39. Dynamic Semantics

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Abstract 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. An in-depth description of a paradigm version of dynamic semantics, *Dynamic Predicate Logic*, is given in section 2. In section 3 we show how the dynamic paradigm can be used to account for a number of empirical phenomena, and we discuss some extensions of the basic paradigm, systematically incorporating previously deemed pragmatic aspects of meaning. We conclude with a discussion of some theoretical issues surrounding dynamic semantics in section 4.

1. Introduction

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 twentieth century. Meaning is not some abstract Platonic entity, but it is something that changes information states. "Natural languages are programming languages for minds", it has been said. A more modest way of putting the same point consists in acknowledging that natural language is not only devised to describe an independently given world. Natural languages have other points and there are lots of other functions of language than just a descriptive one. Eventually a theory of natural language meaning ought to extend the standardly given framework of a descriptive or referential semantics, and seek to incorporate arguably pragmatic aspects of interpretation. The term 'dynamic semantics' may serve as a generic label for this type of theorizing that does not deny its well-established philosophical, logical, and linguistic roots.

The analytical study of language finds its roots in the philosophy of knowledge, science, logic and language. The interplay between language, meaning, knowledge and belief has become one of the major themes in the late 19-th and the early 20-th century in the writings of Frege, Peirce, Russell, Wittgenstein, Carnap and Tarski, all of them sharing the interest in a core notion of truth. From the very start it has been acknowledged that the issues of truth and meaning are hard to separate from notions of context and use. In the second half of the 20-th century Wittgenstein, and fellow philosophers like Strawson, Austin, and Grice have made the use of language a matter of focal concern. From there it is just a small step to a conception of meaning as something that is both context dependent, and capable of changing the very same context, a dynamic notion of meaning, that is.

In the second half of the 20-th century, in the area of cognitive psychology, meaning has been located in the mind, and cognitively oriented approaches endorsed by Fodor, Lakoff, and Jackendoff, have taken recourse to mental languages, as the internalized carriers of meanings. No matter their misgivings, the view of the mind as a goal directed information processor has gained prominence, and it has inspired the study of language as a means for updating and processing information. The prominent framework of discourse representation theory has been put forward with the aim of reconciling the psychologically realistic models of interpretation with those of a logico-philosophical nature.

The later quarter of the 20-th century witnessed the development of dynamic logics in the area of computer science. Dynamic logics give one the tools to reason about, e.g., correctness, and termination conditions of computer programs. Programs here are abstractly understood as certain transformations of computer states, induced, for instance, by runs of a program. Formally characterized these are relations on computer states, viz., the so-called input — output relation of runs of the program. This perspective on programming languages has been taken as a metaphor for natural language, so that the meanings of sentences can be conceived of as state transformers as well.

The three developments mentioned, in philosophy, psychology and artificial intelligence, have provided a breeding ground for the type of dynamic semantics discussed in this article. Its conception didn't come without a proper logico-linguistic motivation, though. There was motivation internal to linguistic theorizing.

The linguistic impetus A variety of linguistic observations point to the need of a dynamic semantics for natural language or, at least, a dynamic account of interpretation. Consider the following simple examples.

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

(2) a. If a cat is hungry it usually meows.
b. ?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 antecedent. 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.

Basically the same goes for definite descriptions.

(3) a. Mike has children. Mikes sons are blues and his daughters are soul.
b. 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. (Or the conclusion should be more pregnant, as with "Well, you know, that's what it means, 'having children'!")

The following pair of examples has to do with presuppositions.

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

Since one can regret only something which has happened, it is odd to state that Rebecca married Thomas after we already heard she did, when she was said to have regretted it. The next examples display specific discourse relations.

(5) a. Bob left. Conny started to cry.
b. Conny started to cry. Bob left.

If the two reported events are ordered as they are presented in (5a), Bob's leaving seems by default to precede, and cause, Conny's crying; if they are reported as presented in (5b), Conny appears to have cried first, and then, and probably therefore, Bob left. Of course, it is possible to read the examples in a different way. The main point is that *some* relation between the reported events gets assumed and that the interpretation of the two sentences must allow for such a connection.

Discourse acts are also intrinsically ordered. The following sentence may be true, when uttered, but in a sense a successful assertion of it cannot be successfully repeated.

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

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

The final examples are conditionals, in which, arguably, the antecedent (or *if*-) clause affects the interpretation or evaluation of the consequent clause. The classical example is called a 'donkey sentence', in the folklore.

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

Of course one may asked "Who beats what?", and 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, such an answer can only be given relative to such possible situations as they are set up by the antecedent clause. Finally look at examples (8a) and (8b).

(8) a. If Isabel is in the bathroom, Petra might be there, too.
b. 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 (8a) 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.

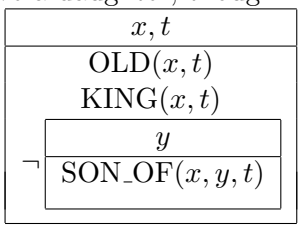
The above are only a limited number of examples which have been raised to show the need of a notion of dynamic interpretation. They show that one cannot always swap two conjuncts, or reverse a conditional, or repeat a sentence. The idea is that language depends on context, and that it changes the context, in discourse, but also in sentences themselves, like in conditional sentences.

Discourse representation theory A dynamic perspective has been adopted in the seminal (Kamp 1984), which was intended to bridge the apparent gap between formal logically oriented approaches to the semantics of natural language, and the cognitive models of reasoning from cognitive psychology. To this end, he employed a 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, viz., truth conditions, of natural language utterances, or rather of that of whole discourses. On the other hand, they form an essential ingredient in the process of interpretation, since already established representations 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. The ensuing architecture is aptly called *discourse representation theory* (*DRT*). (See also article 38 *Discourse representation theory*.)

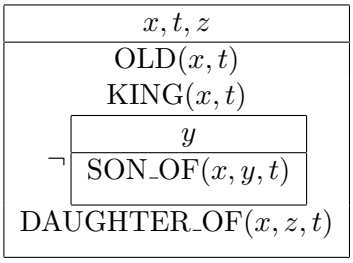
By way of illustration, the *DRS*s in (10) serve the represent the contents of a small, fancy, discourse like (9) at three stages in its interpretation.

(9) 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.

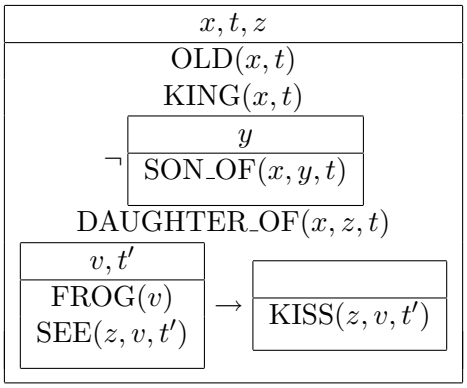
(10) a.



b.



c.



These three *DRS*s represent the contents of the discourse in (10) after processing the first sentence (10a), the first two sentences (10b), and after processing the whole (10c). Notice that the material contributed by the second and the third sentence gets added *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.

Historical remarks We end this introductory section with some historical remarks on the treatment of indefinite anaphoric relationships in terms of discourse reference. The subject has gained prominence by, among many others, the logico-philosophical (Geach 1962), and the seminal but relatively informal work on discourse reference in (Karttunen 1968). Kamp (1984) and Heim (1989) were the first, independently, to present a formal framework of interpretation

for anaphoric phenomena, *DRT* and *File Change Semantics* (*FCS*) respectively. (Slightly misleadingly, both were classified as theories of discourse representation at the time. Heim's main concern was not the representation of discourse, but a compositional architecture of interpretation.)

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 Barwise and Groenendijk and Stokhof, the last one of which gained most prominence. 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. Others were tailored for algebraic and computational applications (Zeevat 1989; Vermeulen & Visser 1996; van Eijck 2001). A detailed overview of the field of dynamic logics can be found in (Muskens, van Benthem & Visser 1997). Of course, discourse representation theory remained an attractive 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, 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 were tailored to giving a treatment of indefinites and pronouns in a standard framework of interpretation.

2. Dynamic predicate logic

Dynamic Predicate Logic (henceforth: *DPL*, Groenendijk & Stokhof 1991), has 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 appears to be a strong case in point. The interpretation of pronouns 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 called for. In *DPL*, an arguably non-representational but dynamic account is presented of the data original *DRT* was developed for.

2.1 Dynamic interpretation

In *DPL*, then, the dynamics of interpretation 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 most immediate way. Noun phrases are associated with indices, or variables, so as to indicate cases of coreference and binding. The kind of information concerned is information about the possible values of these variables, and these possible values may get changed and updated in discourse.

Consider the following little discourse, with indices (variables) on the relevant noun phrases, and some 'check-points' $\checkmark$ for evaluation.

(11) $\checkmark_0$ 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.$\checkmark_3$

At check-point 0 we have no information about the discourse, besides, possibly, some preliminary observations beyond the scope of *DPL*. 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 copy x from professor y. At check-point 2 copy x is qualified as worn-out, and at check-point 3, finally, the supposition is added that professor y studied the copy x intensively.

These rather informal observations have been implemented formally in the system of *DPL* in the following way. The language of (first order) predicate logic is taken as the representational medium. Information about the values of variables is encoded in variable assignments, and for any formula ϕ, the interpretation of ϕ relative to an ordinary model M, $[\![\phi]\!]_M$, is a set of pairs of variable assignments $\langle g, h\rangle$. The idea is that such a pair $\langle g, h\rangle$ is in the interpretation of ϕ relative to M if, and only if, ϕ can be successfully interpreted upon input assignment g, and yield assignment h as a possible output. The meanings of formulas can be conceived of as test upon, and changes in, the information about the possible values of variables.

A language L for *DPL* is an ordinary language for first order logic, based on a set of individual constants, sets of relational constants R of arity n, and a a set of variables. Formulas 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 ($\rightarrow$). Interpretation is defined relative to the usual models $M = \langle D, I\rangle$, consisting of a domain of individuals D and an interpretation function I for the individual and relational constants of L. The interpretation function I assigns an individual $I(c) \in D$ to the individual constants c of L and a set of n-tuples of individuals $I(R) \subseteq D^n$ to its n-ary relational constants R.

In the interpretation of *DPL* we use variable assignments, $g, h, k, l, \ldots$, which assign individuals $g(x) \in D$ to the variables $x \in V$. The interpretation $[t]_{M,g}$ of a term t in a model M, and relative to assignment g, is $I(t)$ if t is an individual constant and $g(t)$ if t is a variable. In what follows we use $g[x/d]$ for the variable assignment h that is like g except that it assigns d to x. We

say $g[x]h$ iff assignment $h = g[x/d]$ for some individual d, and we say $g[X]h$ iff $X = \{x_1, \ldots, x_n\}$ and there are $k_1, \ldots, k_{n-1}$ such that $g[x_1]k_1$, ..., and $k_{n-1}[x_n]h$. Armed with these notation devices we can state the semantics of *DPL* as follows.

Definition 1 (DPL Semantics)

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

Most clauses require the input assignment g and output assignment h to be the same, besides some standard predicate logical conditions. For instance, 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 the standard test succeeds, g is accepted as possible input and the interpretation of the formula does not change anything in its output. If the test fails then g is not accepted as possible input and in that case there is no assignment h such that $\langle g, h\rangle$ is in the interpretation of that formula.

Exactly when this is the case, that is, when the conditions imposed by a formula ϕ upon M and g is 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. Apart from the clauses for existentially quantified formulas and conjunctions, the other clauses in the definition are also static, in the sense that they do not allow input assignments to really change. The associated conditions are straightforward adjustments of the static interpretation of the embedded formulas to the dynamic (relational) interpretation. Only the interpretation of an implication is a bit more involved. An implication $(\phi \rightarrow \psi)$ is satisfied (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.

Changes in assignment functions are due to the interpretation of 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 valu-

ation of x, then the output valuation of x will have to satisfy these conditions. Metaphorically speaking, a 'discourse referent' with the properties attributed to x is introduced by such a formula, and it is labeled with the variable x.

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 delivers 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.

2.2 Dynamic binding

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

(12) 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 h (that is: k) is obtained from g by resetting the value of x so that $h(x) \in I(F)$, and by next resetting the value of y so that $h(y) \in I(D)$ 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 $h(y) = l(y) \in I(U)$. The third conjunct, a negation, tests whether assignment h cannot serve as input to satisfy the embedded formula $\exists z(Tz \wedge Hyz)$. This is the case if we cannot change the valuation of z into anything that is a tail had by $h(y)$. Putting things together, $\langle g, h\rangle$ is in the interpretation of our example (12) if, and only if, $g[\{x, y\}]h$ and $h(x)$ is a farmer who owns a donkey $h(y)$ which is unhappy and does not have a tail. Observe 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 $h'(y) = d$.

In the example discussed above we see 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. This is dynamic binding at work. In the first equivalence we see that a *syntactically free* variable gets *semantically bound* by a previous existential quantifier. The second one shows that this semantic binding gains strong, universal, force in implications. The use of the second equivalence is exemplified by the following, canonical, examples.

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

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

These two sentences have generally been judged equivalent, and so are the naturally associated translations in *DPL*. As a historical remark, back in 1979 Urs Egli has proposed to stipulate the above equivalences, in order to account for the anaphoric puzzles that plagued the literature. One of the merits of *DPL* is that the equivalences show up as true theorems.

The following, classical, equivalences are also valid in *DPL*.

Observation 2 (Equivalences that Hold)

$\neg\neg\neg\phi \equiv \neg\phi$ $\qquad$ $\forall x\phi \equiv \neg\exists x\neg\phi$

$(\phi \vee \psi) \equiv \neg(\neg\phi \wedge \neg\psi)$ $\qquad$ $(\phi \rightarrow \psi) \equiv \neg(\phi \wedge \neg\psi)$

As we have seen $\neg$ is an operator that introduces tests without any further dynamic impact, and as a consequence $\forall$, $\vee$ and $\rightarrow$ do likewise. That is, if ϕ contains a quantifier with binding potential, this potential gets lost when it occurs in the scope of $\neg$, $\forall$, $\vee$ or $\rightarrow$. As a consequence other equivalences typically do not hold in *DPL*.

Observation 3 (Equivalences that do Not Hold)

$\neg\neg\phi \not\equiv \phi$ $\qquad$ $\exists x\phi \not\equiv \neg\forall x\neg\phi$

$(\phi \wedge \psi) \not\equiv \neg(\neg\phi \vee \neg\psi)$ $\qquad$ $(\phi \wedge \psi) \not\equiv \neg(\phi \rightarrow \neg\psi)$

These non-equivalences are 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 the mentioned operators.

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

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

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

The facts about (undoing) dynamic binding, which follow by the definition of the semantics, correspond one to one with the facts about (in-)accessibility of discourse referents in basic *DRT*, cf. article 84 *Accessibility and anaphora*.

2.3 Dynamic consequences

DPL has been motivated by the desire to bring out the logic of a system of interpretation that accounts for anaphoric relationships, like *DRT*. It allows us to study the logical consequences in full formal detail. Before we can see

this more clearly, we have to present the *DPL* notions of truth and dynamic entailment first.

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 $\langle g, h\rangle \in [\![\phi]\!]_M$.
- A (possibly empty) sequence of formulas $\phi_1 \ldots \phi_n$ (in that order) entails 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 $\langle g_0, g_1\rangle \in [\![\phi_1]\!]_M$, ..., 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 required that ϕ can be satisfied, i.e., that there is some output assignment h in the interpretation of M relative to input assignment g. This notion of truth can be conceived of as a mere adaptation of a standard notion of truth to a slightly more involved notion of interpretation.

The notion of entailment is inherently dynamic though. 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) result of interpreting the premises. This formulation allows for binding relations between existentials occurring in the premises and free variables in the conclusion. This actually can be taken to justify two lines of reasoning found in the literature. Consider the following examples, with corresponding, valid, translations.

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

(19) A: A man has just drunk a pint of sulphuric acid.
B: Nobody who drinks a pint of sulphuric acid lives through the day.
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 following observation shows that the *DPL* notion of entailment properly corresponds to the *DPL* notion of implication.

Observation 4 (Deduction Theorem)
$\phi_1, \ldots, \phi_n \models \psi$ iff $\phi_1, \ldots, \phi_{n-1} \models (\phi_n \rightarrow \psi)$ iff $\models (\phi_1 \rightarrow \ldots (\phi_n \rightarrow \psi) \ldots)$.

This observation may also serve to show that existentials in the premises of an entailment are also interpreted strongly, that is, as *any* individual that satisfies the things existentially quantified over. Schematically: $\exists x\phi \models \psi$ iff (deduction theorem) $\models (\exists x\phi \rightarrow \psi)$ iff (donkey equivalence) $\models \forall x(\phi \rightarrow \psi)$.

With the notions of truth and entailment in place, we can bring out what sets *DPL* apart from standard, static, predicate logic, and why. As a first step, it is expedient to define the notion of a normal binding form. In the normal binding form ϕ^* of a *DPL*-formula ϕ the semantic binding relations coincide with the syntactic scope relations. It is defined as follows.

Definition 3 (DPL Normal Binding Form)

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

The following two observations are crucial.

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

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

The first clause tells us that ϕ and ϕ^* are fully equivalent in *DPL*. The second tells us that a normal binding form ϕ^* has standard, static truth conditions. It follows that the normal binding form ϕ^* gives a *static, i.e., standard* account of the truth conditions of ϕ under its *dynamic, i.e.,* DPL interpretation. So, the effects obtained by the dynamic interpretation of a formula ϕ 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 static predicate logic, and *DPL* (or *DRT*, for that matter) is that it allows us to present the truth conditions of $\exists x(\phi \wedge \psi)$ in a dynamic way by means of $(\exists x\phi \wedge \psi)$.

Now we have established that *DPL* has successfully modified static predicate logic in that it (just) allows for dynamic binding of variables, we may inspect on the consequences of this move for the ensuing logic. An immediate and obvious consequence of this dynamification 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. Surely, 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.

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 premises. Hence, the relation is not monotone. (In *DPL*, for instance, $\exists xEx \models Ex$, but $\exists xEx, \exists xOx \not\models Ex$.) Entailment is not reflexive either: a formula may change a context in which it is satisfied into one in which it is not. (In *DPL*, $(Ex \wedge \exists xOx) \not\models (Ex \wedge \exists xOx)$.) 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.

(20) 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 not valid in *DPL*. $((\exists xHx \rightarrow \exists yGy), (\exists yGy \rightarrow Sy), \exists xHx \not\models Sy.)$ 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 interesting consequences for the ensuing logic.

3. Pragmatic generalizations

DPL is only one of a family of interpretational architectures dealing with the dynamics of only one phenomenon, that of singular anaphoric relationships. Extensions of this system to other phenomena can be implemented in a straightforward manner, but these implementations also show that the dynamics of discourse interpretation is a fruitful subject of its own. Paying due attention to the dynamics of discourse interpretation reveals structural relationships which go unnoticed otherwise. This point is illustrated here by a concise overview of three typical subject areas, each exemplifying the pay-off of adopting a dynamic outlook upon interpretation.

3.1 Plurals and generalized quantifiers

The scope of a system of dynamic interpretation can be substantively broadened by extending the sorts of things dynamically talked about and quantified over, taking into account all kinds of things other than plain individuals, that tend to be introduced in discourses and dialogues. The variety of things is in principle unlimited, as it may concern plurals objects, groups, masses, events, times, intervals, facts, propositions, situations, worlds, and what have you. All of them can be handled, in principle, by the dynamic mechanism of setting up, and referring back to, discourse referents, as it has been fleshed out in *DPL* and *DRT*. (See also the articles 38 *Discourse representation theory* and 48 *Mass nouns and plurals*.) A *DPL*, or *DRT*, interpretation procedure can easily account for the semantic dependencies established in the following sentences.

(21) Five students came to the party. They had a splendid evening.
(22) Many liberals voted against the law. They were not convinced.
(23) None of the girls failed. They had studied hard.

The dynamics of discourse is much more involved than these simple examples suggest. It is not just the passing on of information exchanged, and not just the creation and utilization of discourse referents. This type of information comes by in a structured manner, as the following examples serve to show.

Notice, first, that plural pronouns may pick up plural entities which have not as such been introduced in the discourse.

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

Obviously the pronoun "they" should not be taken to refer to either Bob, or one of the others. The pronoun can, however, refer to the couple of Bob and Carol, and also to the whole group of four, Bob, Carol, Ted and Alice. However, this group of four has not been mentioned as such in the first line of example (24). Somehow this plural referent may have to be constructed from the four persons that have been explicitly introduced. (This process of forming plural discourse referents is called 'summation' in Kamp & Reyle 1993.)

Besides this type of summation of individual referents more is at stake. When we deal with plural anaphoric dependencies all questions about the distributive, collective or cumulative interpretation of plurals play up, in a dynamic fashion. Consider the following example.

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

The first sentence here can be taken to introduce group X of pupils and teachers, and a group Y of ballads and rhymes, such that X wrote Y and X performed Y at a certain evening. Of course, the writing of Y by X can be analyzed in more detail. Maybe the intended reading is that the pupils wrote the ballads and the teachers the rhymes. Also, the pronouns "they" and "them" can be taken to require further analysis, possibly depending on the particular kind of reading associated with the first sentence. The performers can be taken to have performed, individually or group-wise, the ballads and rhymes *they wrote* themselves. Upon this rather natural analysis, the truth conditions of the second 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 pattern repeats itself in quantified constructions.

(26) 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 a referent set of students who chose a book, and this is the set of individuals which the pronoun "them" intuitively refers to. However, assuming not everyone of them chose the same book, there is no singular referent figuring as the chosen book, which the pronoun *it* could have referred to. A natural interpretation of the second sentence of (26) is that the students wrote an essay about a book that they individually chose. We witness again a close interaction between the specific interpretation of two noun phrases in one construction, and the dynamic interpretation of dependent pronouns in another.

The examples can be taken to show that the dynamics of discourse does not just consist in the passing on of discourse referents, but in the construction and utilization of more involved entities, like relational structures (as in van den Berg 1996; Nouwen 2007), or parametrized or functional antecedents (as in Krifka 1996; Dekker 2008), or, of course, like representations thereof (as in Kamp & Reyle 1993).

Once adopting a dynamic perspective, further amendments are required in at least two more respects. When meaningful parts of speech get combined, a

(dynamic) conjunction or composition of meanings is surely straightforward. It is not that straightforward to interpret other methods of combination dynamically. For instance, second order quantifiers, which combine set denoting terms, are not that easily handled. Consider the following donkey sentence.

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

Upon the received analysis, the quantifier *MOST* is supposed to hold of two sets A and B, if and only if 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, if 'B' contains a pronoun apparently anaphoric on material in A. This question has raised a whole theoretical tradition of discussion of its own. Kamp & Reyle (1993) and Chierchia (1992) propose that the general, schematic, analysis of sentences like (27) should really be $D(A)(A\&B)$, so that example (27) can be taken to say that most farmers who own a donkey, own a donkey and beat it. Several authors, have argued that for several determiners and in several contexts this delivers too weak truth conditions. 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. Intermediate solutions have been suggested as well, in (Elbourne 2005) for instance. Theoretically, as well as empirically, the preferred dynamic treatment is still an open issue.

Another challenge to the dynamic implementation of discourse reference comes from the co- and subordination of tense and modalities. Consider the following examples, which can be multiplied at will.

(28) Conny opened the door. The room was pitch dark.
(29) Conny switched on the light. The room was pitch dark.
(30) A wolf might enter the house. It would eat Leo.
(31) Roseanne is sure that Mark doesn't have a car. She would have seen it.

In all of these examples, the tense or modality of the second sentence, as well as its content, is related to that of the first, which can be seen to have been set up as a temporal or modal discourse referent. However, there is no unique relation of coreference involved, because the temporal and modal connections come about in complicated structures. In order to deal with these kind of phenomena, then, the system has to allow, not only, for more involved temporal and modal structure, but also for more intricately structured contextual dependencies. See (Roberts 1989; Frank 1997; Geurts 1999) for empirical details and relevant theoretical discussion. See also Stone & Hardt (1999), Brasoveanu (2006), and Fernando (2007), and article 84 *Accessibility and anaphora*.

3.2 Updates in discourse

A dynamic outlook upon interpretation also provides the basis for investigating, detecting, and formalizing systematic pragmatically motivated aspects of interpretation. The dynamics of interpretation has also been studied from a more pragmatic perspective. Stalnaker (1978) has pictured assertions, or the assertive use of indicative sentences, as a kind of acts whose contents depend on their contexts, and which are meant to change these contexts. Assertions can be seen to characterize 'the actual world' as being a certain way, by locating

it among a set of possible ways the world might be. A common ground here figures as a shared body of information which is established between a group of interlocutors engaged in a conversation. The point of an assertion can be taken to be that its contents are *added* to such a common ground, yielding as a new common ground the intersection of the expressed contents with the old common ground.

These pragmatic observations can be combined with those of Grice (1975) about cooperative conversations. A rational and cooperative conversation should proceed according to a couple of gricean maxims, one of which requires speakers to convey information which they have evidence for. A speaker's own private information state, one might say, has to support the things she 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.

These insights about assertions and about cooperative behavior, can be formulated in a system of update semantics (Veltman 1996). In such a system the act of expressing a propositional content, and next incorporating it in a common ground, are fused into a dynamic notion of meaning which is function from information states to (updated) information states. It is written so that if p is the proposition (set of possible worlds) expressed by ϕ, then the update of a state (ground, context, also a set of possible worlds) τ with ϕ, written as $(\tau)[\![\phi]\!]$, equals $(\tau \cap p)$. Such an update system has been taken as the basis for a study of epistemic modalities and presupposition (see the next subsection), but also as a starting point for the study of organized, and rational information exchange.

A driving insight is 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, provided that it is supported by the information of the speaker. This point is well-motivated, and easily accounted for, but once it is made explicit it is obvious that it is not so trivial as it might appear at first glance. For one thing, such a principle need not hold once the interlocutors start making assertions about the conversation itself, or about each other's information (as in example (6) above). For another, it is hard to formualte such a requirement in the framework of *DRT* or *DPL*, because these systems fail appropriate notions of support (Aloni 2000).

Informative types of discourse not only consist of assertions, but they are, typically, also guided by questions: interrogatives, topics which the interlocutors raise, and questions they themselves face. Already at the outset of formal semantic theorizing about questions their *dynamic* role, their role in discourse or dialogue, has been obvious. Adopting a dynamic theoretical perspective, discourses or dialogues then 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, but governed by structural linguistic rules, and highly pragmatic principles of reasonable or rational coordination (Ginzburg 1995; Roberts 1996; Hulstijn 1997). A quite minimal way to account

for this proceeds by representing information as a set of possibilities, one of which is supposed to be actual. The possibilities are grouped in sorts. The sorting indicates 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. Information states then can be taken to be sets of sets of possibilities, which may get updated with further questions and more data in the development of a discourse.

Such a tentative sketch already provides the basics for characterizing certain basic discourse and dialogue notions like that of a coherent and felicitous dialogue. 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. Questions can be required to be non-superfluous as well, so that one doesn't *raise* an issue which is already there. Assertions can also be required to address issues at stake and not to provide unsolicited information. These observation and requirements, and many others, find a neat formulation in update style systems of interpretation. (Aloni, Butler & Dekker 2007) provides examples of much current work in this direction, and the inherent new questions they raise.

3.3 Modality and presupposition

Like we said a pragmatic system of interpretation along the lines of Veltman's update semantics provides a ground for evaluating epistemic modals, assertions made with the auxiliaries *may* and *must* or adverbials like *maybe*, *probably* and *evidently*. The 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. Thus, the effect of a modal $\mathcal{M}$, which expresses contextual epistemic possibility, can be tentatively defined as follows.

(32) $(\tau)[\![\mathcal{M}\phi]\!] = \tau$, if $(\tau)[\![\phi]\!]$ is possible, and $(\tau)[\![\mathcal{M}\phi]\!] = \bot$ otherwise.

Since the interpretation of the modality is stated in terms of the possible update of the current information state τ with the embedded sentence ϕ, the interpretation of these modal sentences may be variable. 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 collected information which rules out she is home. Epistemically used modals *might* and *must* may change their truth, or acceptability, in the course of events. The dynamic logic of such epistemic operators is investigated in detail in various *dynamic epistemic logics*. Groenendijk, Stokhof & Veltman (1996) present a non-trivial combination of Veltman's update semantics with the dynamic interpretation of *DPL*. In a more philosophical setting von Fintel and Gillies have investigated the uses of epistemic modals. Of a more linguistic nature is recent work by Asher, McCready and Ogata.

Also the pragmatic behavior presuppositions lends itself to a natural dynamic treatment. Presuppositions figure as preconditions for linguistic items (expressions) or acts (utterances) to make sense. They are preconditions for

terms to be referring, for predicates to be applicable, or for sentences to be true or false. A presupposition of a sentence is typically 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. Normally, presuppositions are also preserved when they occur under other operators, like modals and quantifiers. Presuppositions need not always be preserved though, and the dynamics of their so-called projection has been studied intensively. Consider one example.

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

The most deeply embedded sentence "Harry quit smoking cannabis" comes with the presupposition that Harry smoked cannabis. If we all know that Harry was a regular cannabis user, then the presupposition that he smoked cannabis is satisfied, and we may obtain a reading according to which Sally's belief concerns Harry's continuing smoking habit. If we are not sure about Harry's use of drugs, it may be that for all we know Sally believes he was a cannabis smoker, and that he didn't stop. It may be a bit awkward, but if Sally is already known to believe that Harry didn't ever smoke cannabis, then she can be taken to believe that he didn't quit doing so. In the cases mentioned, the triggering presupposition either gets cancelled or modified and a lot of the literature about presupposition has been devoted to a study of the cases in which presuppositions are not inherited by larger configurations, or in which they are modified, and how. The two main theories of presupposition in this area nowadays are the 'satisfaction theory' and the 'accommodation and binding theory' (the 'AB theory'). (See also article 102 *Presupposition*.)

According to both theories, presuppositions are required to be contextually given, or 'satisfied', in the common ground. A satisfaction theory requires presuppositions to be semantically satisfied in the local context in which they are evaluated (Karttunen 1974; Heim 1991; Beaver 1995; van Rooij 2005). Since these contexts *change* in the process of updating information, and the information the interlocutors have may grow in the development of a discourse, their different demands on different contexts can be accounted for, or better, are predicted. A most appealing aspect of this theory is that it comes with an automated satisfaction test, because the underlying notion of support is independently argued for. No separate notion of grounding presuppositions is called for.

Consider again the examples (3a) and (3b) from above.

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

If we indicate that a formula χ presupposes that ϕ by means of a subscript as in χ_ϕ, then we can render example (3a) as $(\phi \wedge \chi_\phi)$. According to the update notion of conjunction as function composition, the second formula's presupposition that ϕ ("Mike has children) is automatically satisfied by the update of the context with the first conjunct ϕ. Not so according to the rendering of example (3b) as $(\chi_\phi \wedge \phi)$. This conjunction as a whole still presupposes that ϕ, while its second conjunct still needlessly and explicitly conveys what has already been presupposed by the first. An update semantics precisely accounts for this

difference.

The AB theory of presupposition (van der Sandt 1992; Geurts 1999) is dynamic like the satisfaction theory, but it presents a different account of resolution. According to the AB theory, 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. Being resolved roughly means being semantically invisible, the AB counterpart of being satisfied. If they are resolved they as it were dissolve at the intermediary level of *DRT*'s discourse representation structures. If they are not resolved, they get 'accommodated', or, rather, they accommodate themselves, like true squatters. In such a case their structured contents are settled in a relevant part of a representation which resolves them in the slot where they originally appeared.

For an illustration, consider again example (33).

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

Nowhere in example (33) it is literally said or communicated that Harry did smoke cannabis, or that Sally believes so. So if the preceding context of such an example does not supply a way of resolving this presupposition, it has to accommodate itself. Even though this may require some further contextual support, one way for this presupposition to accommodate itself is right there where it stands, thus bringing about a reading according to which Sally is taken to believe that it is not the case that Harry smoked cannabis and stopped, similar to the last reading above. It may be easier to obtain a reading by accommodating the presupposition in Sally beliefs. Sally would then be taken to believe that Harry did smoke cannabis and didn't stop doing so, as one gets from the second reading above. Probably the most straightforward interpretation is one where the presupposition accommodates itself at the main level of interpretation, so that example (33) is taken to say that Harry used to smoke cannabis, and that according to Sally he didn't stop doing so, basically the first reading again.

While the underlying ideas of the satisfaction and the binding theory on satisfaction and resolution are similar, and while both are dynamic, the specific treatments are quite different though. The first is a logical approach, in that it predicts presuppositions as a type of entailments following from an independently specified semantics; according to the second presuppositions are typically representational constructions. The difference is vast, but not unbridgeable. A semantic variant of the AB theory, which fleshes out a logical notion of the meaning or interpretation of the unresolved presuppositional structures, is presented in (Dekker 2008).

4. Methodological issues

In this section we discuss some more theoretical themes related to the adoption of a dynamic notion of meaning. They are concerned with the issues compositionality, representationalism, dynamicity and contextuality. All of these are good old Fregean themes, and still actual in the current debate.

Representationalism and dynamism The dynamic remodeling of semantic theory has given rise to a revival of an old philosophical discussion around the representation and dynamics of meaning. The discussion has, largely inadvertently, concentrated on the phenomenon of inter-sentential anaphoric relationships, but it can be taken to relate to all kinds of dynamic interpretation. See also articles 6 *Compositionality* and 11 *Formal semantics and representationalism*.

It has been claimed, in particular by those who adhere to a *DRT*-style framework, that a principled account of certain semantic phenomena requires access to an independent level of representation. It has also been claimed, by advocates of a dynamic approach, that a compositional account of structural relations in discourse requires the adoption of a dynamic notion of meaning. It appears that the adoption of, at least some, dynamic aspects of interpretation are unavoidable also in a framework like *DRT*. The update of discourse representation structures proceeds in a typically dynamic fashion, and its embedding or satisfaction conditions are often stated in a dynamic way, most notably the satisfaction conditions of conditional structures.

But also a dynamic framework has to acknowledge, at least some, representational aspects of the way in which information is given. Already when only anaphoric relationships are at issue, both *DRT* and *DPL* need access to some notion of a 'discourse referent', and it seems discourse referent cannot but be taken to model the fact that in some ongoing discourse a noun phrase has been used in a specific way. It establishes "a fact about the conversation, and not about the subject matter," as (Stalnaker 1998, p. 13) puts it, or, in the words of Groenendijk, Stokhof & Veltman (1996, p. 183): "When one is engaged in a linguistic information exchange, one (. . .) has to store *discourse information*. . . . . Discourse information of this type looks more like a book-keeping device, than like real information."

It appears, however, that the phenomena at issue do no motivate more radical conclusions. True representationalists might want to convince themselves that the data show that meaning is irreducibly representational, but such a conclusion seems unfounded. The dynamic semantic reformulations of *DRT*'s treatments of anaphora and presupposition show that a realist, or referentially based, theory of meaning can be maintained if the interpretational architecture allows access to some representational aspects of the presentation of information. Convicted pragmatists may be tempted to believe that meaning is an inherently dynamic notion. Again, the data do not seem to support such a conclusion. Dynamic accounts of anaphora and presupposition have been given a static reformulation, or one based on traditional, algebraic and satisfaction based notions of meaning, with the addition of some suitable dynamic module of conjoining information (Zeevat 1989; Dekker 2008).

Summing up, in either case, a rather standard notion of meaning may remain as a basis for systematic extensions, extensions with the dynamic, or pragmatic, representational tools, which are required to establish meaningful relations in discourse. And even though this hasn't been done in a down to atomic level in basic *DRT* and *DPL*, it can be done in a fully compositional way. The basic adaption required to this end consists in assigning sentences, not the basic type t of truth values, but a new type *ccp* of context change potentials,

for instance, the *DRT* or *DPL* type of relations between variable assignments or some type of update functions. Needless to say that such a program can be carried out in many different ways, for there are various insights as to what kinds of entities live in the *ccp* domain, and the way in which they relate to the usual objects of the sentential type t. Some systems employ versions of Montague's own *intensional logic*, or multi-sorted type theory, or a constructive type theory, or a theory with simultaneous abstraction. Arguably the most perspicuous version has been given by Muskens (1996). Specific alternatives worth mentioning include Reyle's Underspecified DRT, Kohlhase and Kuschert's Λ-DRT, and Asher and Lascarides' Segmented DRT.

Pragmatics and contextuality According to a well-established division of labour, 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, arm-chair syntacticians and semanticists have happily and reflectively studied 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. See also article 5 *Meaning in language use*.

Under the influence of Wittgenstein and Strawson, and Austin and Searle later, 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. With the advent of systems of dynamic semantics such a pragmatic development of natural language semantics seems to have found a solid formal 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, etc. Such, however, raises the question 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 remains eventually tenable at all.

A dynamic semantics typically takes account of matters of usage which are or were seen to be of a pragmatic nature. Next to truth conditions it takes usage conditions into account. The question is how far this may take us, and this, really, is an open question. For, ascriptions of beliefs and desires to other people are highly context-sensitive as well, and so are the notoriously vague predicates like 'small' and 'bald' and 'generous'. It seems quite unfortunate to have to list all of the different kinds of uses to which these ascriptions and predicates can be put, and, hence, make them multiply ambiguous. It is unclear, however, what 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, viz., that whatever it is that we ideally end up with, it is so totally and deeply pragmatically infected ambiguous, that still calling it 'meaning' or 'semantics'

would be quite vacuous indeed.

This last point concerns a very open question, a live issue in the 'contextualist debate' (see, e.g., Recanati 2004; Stanley 2005). For now, we simply stop here and conclude that this year, in 2009, dynamic semantics has grown beyond the age of 21, it is grown up, quite successful, and alive. Its success may be attributed to the fact that it comes without a particular philosophical message but with a specific methodological advantage. It is a semantic system open to pragmatic intrusion and it easily escapes the straightjacket of standard truth-conditional semantics. Maybe too easily, but that has not been our concern here.

5. References

Aloni, Maria 2000. Conceptual Covers in Dynamic Semantics. In: Nick Braisby Lawrence Cavedon, Patrick Blackburn & Atsushi Shimojima (eds.) *Logic, Language and Computation, Vol III*, Stanford, CA: CSLI. 23–48.

Aloni, Maria, Alastair Butler & Paul Dekker (eds.) 2007. *Questions in Dynamic Semantics*, volume 17 of *CRISPI*. Amsterdam: Elsevier.

Barker, Stephen J. 1997. E-Type Pronouns, DRT, Dynamic Semantics and the Quantifier/Variable-Binding Model. *Linguistics and Philosophy* 20(2), 195–228.

Barwise, Jon 1987. Noun Phrases, Generalized Quantifiers and Anaphora. In: Peter Gärdenfors (ed.) *Generalized Quantifiers: Linguistic and Logical Approaches*, Dordrecht: Reidel. 1–30.

Beaver, David 1995. *Presupposition and Assertion in Dynamic Semantics*. Ph.D. thesis, CCS, Edinburgh. Published in 2001 by CSLI Publications, Stanford.

van den Berg, Martin H. 1996. *The Internal Structure of Discourse*. Ph.D. thesis, Universiteit van Amsterdam, Amsterdam.

Brasoveanu, Adrian 2006. Structured Discourse Reference to Propositions. In: Beáte Gyuris, Lázló Kálmán, Chris Piñon & Károly Varasdi (eds.) *Proceedings of the Ninth Symposium on Logic and Language*. Besenyőtelek, 35–44.

Chierchia, Gennaro 1992. Anaphora and Dynamic Binding. *Linguistics and Philosophy* 15(2), 111–83.

Dekker, Paul 2008. A Multi-dimensional Treatment of Quantification in Extraordinary English. *Linguistics and Philosophy* 31(1), 101–127.

van Eijck, Jan 2001. Incremental Dynamics. *Journal of Logic, Language and Information* 10(3), 319–351.

Elbourne, Paul 2005. *Situations and Individuals*. Cambridge, MA: MIT Press.

Fernando, Tim 2007. Observing events and situations in time. *Linguistics and Philosophy* 30(5), 527–550.

Frank, Anette 1997. *Context Dependence in Modal Constructions*. Ph.D. thesis, Universität Stuttgart, Stuttgart.

Geach, Peter T. 1962. *Reference and Generality. An Examination of Some Medieval and Modern Theories*. Ithaca: Cornell University Press.

Geurts, Bart 1999. *Presuppositions and Pronouns*, volume 3 of *CRISPI*. London: Elsevier.

Ginzburg, Jonathan 1995. Resolving Questions, I & II. *Linguistics and Philosophy* 18(5,6), 459–527 and 567–609.

Grice, H.P. 1975. Logic and Conversation. In: Peter Cole & Jerry L. Morgan (eds.) *Syntax and Semantics, Vol III: Speech Acts*, New York: Academic Press. 41–58.

Groenendijk, Jeroen & Martin Stokhof 1991. Dynamic Predicate Logic. *Linguistics and Philosophy* 14(1), 39–100.

Groenendijk, Jeroen, Martin Stokhof & Frank Veltman 1996. Coreference and Modality. In: Shalom Lappin (ed.) *The Handbook of Contemporary Semantic Theory*, Oxford: Blackwell. 179–213.

Heim, Irene 1989. *The Semantics of Definite and Indefinite Noun Phrases*. Ithaca: Garland.

Heim, Irene 1991. On the Projection Problem for Presuppositions. In: Steven Davis (ed.) *Pragmatics: A Reader*, Oxford: Oxford University Press. 397–405.

von Heusinger, Klaus 2004. Choice functions and the anaphoric semantics of definite NPs. *Research in Language and Computation* 2(3), 309–329.

Hulstijn, Joris 1997. Structured Information States. Raising and Resolving Issues. In: Anton Benz & Gerhard Jäger (eds.) *Proceedings of MunDial97*, University of Munich. 99–117.

Kamp, Hans 1984. A Theory of Truth and Semantic Representation. In: Jeroen Groenendijk, Theo Janssen & Martin Stokhof (eds.) *Truth, Interpretation and Information*, Dordrecht: Foris. 1–41.

Kamp, Hans & Uwe Reyle 1993. *From Discourse to Logic*. Dordrecht: Kluwer.

Karttunen, Lauri 1968. *What Do Referential Indices Refer To*. Technical Report P-3854, RAND Corporation. Reproduced by the Indiana University Linguistics Club.

Karttunen, Lauri 1974. Presupposition and Linguistic Context. *Theoretical Linguistics* 1(1), 181–193.

Krifka, Manfred 1996. Parametrized sum individuals for plural reference and partitive quantification. *Linguistics and Philosophy* 19(6), 555–598.

Muskens, Reinhard 1996. Combining Montague semantics and discourse representation. *Linguistics and Philosophy* 19(2), 143–186.

Muskens, Reinhard, Johan van Benthem & Albert Visser 1997. Dynamics. In: Johan van Benthem & Alice ter Meulen (eds.) *Handbook of Logic and Language*, Amsterdam: Elsevier. 587–649.

Nouwen, Rick 2007. On Dependent Pronouns and Dynamic Semantics. *Journal of Philosophical Logic* 36(2), 123–154.

Recanati, François 2004. *Literal Meaning*. Cambridge: Cambridge University Press.

Roberts, Craige 1989. Modal Subordination and Pronominal Anaphora in Discourse. *Linguistics and Philosophy* 12(4), 683–722.

Roberts, Craige 1996. Information structure in discourse. In: J. H. Yoon & A. Kathol (eds.) *Working Papers in Linguistics 49*, Ohio State University. 91–136.

van Rooij, Robert 2005. A Modal Analysis of Presupposition and Modal Subordination. *Journal of Semantics* 22(3), 282–305.
van der Sandt, Rob A. 1992. Presupposition Projection as Anaphora Resolution. *Journal of Semantics* 9(4), 333–377.
Slater, Hartley 2000. Quantifier/variable-binding. *Linguistics and Philosophy* 23(3), 309–321.
Stalnaker, Robert 1978. Assertion. In: Peter Cole (ed.) *Syntax and Semantics 9 – Pragmatics*, New York: Academic Press. 315–332.
Stalnaker, Robert 1998. On the Representation of Context. *Journal of Logic, Language and Information* 7(1), 3–19.
Stanley, Jason 2005. Semantics in context. In: Gerhard Preyer & Georg Peter (eds.) *Contextualism in Philosophy: Knowledge, Meaning, and Truth*, Oxford: Oxford University Press. 221–254.
Staudacher, Peter 1987. Zur Semantik indefiniter Nominalphrasen. In: Brigitte Asbach-Schnitker & Johannes Roggenhofer (eds.) *Neuere Forschungen zur Wortbildung und Histographie der Linguistik. Festgabe für Herbert E. Brekle*, Tübingen: Gunter Narr Verlag. 239–258.
Stone, Matthew & Daniel Hardt 1999. Dynamic Discourse Referents for Tense and Modals. In: Harry Bunt & Reinhard Muskens (eds.) *Computing Meaning*, Dordrecht: Kluwer. 302–321.
Veltman, Frank 1996. Defaults in Update Semantics. *Journal of Philosophical Logic* 25(3), 221–261.
Vermeulen, Kees & Albert Visser 1996. Dynamic Bracketing and Discourse Representation. *Notre Dame Journal of Formal Logic* 37(2), 321–365.
Zeevat, Henk 1989. A Compositional Approach to Discourse Representation Theory. *Linguistics and Philosophy* 12(1), 95–131.

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