express consistence with the *current* context of information, and *must* to express something that can be derived from this context (Veltman 1996). Since the context in a discourse is taken to be always changing, so is the evidential interpretation of these modals. For instance, it may be the case at one point in an exchange that Nancy might be home, for as far as we all know, while later in the discourse we may have brought together information from which we see she cannot possibly be home, she must be out.

Of course such modal expressions do not always and only relate to common grounds, but they may relate to any kind of what Angelika Kratzer calls 'modal bases', a sort of stores of information, and their typical role in discourse is admittedly dynamic and involved. For one thing, people may disagree about what might and must be the case, even without considering it worth an argument. Consider the following dialogue:

A : Nancy might be home now.
B : Ahmm. (You think so, but I know better; she is freaking out in the Jungle Bar, but why should I bother you with that?)
A : So, let's see if we can find here there.
B : But maybe she isn't home. Why take the effort?

In this little dialogue B refrains from giving all information she has (e.g., that Nancy is definitely not home), but she does this without getting committed to something she does not want to be committed to. In a recent series of papers

Kai von Fintel and Anthony Gillies have investigated these uses of epistemic modals, and the evidence that can be taken to support them (von Fintel and Gillies 2007). Of quite a different, linguistic rather than philosophical, nature is recent work on evidential modals by Nicholas Asher, Eric McCready and Norry Ogata. These authors argue that Japanese evidential modals are very well accounted for in a probabilistic dynamic semantics (McCready and Ogata 2007).

Of a very recent date is a discussion whether it is really possible to give a semantics, not pragmatics, for imperatives, permissives, and other expressions changing, not the interlocutor's information in the first place, but their rights and obligations. Of course there is a long tradition in the logic of obligations and permissions, so-called deontic logic, but its use in the semantics of natural language is new, and challenging. The, open, question, is, whether we can adequately represent the effect of an imperative or a permissive in terms of a context change, like the changes induced by exchanging information, or should we take into account rights and obligations in an intrinsic manner which cannot adequately be so represented. The question is very open at the moment, and we refer here to two recent PhDTheses which address the matter (Mastop 2005; Schwager 2006); see also (Asher and Lascarides 2003; van Rooy 2000; Zarnic 2003) for relevant discussion.

5 Thematic Issues

In this section we discuss three more philosophical and/or theoretical themes related to the adoption of a dynamic notion of meqaning. In the first subsection we discuss some of the foundational issues which have accompanied the development of dynamic semantics from its invention. In the second we shortly discuss its role as a general framework for linguistic theorizing, and in the third we look back at some of the philosophical roots of dynamic semantics, this time from a dynamic semantic viewpoint itself.

5.1 Representationalism and Compositionality

In this section we give an impression of the some more philosophical issues and viewpoints which the dynamic remodeling of semantic theory has given rise to. We stick to the reformulation of these issues for as far as they apply to basic *DRT* and basic *DPL*, since that's what the discussions have focused on mainly, and because, apart from the discussion taken up in subsection 3, they apply mutatis mutandis to extensions of both frameworks. The discussion can be seen to focus on four dogmas, which, if not stated explicitly, have been adhered to by several pro- and antagonists in the debate.[28]

The first dogma derives, maybe not from the contents, but certainly from the title of Kamp's original *DRT*-paper.

28. Much of the discusison here draws from (Dekker 2000) and (Zimmermann 1999).

Dogma 1 (Representationalism) In order to account for certain structural phenomena in the interpretation of natural language, recourse to an independent level of representation is a sine qua non.

With regard to the question which phenomena are at issue, the discussion has, largely inadvertently, focused on the phenomenon of inter-sentential anaphoric relationships, but it can be taken to cover all sorts of discourse relations, and the same points can be made with regard to intra-sentential semantic relationships. With an eye on the whole variety of interpretational processes, (Kamp 1990, among many others) hasn't deemed representationalism an unavoidable option, but he has emphasized, first, that in the actual process of interpreting natural language or discourse a substantial amount of computation is essential, and that computations necessarily involve things to compute on, representations that is, not things represented (as in Jerry Fodor's 'computational mind'). Clearly, then, *DRT* neatly obeys this dogma, while *DPL* does not. Like we said, *DPL* was in a sense developed to show that at least the treatment of singular anaphoric relationships does not require such an intermediate level of representation.

Indeed, *DPL* was argued to be non-representational, and this brings us to the second dogma in the discussion.

Dogma 2 (Non-representationalism) If possible at all, an account of the meaning of a language should be stated in terms of entities or stuff belonging to an independently motivated realm of being.

An ideal realm of this kind would be, for instance, the actual world and/or the things belonging to it, or a platonist or fregean realm of abstract meanings, or some suitable notion of information itself. A suitable and very generally accepted notion of the meaning of a sentence is the one stated in terms of truth-conditions, as it can be traced back and motivated by the work of Frege and the early Wittgenstein. Cutting long and enduring discusisons short, the idea of this notion, or dogma, is to supply a ground for the meaning and intersubjective use of a language. And as appears from its label, the intention of this dogma is also that representations do *not* qualify for this purpose. Representations can be taken to belong to a representation language, and would require for their motivation an interpretation of that language. These representations could therefore hardly qualify as being independently motivated themselves.

Obviously, as *DRT* is formulated it does not qualify as complying with this dogma, since its architecture is throughout representational.[29] One objection against this kind of representationalism is the same as that against any form of mentalism: that is normally leaves us without an account of the inter-

29. With a caveat, however. Once one has independent motivation for assuming meanings which are (formalized as) discourse representation structures, one can state a semantics in terms of updates of these structures, as happens in *DRT*, without leaving the non-representational dogma behind.

subjective nature of meaning and of its ordinarily assumed realistic roots. And besides, even if such an account were forthcoming, it would seem to tie any representational theory to a kind of psychological realism about the representational structures it adheres to, and which may be devastating for its possible empirical success.[30]

Be this as it may, does it all mean that *DPL*, and other versions of dynamic semantics, is non-representational? Before we consider this point in more detail, it is usefull to state another dogma which always plays up in this context, the dogma, or principle, of compositionality:

Dogma 3 (Compositionality) The meaning of a compound construction is a function of the meanings of its parts and its mode of construction.

This dogma, which can be traced back to Frege, and which has been most thoroughly investigated by Theo Janssen (Janssen 1986), provides another impetus for the dynamic treatment of anaphora. For theories dealing with intersentential anaphora, the dogma has one major consequence: if the intended meaning or truth conditions of a sequence of sentences involves the establishment of anaphoric relations between terms (notably indefinite noun phrases and pronouns) in different constituent sentences, then the contributing meanings of these constituent sentences cannot be seen to be exhausted by their truth conditions. According to Groenendijk and Stokhof, the main moral of this, also accepted by Kamp, is that apparently there is more to meaning then truth conditions alone.

It can be said that both *DRT* and *DPL* find the required extension of a traditional notion of meaning in the notion of a discourse referent, a notion implemented in a straightout representational way in the one theory, and in a dynamic fashion in the other. Groenendijk and Kamp agree that this additional kind of information really is some kind of discourse information. A discourse referent models the fact that in some ongoing discourse a certain kind of noun phrase has been used, as, for instance, (Stalnaker 1998) puts it, one which can be referred back to by means of pronouns. In the telling words of (Groenendijk et al. 1995): "Information states contain two kinds of information: information about the world, and discourse information. In the end, it is information about the world that counts, but in acquiring such information through discourse, one also has to store information pertaining to the discourse as such."[31] In any case, the role of discourse referents is not substantial, since, in the end, when we descend to the level of truth-conditions in either *DRT* or *DPL*, discourse

30. For assume that a neat account is given of a certain linguistic phenomenon in a representational format, and that independent experimental evidence shows the employed representations to be psychologically unrealistic. In that case, the purported explanation of the phenomenon automatically falls apart as well.

31. In (Zimmermann 1999) this is called the 'meta discourse' account of discourse referents; in Dekker 2000) I have labeled it their 'de dicto' understanding.

referents lose their point.

Since discourse referents play an essential role in the interpretation of discourse in both *DRT* and*DPL*, and since they relate to the manner of representing the world, which itself is deemed immaterial, the extended type of information used in interpreting a discourse may be called 'weakly' representational at least. Not so surprising for *DRT*, since this has already been deemed fully representational, but possibly surprising for the claimed non-representational theory of *DPL*.

As a matter of fact, however, the situation is not so surprising at all. When we are dealing with anaphoric relationships we are typically dealing with the interpretation of relatively simple terms in natural language: indefinite noun phrases, anaphoric pronouns, but proper names and definite descriptions fit the picture equally well. Dealing with their interpretation means dealing with their possible denotations, and for the interpretation of certain chunks of discourse we may have to assume that certain of these terms (notably pairs of indefinites and pronouns) have to be coinstantiated, What 'discourse referents' do is keeping track of the possible values of these terms, and coordinate their interpretation when needed. Notice, however, that this is typically what variable assignments do in ordinary logic, or even better, what possible satisfying witnesses do in Tarski's original formulation of predicate logic. Even for those who endorse a notion of meaning as truth conditions, meanings in general have to be more involved things for reasons deriving from the compositionality dogma. For instance, in order to spell out the semantics of first order predicate logic in a compositional way, one needs access to variable assignments, or to (sequences of) satisfying individuals. Indeed, the very same things which are needed to flesh out the roles of discourse referents.

Now, however, we touch upon another delicate issue. For it seems to be at least implicitly assumed in *DPL* that a treatment of anaphoric relationships at least requires, if not a representational, then a dynamic notion of meaning:

Dogma 4 (Dynamic Meanings) A compositional account of structural relations in discourse requires the adoption of a dynamic notion of meaning.

It is true that in both *DRT* and *DPL*, as ruled by this dogma, dynamic interpretation mediates in the establishment of eventually static meanings. But does this mean that a system of dynamic interpretation therefore has to deal with an intermediary, and eventually negligible, dynamic semantic objects?

As a matter of fact it doesn't. In (Zeevat 1989) for instance it is shown that the algebraic structures required for the interpretation of ordinary predicate logic can be employed to account for intersentential anaphoric relationships. Something is missing in Zeevat's account, namely the asymmetric, often deemed dynamic, nature of anaphoric relationships. In (Dekker 2004), however, it is shown that this type of dynamics can be derived from an asymmetric, or dynamic notion of conjunction. In that paper meanings themselves are basi-

cally non-dynamic; apparently dynamic effects derive from the compositional, but dynamic and asymmetric, methods of composing these meanings in larger wholes.

Summing up, a minimal form of representationalism is unavoidable, some dynamics of interpretation is undeniable, but there doesn't seem to be a need to resort to a theory of interpretation in which meanings are essentially representational and/or dynamic. Of course, these conclusions mainly concern the treatment of anaphoric relationships, and, like we said, many more phenomena are relevant to the whole discussion. See for instance (Steedman and Stone 2006) for a recent discussion.

5.2 Type Theory and Computability

From the very start of the development of dynamic semantics as a framework of interpretation, the question has been raised as to whether and how its underlying ideas can be fleshed out further in a fully compositional theory of interpretation along the line of Richard Montague, in the first place, and many of his followers. For a part this has been an exercise with more or less efficient and elegant solutions, but not one without pitfalls.

The major innovation employed in getting such a compositional interpretation consists in, in the first place using (a variant of) type theory, so as to be able to formulate the meaning of sub-sentential expressions by λ-abstraction as their contribution to the meanings of the whole in which they may occur. This part is, of course, anticipated by Montague's own algebraic formulation of interpreted grammars for fragments of English. In the second place, the real shift is supposed to take place at the basic level, or in the basic type, of these relevant whole. In stead of adopting a type t of truth values here, new types *ccp* of context change potentials have shown up. The idea being that there are basic type of individuals (for nominal types of terms) and context change potential (for sentential expressions), and that there is the full function space which can be built over these two types of objects.

The basic ideas of such a 'dynamic Montague grammar' or 'compositional DRT', can be developed according to this program. The system may start from an initial notion of a context change potential, which can be primitive itself, or a function over or relation between contexts, which themselves again can be taken to be primitive or, for instance, sets of possibilities of some kind (worlds, facts, events, ...). Sentences then can be interpreted as objects of this type *ccp*. Sentential operators can be taken to be operations on objects of this type, so that a binary sentential operator like conjunction doesn't combine two objects of type truth value into an object of type truth value, but, rather, it combines two context change potentials into a new one: the live in the type $\langle ccp, \langle ccp, ccp\rangle\rangle$. Sentential functions like predicates or relations are no longer, basically, functions from (pairs of) individuals to truth values, but functions from (pairs of) individuals to context change potentials: $\langle e, ccp\rangle$, or $\langle e, \langle e, ccp\rangle\rangle$.

Likewise, generalized quantifiers, which used to denote functions from sentential functions to truth values now show up to denote functions from the new type of sentential functions to context change potentials: so in stead of $\langle\langle e, t\rangle, t\rangle$ we get $\langle\langle e, ccp\rangle, ccp\rangle$. Given an existing version of Montague grammar the (re-)typing of expressions consists in an alphabetical reformulation: systematically replace t by ccp.

Needless to say that this general program for formulating a compositional interpretation system can be, and has been, carried out in many different ways. There are various insights as to what the kinds of entities are that live in the ccp domain, the way in which they relate to usual sentential type t, that of truth values, and the combinatorics of the system. Some of these systems have employed a particular version of Montague's own *intensional logic*, in "Dynamic Montague Grammar" for instance, others have employed alternatives to type theory, like one adopting simultaneous abstraction, or a constructive type theory, but probably the most perspicuous version has been given by Reinhard Muskens in his "Compositional Discourse Representation Theory (Muskens 1996, cf., also van Eijck and Kamp 1997). Here we may also mention more representationally oriented systems like Uwe Reyle's Underspecified DRT, Michael Kohlhase and Susanne Kusschert's Λ-DRT, and Nicholas Asher and Alex Lascarides' Segmented DRT, all of whom extend DRT with more computational structure.

For all of these compositional versions of dynamic semantics, the envisaged benefit has been that it enhanced straightforward applications and implementations, although, of course, the logical cost is high. The required means and methods are typologically speaking higher order and therefore undecidable and incomplete.

5.3 Pragmatics and Contextuality

According to a well-established division of labour, which has worked well as a neat methodology, the study of language divides up in syntax, semantics and pragmatics. It is the task of syntacticians to describe what are the well-formed expressions of some language, of the semanticists to characterize the meanings of these expressions, and that of the pragmaticians to determine what one can do with these expressions with their assigned meanings. As a result, in one of those golden eras, syntacticians and semanticists happily lived in their armchairs, reflectively studying the structural aspects of language, under complete abstraction of its use. Apparent, dirty, counterexamples to aesthetically appealing theories could be hand-waived as being of a pragmatic origin.

Under the influence of Ludwig Wittgenstein and Peter Strawson, more pragmatically oriented philosophers and linguists became to realize that, for a general understanding of the meaning of language, aspects of its use could or should not be neglected. In the sixties of the previous century, for example, this has led Keith Donnellan, among others, to point at a distinction between so-called attributive and referential uses of definite descriptions. Depending on the

type of use of these descriptions, different interpretations could be the result, so there was claimed to be some ambiguity at stake, even though it was not claimed to be semantic. A 'pragmatic ambiguity', Donnellan labeled it, in lack of a better term.[32]

With the advent of systems of dynamic semantics such a pragmatic development of natural language semantics seems to have found a solid ground. In most of the applications studied above arguably pragmatic aspects of the use of language make their way in a systematic account of meaning or interpretation. Typical examples of dynamic interpretation relate to matters of use, such as introducing discourse referents, updating discourse contexts, establishing discourse structure, and interference with the information of interlocutors.

On the old picture, that of the golden era, semantics had to do with structural aspects of language, which are assumed to be of a truth-conditional nature. At least, such an assumption could serve to motivate a notion of meaning at a certain level of sufficiently objective or at least intersubjective significance. From the very moment that pragmatic aspects of meaning show up, as they arguably do in dynamic semantics, the old picture has to give way, and the question becomes what, then, can be said to properly belong to the area of semantics, and what to that of pragmatics, if any such distinction of fields is eventually tenable at all

Donnellan said that the attributive and the referential use of descriptions invoked a 'pragmatic' ambiguity, because he associated the two with a different interpretation and hesitated to call this a difference in meaning, or a semantic difference. Saul Kripke, one of Donnellans main opponents, deemed the difference Donnellan pointed at a pragmatic one, so not a structural ambiguity, worth our semantic concerns.[33]

It appears to be beyond doubt, however, that there are languages that syntactically or morphologically encode instructions on nominals which typically govern their use, qualifying them as being specific (referential) or arbitrary (attributive) or otherwise. These instructions may not be truth-functional or truth-conditional themselves, and not semantic in the standard logical sense, but they appear to be structural, and it seems appropriate to accommodate their, significant, contribution in a comprising theory of interpretation.

As a matter of fact there seems to be a decisive reason to assume that a specific use of pronouns and presuppositions has to be realized at some level of analysis, that is, lacking at decent alternative, at the level of logical form. For

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32. It may be typical of the spirit in the golden age that Peter Geach qualified the 'referential' kind of 'use' of definite descriptions as "of negligible importance for logic." He mentioned it, like he said, "only to get it out of the way" (Geach 1962, p. 8).

33. The argument, in a nutshell, was that if it were an ambiguity, it would be structurally encoded, and one would have to expect languages that disambiguate it. Since Kripke couldn't think of any such languages, and since he had arguments why such a disambiguation would not neatly fit in the (semantic) content / (pragmatic) use distinction at that time, he ruled that possibility out on methodological grounds.

instance, consider example (48):

(48) Professor Gale introduced every student to his class, and professor Horn did, too.

If the full analysis of this example leaves it unspecified whether the possessive pronoun "his" is used with reference to the professors, or with reference to the students, then an utterance may obtain a mixed reading according to which Gale introduced all students to their (i.e., the students') classes, and professor Horn introduced every student to his (i.e., Horn's) class. The sentence clearly does not have this reading, and this implies that in the structural analysis of the sentence it has to be decided what the intended interpretation of the pronoun "his" is.

For another example, consider:

(49) Jane and Eric visited a student in Stuttgart because a professor told them to do so.

in which both the terms 'a student' and 'a professor' could be used specifically, or non-specifically. If, upon analysis, this usage is left unspecified, then the sentence would allow for a reading which it does not have: that Jane visited an arbitrary student because a specific professor told her to do so (i.e., visit some arbitrary student) and that Eric visited a specific student because an arbitrary professor told him to do so (i.e., visit that student). If the indefinite terms can be used either way, and if this 'mixed' reading has to be ruled out, it has to be indicated in which way the terms, upon occasion, are used. And if the distinguished interpretations of the indefinites are a matter of pragmatics, then it means that pragmatic matters have to find their formulation on a structural level, that of logical form.

It seems, then, that we have to assume that different uses of descriptions, different interpretations of terms, and also different resolutions of presuppositions, may have to be structurally realized. In other words, we may have to assume that matters which seem to be pragmatic in nature, have to be dealt with at a level of logical form.[34]

From the above observations it follows that a dynamic semantics typically encodes, or takes account of, matters of usage which are or were seen to be of a pragmatic nature. Next to truth conditions we may find usage conditions, so to speak. The question is how far this may take us, and this, really, is an open question. For instance, ascriptions of beliefs and desires to other people are highly context-sensitive, and so are the notoriously vague predicates like 'small' and 'bald' and 'generous' and the like. It seems quite undoable to list all of the different kinds of uses to which these ascriptions and predicates can be put, and, hence, make them multiply ambiguous.[35] It is unclear, however, what

34. Basically the same can be said about the meaning of discourse particles.

35. And notice that eventually all predicates are vague, in the sense of not being designed to apply in all of the most weird scenarios of interpretation.

would be the rationale to stop here, or somewhere else. Otherwise, if we don't stop here, it seems we get lost in something like a radical type of contextualism: that whatever we ideally end up with, is so totally and deeply pragmatically infected, that still calling it 'meaning' or 'semantics' would be quite vacuous indeed.

Like we said, the last remarks concern a very open question, which is a live issue in the 'contextualist debate' (see, e.g., Recanati 2004; Stanley 2005). For now, we may conclude that this year, in 2008, dynamic semantics has reached the age of 21 and it is grown up, alive and successful. Its success may be attributed to the fact that it comes without a particular philosophical message but with a specific methodological advantage: that it is a semantic system open to pragmatic intrusion so that it easily escapes the straightjacket of standard truth-conditional semantics. Maybe too easily, but that has not been our concern here.

Appendix

In this appendix we provide some definitions of, and general observations about, three toy systems dealing with intersentential anaphora in a predicate logical language, without further comments and details. The language deals with pronouns as an additional set of terms, which can be taken to refer back to witnesses associated with existentially quantified phrases. The first system spells out a Tarskian satisfaction relation, the second one spells out the support a speaker can be required to have for using sentences, and the third is an update system for a potential hearer of them. It is shown that each of the three can be taken as basic, and that they are pragmatically well-behaved.

We assume a model $M = \langle W, D, I\rangle$ which consists of a set of possibilities, or worlds, W; a domain of individuals D (world dependent if you want); and an interpretation function I such that $I(R)$: $W \rightarrow \mathcal{P}(D^n)$, $I(c)$: $W \rightarrow D$. Interpretation is relative to variable assignments g such that for any variable x: $g(x)$ is in $W \rightarrow D$ and sequences of witnesses $\vec{c}$ such that the i-th element $\vec{e}_i$ is in $W \rightarrow D$. The interpretation of terms (constants c, variables x and pronouns $\mathtt{p}_i$) is given as: $[c]_{M,w,g,\vec{c}} = I(c)(w)$, $[x]_{M,w,g,\vec{c}} = g(x)(w)$, and $[\mathtt{p}_i]_{M,w,g,\vec{c}} = \vec{c}_i(w)$.

Definition 5 (Satisfaction Semantics)

- $[\![Rt_1 \ldots t_n]\!]_{M,g,\vec{c}\vec{e}} = \{w \in W \mid \langle [t_1]_{M,w,g,\vec{c}}, \ldots, [t_n]_{M,w,g,\vec{c}}\rangle \in I(R)(w)\}$
- $[\![\neg\phi]\!]_{M,g,\vec{c}\vec{e}} = \{w \in W \mid \neg\exists\vec{a}\colon w \in [\![\phi]\!]_{M,g,\vec{a}\vec{c}\vec{e}}\}$
- $[\![\exists x\phi]\!]_{M,g,b\vec{c}\vec{e}} = [\![\phi]\!]_{M,g[x/b],\vec{c}\vec{e}}$
- $[\![\phi \wedge \psi]\!]_{M,g,\vec{a}\vec{c}\vec{e}} = [\![\phi]\!]_{M,g,\vec{c}\vec{e}} \cap [\![\psi]\!]_{M,g,\vec{a}\vec{c}\vec{e}}$

Definition 6 (Support Calculus)

- $\sigma \models_{M,g,\vec{c}\vec{e}} Rt_1 \ldots t_n$ iff $\forall w \in \sigma$: $\langle [t_1]_{M,w,g,\vec{c}}, \ldots, [t_n]_{M,w,g,\vec{c}}\rangle \in I(R)(w)$
- $\sigma \models_{M,g,\vec{c}\vec{e}} \neg\phi$ iff $\forall w \in \sigma$: $\neg\exists\vec{a}$: $\{w\} \models_{M,g,\vec{a}\vec{c}\vec{e}} \phi$

- $\sigma \models_{M,g,d\vec{c}\vec{e}} \exists x\phi$ iff $\sigma \models_{M,g[x/d],\vec{c}\vec{e}} \phi$
- $\sigma \models_{M,g,\vec{a}\vec{c}\vec{e}} \phi \wedge \psi$ iff $\sigma \models_{M,g,\vec{c}\vec{e}} \phi$ and $\sigma \models_{M,g,\vec{a}\vec{c}\vec{e}} \psi$

Definition 7 (Update Algorithm)
- $(\tau)[\![Rt_1 \ldots t_n]\!]_{M,g,\vec{c}\vec{e}} = \{w \in \tau \mid \langle [t_1]_{M,w,g,\vec{c}}, \ldots, [t_n]_{M,w,g,\vec{c}}\rangle \in I(R)(w)\}$
- $(\tau)[\![\neg\phi]\!]_{M,g,\vec{c}\vec{e}} = \{w \in W \mid \neg\exists\vec{a}\colon w \in (\tau)[\![\phi]\!]_{M,g,\vec{a}\vec{c}\vec{e}}\}$
- $(\tau)[\![\exists x\phi]\!]_{M,g,\vec{c}\vec{e}} = (\tau)[\![\phi]\!]_{M,g[x/b],\vec{c}\vec{e}}$
- $(\tau)[\![\phi \wedge \psi]\!]_{M,g,\vec{a}\vec{c}\vec{e}} = ((\tau)[\![\phi]\!]_{M,g,\vec{c}\vec{e}})[\![\psi]\!]_{M,g,\vec{a}\vec{c}\vec{e}}$

Observation 7 (Interdependence)
- $\sigma \models_{M,g,\vec{c}} \phi$ iff $\sigma \subseteq [\![\phi]\!]_{M,g,\vec{c}}$
- $(\tau)[\![\phi]\!]_{M,g,\vec{c}} = \tau \cap [\![\phi]\!]_{M,g,\vec{c}}$
- $\sigma \models_{M,g,\vec{c}} \phi$ iff $\sigma = (\sigma)[\![\phi]\!]_{M,g,\vec{c}}$
- $(\tau)[\![\phi]\!]_{M,g,\vec{c}} = \{w \in \tau \mid \{w\} \models_{M,g,\vec{c}} \phi\}$

Observation 8 (Supported Updates)
- If $\sigma \models_{M,g,\vec{c}} \phi$ and $(\tau)[\![\phi]\!]_{M,g,\vec{c}} = \tau'$ then $(\sigma \cap \tau) \subseteq (\sigma \cap \tau')$.

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