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37. Discourse Representation Theory

Abstract

Discourse Representation Theory (DRT) originated from the desire to account for aspects of linguistic meaning that have to do with the connections between sentences in a discourse or text (as opposed to the meanings that individual sentences have in isolation). The general framework it proposes is dynamic: the semantic contribution that a sentence makes to a discourse or text is analysed as its contribution to the semantic representation – Discourse Representation Structure or DRS – that has already been constructed for the sentences preceding it. Interpretation is thus described as a transformation process which turns DRSs into other (as a rule more informative) DRSs, and meaning is explicated in terms of the canons that govern the construction of DRSs. DRT's emphasis on semantic representations distinguishes it from other dynamic frameworks (such as the Dynamic Predicate Logic and Dynamic Montague Grammar developed by Groenendijk and Stokhof, and numerous variants of those). DRT is – both in its conception and in the details of its implementation – a theory of semantic representation, or logical form.

The selection of topics for this survey reflects our view of what are the most important contributions of DRT to natural language semantics (as opposed to philosophy or artificial intelligence).

1. Introduction

1.1. Origins

The origins of Discourse Representation Theory (DRT) had to do with the semantic connection between adjacent sentences in discourse. Starting point was the analysis of tense,

but with time this resistance appears to have lessened, largely because of the growing trend to see linguistics as a branch of cognitive science. (How good the representations of DRT are from a cognitive perspective, i.e. how much they tell us about the way in which humans represent information – or at least how they represent the information that is conveyed to them through language – is another matter, and one about which the last word has not been said.)

In the course of the 1980s the scope of DRT was extended to the full paradigm of tense forms in French and English, as well as to a range of temporal adverbials, to anaphoric plural pronouns and other plural NPs, the representation of propositional attitudes and attitude reports, i.e. sentences and bits of text that describe the propositional attitudes of an agent or agents (Kamp 1990; Asher 1986; Kamp 2003), and to ellipsis (Asher 1993; Lerner & Pinkal 1995; Hardt 1992.) The nineties saw, besides extension and consolidation of the applications mentioned, a theory of lexical meaning compatible with the general principles of DRT (Kamp & Roßdeutscher 1992; Kamp & Roßdeutscher 1994a), and an account of presupposition (van der Sandt 1992; Beaver 1992; Beaver 1997; Beaver 2004; Geurts 1994; Geurts 1999; Geurts & van der Sandt 1999; Kamp 2001a; Kamp 2001b; van Genabith, Kamp & Reyle 2010). The nineties also saw the beginnings of two important extensions of DRT that have become theories in their own right and with their own names, *U(nderspecified) DRT* (Reyle 1993) and *S(egmented) DRT* (Asher 1993; Lascarides & Asher 1993; Asher & Lascarides 2003). SDRT would require a chapter on its own and we will only say a very few words about it here; UDRT will be discussed (all too briefly) in Section 8.2. In the first decade of the present century DRT was extended to cover focus-background structure (Kamp 2004; Riester 2008; Riester & Kamp 2010) and the treatment of various types of indefinites (Bende-Farkas & Kamp 2001; Farkas & de Swart 2003).

2. DRT at work

In this section we show in some detail how DRT deals with one of the examples that motivated its development.

2.1. Tense in texts

As noted in Section 1, the starting point for DRT was an attempt in the late seventies to come to grips with certain problems in the theory of tense and aspect. In the sixties and early seventies formal research into the ways in which natural languages express temporal information had been dominated by temporal logics of the kind that had been developed from the fifties onwards, starting with the work of Prior and others (Prior 1967; Kamp 1968; Vlach 1973). It became increasingly clear, however, that there were aspects to the way in which temporal information is handled in natural languages which neither the original Priorean logics nor later extensions of them could handle.

One of the challenges that tenses present to semantic theory is to determine how they combine temporal and aspectual information and how those two kinds of information interact in the links that tenses establish between their own sentences and the ones preceding them. (1) and (2) are striking examples of this challenge. Here we will look at a pair of slightly simplified discourses which illustrate the same point.

here. Proper names like *Alain* are also treated as predicates, with a built-in *referential uniqueness*. For instance, Alain(x) means that the discourse referent x represents the individual referred to (in the represented utterance) by the name *Alain*.

This completes the informal description of the different parts of the DRS in (5). A formally precise description is provided by the model-theoretic semantics for DRSs. From a logical point of view DRSs are the formulas of DRT's semantic representation languages. These languages come – like other logical formalisms, such as the predicate calculus – with a syntax which defines the possible forms of expressions (here: the well-formed DRSs and DRS-conditions), and with a model theory which describes for each of the well-formed expressions its denotation in each of the models that it specifies for the given DRS-language. We won't go into the formal definition of the models for DRS languages that include DRSs like that in (5), but refer the reader to the literature (Kamp & Reyle 1993 or van Genabith, Kamp & Reyle 2010).

Since the DRSs of our formalism involve discourse referents for entities of various sorts, models must have a fairly complicated structure (much more so than the models for standard first order logic): they must have a time structure as well as temporal relations between times and eventualities (*eventuality* is used as a cover term for both events and states). For any model M the *denotation of* (5) in M will be the set of all functions of the universe of (5) into the universe of M such that: (i) f(t) is a time of M (i.e. an interval or point of the time structure of M), (ii) f(e) is an event of M, (iii) f(x) is an individual of M, (iv) the conditions of (5) are all satisfied in M by the f-values of their arguments: (a) f(t) temporally precedes the utterance time of the first sentence of (3); (b) f(e) is temporally included in f(t); (c) f(x) is Alain (i.e. the person referred to by the speaker in using *Alain* on the given occasion; it is assumed that Alain is one of the individuals of M); (d) f(e) is an event of f(x) waking up. Such functions, from the universe of a DRS into the universe of a model, are usually called *embedding functions* or, simply, *embeddings*. If an embedding function verifies all the conditions of the DRS in the model – in the case of (5) this means that it satisfies the requirements (a) - (d) – then it is called a *verifying embedding*.

With this definition of the denotation of (5) in a model comes a definition of truth: (5) is *true in* M if there exists a verifying embedding of (5) in M, i.e. if the denotation of (5) in M is non-empty. Note the existential form of this definition: (5) is true in M if *there exists* a way of associating entities from M with the universe of (5) such that the conditions of (5) are satisfied in M.

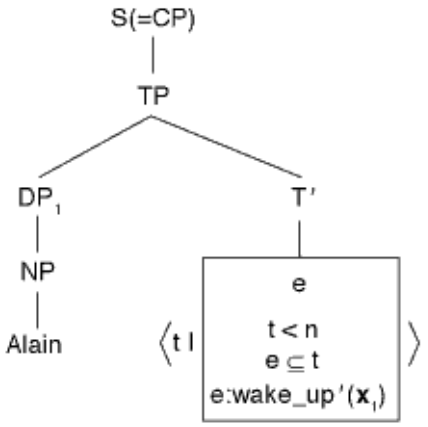
To construct (5) from (4) we proceed bottom up, associating semantic representations with the nodes of (4) as we traverse the tree from its leaves to its root, working our way up, roughly speaking, from bottom right to top left. We start by replacing the given occurrence of the verb, *wake up*, with the appropriate instantiation of its semantic representation. This representation is provided by the lexical entry for the verb, which we assume is given in the following form.

(6)	*wake up*	verb	nom
		e	**x**
	Selectional Restrictions:	event	animal
	Semantic Representation:	e:wake_up′(**x**)	

This entry says that *wake up* is a verb, that its referential argument is an event (see the Selection Restrictions), that *wake up* has one non-referential argument, which must

event e of VP is located is represented by a discourse referent t (introduced when the construction reaches T) and the location relation between e and t is given by the condition $e \subseteq t$. t itself is related to the speech time n by the information PAST at T. For occurrences of the past tense in simple sentences this relation is represented by the condition $t < n$. It is assumed that the operation which temporally locates the described event e also leads to existential binding of the discourse referent e that represents the event. Existential binding takes the form of transferring e from the store into the universe of the DRS to its right. The new discourse referent t still requires binding, and to this end it is placed in the store. (The discourse referent n, which represents the utterance time, is subject to a special indexical binding regime, which is reminiscent of the treatment of the word *now* as an indexical (Kaplan 1989). We follow the convention adopted in much DRT-based work that 'n' is not placed in any DRS-universe or -store, as a way of emphasising the special way in which n is bound.)

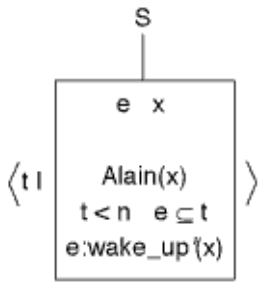
(8)



The next steps assign a semantic representation to the subject DP. The NP *Alain* of this DP has the form of a proper name. For now we will assume that names act as nominal predicates which introduce a discourse referent – x, in the present example – for the individual they are being used to refer to, together with a condition which expresses that the discourse referent stands for this individual. Here we use the condition Alain(x) to express this. With these assumptions the semantic representation for the NP can be given as ⟨ x | Alain(x)⟩. About the binding of x (as part of the interpretation of the DP *Alain*) more will be said in Section 3. At this point we will make do with the solution proposed in earlier versions of DRT, according to which x is existentially bound while the condition Alain(x) imposes the constraint that the only possible value for x is the individual that *Alain* refers to.

The coindexation of the subject DP with the argument position marker **x** in (7) and (8) will be instrumental in the next step, which combines DP and TP. This step inserts the representing discourse referent of the DP into the argument slot marked by **x** in the TP representation. Part of this insertion process is that the DRSs of TP and DP get merged. We will assume – but again this is a kind of stop-gap measure; see Section 3 – that as part of this process the discourse referent x which represents the referent of the DP is existentially bound by being transferred from the DP store to the universe of the DRS that results from the merge. This leads to the representation in (9).

(9)

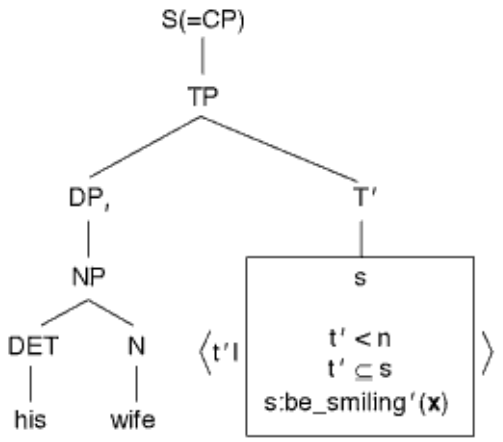


The one remaining task is the binding of t. In the present case, where the S node we are dealing with is the S node of a discourse-initial main clause, binding of the discourse referent t is existential, which once again amounts to transferring the discourse referent from its store to the universe of the DRS adjacent to it. The resulting representation is the one that was already shown as (5).

We now turn to the two second sentences (a) and (b) of (3). This is where the special features of DRT, which concern the semantic relations between successive sentences in a discourse, come into prominence. We start with sentence (3b). To avoid unhelpful complications we treat the form *be smiling* as a single verb, which serves to describe states: the condition s: be_smiling′(x) means that s is a state to the effect that x is smiling.

Construction of the semantic representation of (3b) proceeds in much the same way as that of the first sentence of (3). The only differences have to do with the temporal location of the state s, with the representation of the subject phrase *his wife* and with the binding of the temporally locating discourse referent t′. The first difference manifests itself in the transition from VP to TP. We assume that states are located at times in the sense that the time is one at or during which the state holds; that is, the location relation between t′ and s is t′ ⊆ s (rather than the converse relation which was assumed for events). So we get as representation at this construction stage:

(10)



The representation of the subject phrase *his wife* differs from that of *Alain* in several respects. First, the discourse referent introduced as referential argument of wife′ must be a fresh discourse referent (i.e. one that is distinct from the discourse referents that have been previously introduced into the representation of the discourse) so that no clashes can occur between the referential roles they are meant to play. In particular, the new

(13)

t′ s x′ u
wife′(x′, u)
t′ < n t′ ⊆ s t′ = t u = x
s:be_smiling′(x′)

The identification of t′ with t also amounts to a kind of anaphora resolution. In fact, past tenses in non-initial sentences of a discourse tend to be *anaphoric* in this sort of way. It is this anaphoric dimension which enables them to contribute to the temporal connectedness of texts and discourses, something that the present examples are meant to illustrate.

Note that (13) is not a *proper* DRS in the sense that some of the discourse referents occurring in its conditions (viz. x and t) do not occur in its universe. Such improper DRSs do not have well-defined denotations in the sense we specified earlier: embeddings of their universes do not determine the satisfaction of all of their conditions. The improperness of (13) disappears, however, when it is merged with the representation of the first sentence (by forming the union of their universes and the union of their condition sets). The result of the merge is given in (14).

(14)

t e x t′ s x′ u
Alain (x)
t < n e ⊆ t
e:wake_up′ (x)
wife′(x′,u)
t′ < n t′ ⊆ s t′ = t u = x
s:be_smiling′(x′)

(14) is the joint representation of the two sentences of (3b). It is a proper DRS and thus has a denotation and a truth value in every model.

The representation construction for (3a) is in most respects like that for (3b). The only differences have to do with the fact that (3a) functions as an event description, and not, like (3b), as a state description. This difference shows up, first, in that the verb *smile* introduces an event discourse referent e′ (and not a state discourse referent) and, second, in that the temporal relation established between e′ and e is different from that between s and e in the case of (3b).

Intuitively, we saw, the relationship between e′ and e is that e′ follows e. But how does this relationship get established? Although this has been the subject of discussion for several decades, it continues to be a topic for ongoing research and debate. But this much is clear: How successions of event sentences are interpreted depends very much on the rhetorical relations between them, and these vary. For instance, the event described in the second of two connected sentences in a discourse is sometimes understood as a *reaction* to the event described in the first sentence – the natural interpretation in the case of (3a) – but in other cases it can also be understood as the *cause* of that event – the most salient interpretation for *John fell. Bill pushed him*; or it can be understood as an elaboration

What is still missing, though, is a precise articulation of the steps that provide the links between the two sentence representations. A more detailed proposal for how such links are established will be discussed below in Section 3.

2.2. Donkey sentences and complex DRS conditions

Before we get to that discussion we will first have a look at examples, given in (16) and (17), of the two types of *donkey sentences* which were used in Geach (1962) to illustrate the puzzle known as the *donkey sentence problem* or the *donkey pronoun problem*. The early development of DRT, and its initial reception, were closely connected with this problem.

(16) If Alain owns a donkey he beats it.

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

In both these sentences the pronoun *it* is understood as referring back to the indefinite DP *a donkey*. The methods that are suggested by classical predicate logic for constructing logical forms for these sentences, in which pronouns are treated as bound variables and indefinite DPs as existential quantifiers, have trouble with such sentences – their logical forms come out either as ill-formed or they give the wrong truth conditions. The two apparent options for (16) are shown in (18) and (19).

(18) $\exists y(\text{donkey}'(y) \wedge \text{own}'(a,y)) \rightarrow \text{beat}'(a,y)$

(19) $\exists y(\text{donkey}'(y) \wedge (\text{own}'(a,y) \rightarrow \text{beat}'(a,y))$

In (18) the final occurrence of y is not bound, so we have an open formula, which doesn't determine any definite truth conditions. This problem does not arise for (19), but the truth conditions of this formula are clearly not those of (16). The solution of DRT (Heim 1982; Kamp 1981a) was based on a conceptual parallel between the sentences in (16) and (17) and a two sentence discourse like (20).

(20) Alain owns a donkey. He beats it.

In (20) the pronouns *he* and *it* of the second sentence are anaphoric to *Alain* and *a donkey* in the first sentence in the same way that *his* is anaphoric to *Alain* in (1) and (3); and a DRT-based interpretation of (20) will establish these anaphoric links in the same way in which we assumed the link was established between *his* and *Alain* in the treatment we have presented of (3b). The point about (16) and (17) is that here too the same linking mechanism is involved. Let us focus first on (16). This sentence has the form of a conditional "if A then B". The DRT conception of a conditional is this: the antecedent A functions as the description of a certain type of situation, and the conditional as a whole has the function to express that if a situation is of this type then it is also of the type described by the consequent B. And since it is about situations of the type described by A that the claim is made that they also satisfy the description given by B, it is

verify that this stipulation of when DRS conditions of the form $K \Rightarrow K'$ are true assigns the following truth conditions to the DRS condition in (21d): If at the utterance time n there is a donkey f(y) such that Alain owns f(y), then at n Alain beats f(y). These are the truth conditions that speakers associate with (17), or at least they come quite close to those. (Certainly much closer than the "logical form" in (18), which comes nowhere near.)

The expression in (21d) is a DRS condition, we said. But (16) is a sentence that can be asserted in its own right (i.e. without the benefit of a discourse context provided by preceding sentences). So we want a DRS to represent it, as a "one sentence discourse" so to speak, with well defined truth conditions (just as we wanted and had a DRS for the first sentence of (2)). We resolve this conflict by taking the DRS for (16) to be the one which has an empty universe and whose condition set contains just the condition $K_1 \Rightarrow K_2$. (What we have said here isn't entirely accurate. In the standard representation for this sentence (Kamp & Reyle 1993) the discourse referent x and the condition Alain(x) are part of the main DRS and not of the antecedent DRS K_1. As promised in connection with the treatment of (2) we will return to this matter when we come to discuss presupposition in Section 3.)

(21d) is our first example of a *complex* DRS condition. All conditions we encountered previously were *atomic* DRS conditions – they consist of a predicate of the given DRS language with discourse referents as arguments. The expressive power of DRSs that are built just from discourse referents and atomic conditions is quite limited – semantically speaking such DRSs are always existential quantifications over conjunctions of atomic predications. Negation, disjunction, implication and universal quantification – to mention just the operations familiar from standard first order logic – cannot be expressed with these means and require complex conditions of some form. To this end DRT employs a number of operators which form DRS conditions out of one or two DRSs: $\neg$ for negation, $\Rightarrow$ for implication, $\vee$ for disjunction and  for universal quantification. The

syntax of a DRS language which includes all or some of these operations requires a simultaneous recursion over DRSs and DRS conditions:

Definition 1 (Syntax for DRS languages with complex conditions)

(a) A *DRS* is a pair ⟨U,Con⟩, where U is a set of discourse referents and Con is a set of DRS conditions.

(b) (i) An *atomic DRS condition* is of the form $P_n(x_1,..,x_n)$, where P_n is an n-place predicate and $x_1,..., x_n$ are discourse referents.

(ii) If K_1 and K_2 are DRSs and x is a discourse referent,

then $\neg K_1$, $K_1 \Rightarrow K_2$, $K_1 \vee K_2$ and K_1  K_2 are *(complex) DRS conditions.*

For each of the complex DRS conditions in (b-ii) we need model-theoretic *verification conditions.* So far, we have given these only for $\Rightarrow$. The following definition restates these more formally and adds those for the other operators. We use the following notation: Where f and g are functions from sets of discourse referents into the universe of a

model $\mathcal{M}$ and X is a set of discourse referents, $g \sqsupseteq_x f$ means that $Dom(g) = Dom(f) \cup X$. Moreover, when K is a DRS, then $g \sqsupseteq_K f$ is short for $g \sqsupseteq_x f$, where $X = U_K$.

Definition 2 (Verification of complex DRS conditions)

Let f be a function from discourse referents to elements of the model $\mathcal{M}$, and let K_1 and K_2 be DRSs.

(a) f *verifies* $\neg K_1$ *in* $\mathcal{M}$ if there is no extension $g \sqsupseteq_{K_1} f$ which verifies all the conditions of K_1 in $\mathcal{M}$.

(b) f *verifies* $K_1 \Rightarrow K_2$ *in* $\mathcal{M}$ if every extension $g \sqsupseteq_{K_1} f$ which verifies all the conditions of K_1 in $\mathcal{M}$ has an extension $h \sqsupseteq_{K_2} g$ which verifies all the conditions of K_2 in $\mathcal{M}$.

(c) f *verifies* $K_1 \vee K_2$ *in* $\mathcal{M}$ if either there is an extension $g1 \sqsupseteq_{K_1} f$ which verifies all the conditions of K_1 in $\mathcal{M}$ or there is an extension $g2 \sqsupseteq_{K_2} g$ which verifies all the conditions of K_2 in $\mathcal{M}$.

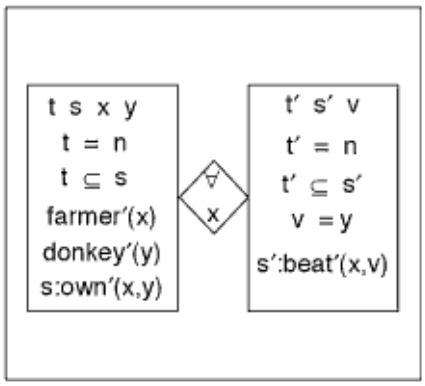
(d) f *verifies* $K_1 \Diamond_{\alpha}^{\forall} K_2$ *in* $\mathcal{M}$ if every extension $g \sqsupseteq_U f$, where $U = U_{K_1} \cup \{\alpha\}$, such that g verifies all the conditions of K_1 in $\mathcal{M}$ has an extension $h \sqsupseteq_{K_2} g$ which verifies all the conditions of K_2 in $\mathcal{M}$.

DRS languages which include the operators mentioned in Def. 1 (with the semantics given for them in Def. 2) have at least the expressive power of first order predicate logic. As in standard formulations of first order logic the set of operators is redundant – some operators in the set can be expressed with the help of others. But for the given set of DRS operators the redundancy is more extreme. Since existential quantification and conjunction are built into the structure of DRSs, just adding $\neg$ already suffices to express all the remaining classical operators.

It should be stressed, however, that the operators of extensional logic cover only a small part of the operator-like constructions that are found in natural languages and that play a crucial part in making natural languages the powerful and flexible instruments of expression and communication they are. In order to cover more of these operations DRS languages have been extended repeatedly as time went on. Some such extensions will be discussed in Section 6.

We return to the discussion of the sentences in (16) and (17). The point of departure for that discussion was the analogy between those sentences and discourses like (20): The discourse context that the first sentence (20) provides for the second sentence of (20) is provided in the conditional sentence (16) by the conditional's antecedent for the conditional's consequent. A similar analogy applies to (17), where it is the restrictor of the quantifier that provides a discourse context for the nuclear scope. The DRS for (17) is given in (22).

(22)



We omit details about the construction of (22), but see e.g. Kamp & Reyle (1993) or Reyle, Rossdeutscher & Kamp (2008).

The recursion in Def. 1 entails that DRSs can have arbitrarily complex structure – they can have complex conditions built from DRSs containing complex conditions built from DRSs containing ... . With the nesting structure of DRSs within DRSs within DRSs ... comes a notion that is central to the way in which DRT deals with anaphora and presupposition. This is (DRS-)*accessibility*. Accessibility is a relation between sub-DRSs of a given DRS K, with K itself also counting as an (improper) sub-DRS of K. A pronoun belonging to a sentence part that gives rise to a sub-DRS K′ of the DRS K for the sentence as a whole can be anaphoric to a DP elsewhere in the sentence only if the discourse referent introduced by this DP occurs in the universe of K′ itself or else in a universe of a sub-DRS of K that is accessible from K′. We will see in Section 3 that a similar constraint holds for presupposition justification. A proper definition of accessibility must partake in the recursive definition of DRSs and DRS conditions. We refer to Kamp & Reyle (1993) for details. Here we just give some examples: (i) the antecedent K_1 of a DRS condition $K_1 \Rightarrow K_2$ is accessible from the consequent but not conversely; (ii) the restrictor DRS K_1 of a DRS condition $K_1 \overset{\forall}{\underset{\alpha}{\diamond}} K_2$ is accessible from the nuclear scope DRS but not conversely; (iii) the DRS K_1 of a condition $\neg K_1$ is *not* accessible from any condition belonging to the same condition set as $\neg K_1$; (iv) neither of the two DRSs K_1 and K_2 of a condition $K_1 \vee K_2$ is accessible from the other.

3. Presupposition and binding

For a long time presupposition was a concern of logicians. Their concern mostly took the form of a worry – that failed presuppositions would cause lack of truth value and thereby compromise the validity of classical, bivalent logic. And their concern was exclusively with referential terms, all of which they tended to identify with definite descriptions: when such a term would fail to properly denote and thereby violate the presupposition that it does properly denote, then that would create a truth value gap for the sentence and this would lead to the failure of certain logical laws. It was only the late sixties that saw a shift both in our understanding of the nature and role of presuppositions and in the communities that preoccupied themselves with presuppositional phenomena. In

fact, there were two new perspectives, each of them focussed more on the structure and use of natural language than on the properties of logical calculi. The first, best known through the writings of Stalnaker (Stalnaker 1972; Stalnaker 1974; Stalnaker 1979), is the view that presupposition is a pragmatic phenomenon, in the following sense. When we use language to communicate we always assume that there is much information we already share with those we are trying to communicate with; without such a supporting *Common Ground* it would be virtually impossible to convey any information concisely and clearly. So it is a natural and ubiquitous feature of verbal communication that much information is *presupposed* without which we couldn't express ourselves as concisely as we want to. The second perspective – sometimes somewhat unfortunately referred to as "semantic" – emphasises the conventional aspect of presupposition: Certain words and grammatical constructions come with presuppositions in the sense that no utterance in which these words or constructions occur can be considered felicitous unless the context in which the utterance is made verifies the presuppositions they introduce. A speaker who uses such words or constructions *cannot help but* make the corresponding presuppositions, the Common Ground of which she assumes that it obtains between her and her interlocutors must verify those presuppositions. Historically this second view, according to which linguistic presuppositions are conventionally associated with their triggers, is primarily connected with the names of Langendoen and Savin, Kiparsky, and Karttunen (Langendoen & Savin 1971; Kiparsky & Kiparski 1970; Karttunen 1973; Karttunen 1974). (See also article 91 (Beaver & Geurts) *Presupposition.*) It is this second perspective that motivates the treatment of presupposition within DRT.

With the semantic perspective came the awareness that presupposition is much more widespread than had previously been assumed. Presuppositions are not only triggered by definite descriptions and other singular terms, but also by many other words and constructions. Indeed, when investigations inspired by this new awareness got under way, a significant part of the work consisted in identifying the presupposition triggers that can be found in English and other natural languages; and even today that search is far from over.

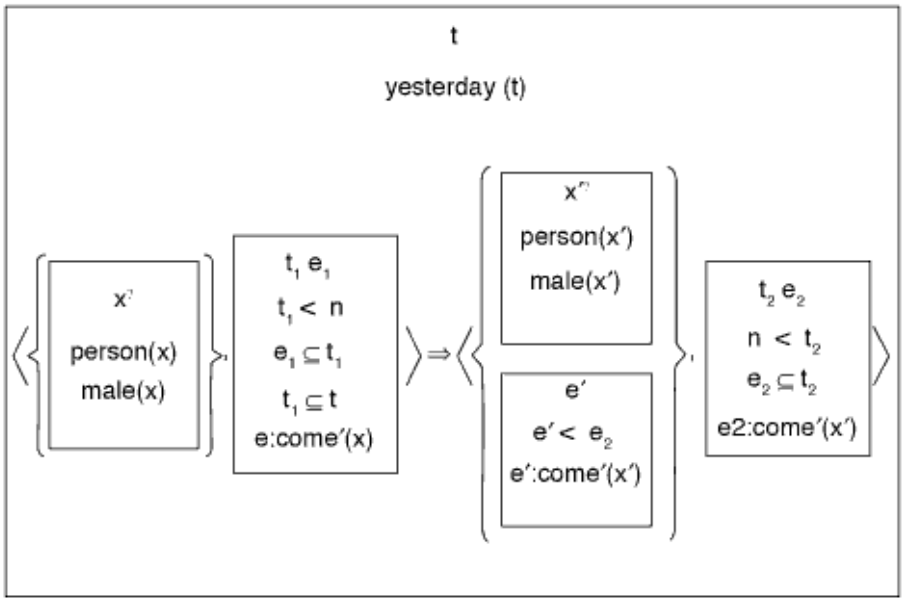
The central challenge that this way of looking at presupposition was soon seen to present for the theoretical linguist, however, was the Projection Problem (Karttunen 1973). Karttunen noted that presuppositions carried by simple sentences often disappear when these sentences are embedded within more complex ones. Our intuitions about the truth and felicity conditions of simple sentences give us reliable information about which words and constructions are presupposition triggers, and about what presuppositions they trigger; but sometimes, when the triggers occur in logically complex sentences, these very presuppositions seem to be absent nonetheless. To give an example: the word *again* carries the presupposition that an event or state of the kind described by the clause containing it happened or obtained at some time preceding the event or state that is being described. Thus compare the utterances (23a) and (23b).

(23) a. He will come.
b. He will come again.
c. He won't come again.
d. Will he come again?

pronoun is different in form from the presupposition imposed by a word like *again*, but that is as far as the difference goes. In van Genabith, Kamp & Reyle (to appear) a distinction is made between *anaphoric* and *non-anaphoric* presuppositions. Anaphoric presuppositions always involve anaphoric discourse referents and impose on the context the constraint that it supplies discourse referents which can serve as antecedents for those. The anaphoric discourse referent is then interpreted as standing to its antecedent in a certain relation; often this relation is coreference, but not always (not e.g. in cases of temporal anaphora). Non-anaphoric presuppositions are presuppositions in the sense of presupposition theory "before DRT" and act as entailment requirements: they express presuppositions that the context is required to entail. (As a matter of fact, both these types of presuppositions can be seen as special cases of a more general form of *anaphora cum presupposition:* a constraint to the effect that the context provides one or more discourse referents for which it entails certain properties and/or relations; arguably van der Sandt's theory can be interpreted as advocating this generalised notion.)

Here we follow the version of presupposition theory presented in van Genabith, Kamp & Reyle (to appear). In this version anaphoric pronouns are treated as triggers of presuppositions of the form: <x?,C1(x),..,Cn(x)>, where x is the discourse referent representing the pronoun and C1,..,Cn are conditions connected with the pronoun in question (e.g. a condition to the effect that the referent must be a person of the female sex) and as before the question mark behind the discourse referent x serves as indicator that the context must provide an antecedent discourse referent with which x is to be identified. With this new treatment of anaphoric pronouns the representation of (23b) will no longer require a store. (However, we will see below that stores are still needed.) Instead the two pronoun occurrences now each contribute a presupposition. The new representation, which replaces (25b), is given in (26).

(26)



Resolution of the first pronoun presupposition is possible only if a suitable discourse referent is provided by the utterance context. In such a context the second pronoun presupposition can then also be resolved to that discourse referent. This will lead to

as argument phrase). But in addition to that the discourse referent must also be bound. In DRT, binding in the nominal domain (i.e. of the discourse referents representing DPs) can take three different forms: In all cases part of the binding operation is to place the discourse referent that is being bound in some DRS universe. But otherwise the operations differ. The three types of binding are:

(i) quantificational binding
(ii) presuppositional binding
(iii) structural binding

ad(i): Cases of quantificational binding are those in which the discourse referent α representing the DP is bound by the logical operator denoted by the DP's determiner. An example is the binding of x by the universal quantifier denoted by *everyone* in the DRS (22) for (17). In this case the bound discourse referent x appears in the universe of the restrictor of the duplex condition introduced by the quantificational DP as well as jointly with the operator in the central component of the condition.

ad(ii): A discourse referent α representing a definite DP is always bound via presuppositional resolution. In these cases the context must provide a discourse referent β with which α can be identified (or, sometimes, related in some other way). Resolution of the presupposition (with or without accommodation) implies that β belongs to some universe of the context representation; identification of α with β can be implemented either by replacing α everywhere by β or by inserting α into the universe of the DRS to which the presupposition representation was left-adjoined and adding the equation $\alpha = \beta$ to the condition set of that DRS.

ad(iii): Structural binding has often been seen as DRT's main claim to faim. In the original versions of DRT it applied just to indefinite DPs. This is still true as far as the nominal domain is concerned: of the different types of DP that are found in a language like English – quantificational, definite and indefinite – it is only the indefinites that give rise to this kind of binding.

The name 'structural' for the type of binding described under (iii) reflects the idea that it is simply by virtue of belonging to a certain DRS universe that the discourse referents representing indefinite DPs get their quantificational force. This force derives from the truth definition for DRSs, and it is because of the existential element in this definition – 'there exists an embedding function from the DRS universe into the universe of the model which verifies the conditions of the DRS' – that indefinites often have existential force. However, this isn't always so. See for instance the discussion of donkey sentences in Section 2.2.

In the examples we have considered so far each indefinite contributed its discourse referent to its local universe (i.e. to the universe of the most deeply embedded (sub-) DRS representing a part of the sentence in which the indefinite is contained). There are cases, however, where indefinites are not interpreted as having local scope. The earliest examples are due to Farkas (1981). A much discussed example, due to Farkas, is that in (28).

(28) Every student in the syntax class has to discuss three arguments why some claim of Chomsky is wrong.

meanings of *awake*, *asleep* and *unconscious*. But where would this information be stored if it isn't part of the entry for *wake up*?

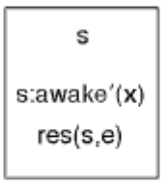
This brief discussion shows that the lexicon builder is facing two connected questions: (i) What semantic information about individual words should the lexicon make available? and (ii) Where should which information go? There are no simple answers to these questions. Answers to the first depend on what inferences we want our system to be able to draw. But even when these answers are settled, that won't in general settle the second question. Since most of the information that needs to be coded is relational – it concerns the meanings of two or more lexical items, not of a single one – there are several suggestions that come to mind as to where it should be stored: as part of the entry for the first lexical item, as part of the entry for the second, ... ; as part of each of those entries (creating a good deal of redundancy); or in some other place altogether. The last option is in essence that of coding lexical semantic information in the form of *meaning postulates* in the sense in which this notion has come down to us from the work of Carnap and Montague (who however use meaning postulates primarily as ways of coding information about single lexical items). The use of meaning postulates as part of a DRT-based lexicon goes back to Kamp & Rossdeutscher (1994a), where they serve as the axioms of *Lexical Theory*, a formal axiomatic theory which supports inferencing from representations that contain the lexical predicates which its postulates are about. The core vocabulary of this theory consists of so-called *lexical primes*, predicates that are used to articulate fundamental ontological relationships such as those that determine the structure of time and space, motion and causation. (Thus Lexical Theory is assumed to include formal ontology as a part.)

Here we will give two examples of how connections between lexical predicates can be made explicit. That between *wake up* and *awake* is naturally captured by changing the semantics of the lexical entry for *wake up* so that it says that the events described by *wake up* are transitions from a state in which the subject is not awake to one in which it is. The new entry is given in (31).

(31)

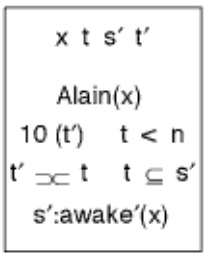
wake up	(verb)	nom
	e	**x**
Sel. Restr.:	event	animal

Sem. Repr.:



Here res(s,e) is to be read as "s is the state resulting from the event e". ("res" is one of the primes of the Lexical Theory.) The relation between *awake*, *asleep* and *unconscious* is one of those that are naturally cast in the form of meaning postulates, as in (32).

(35)

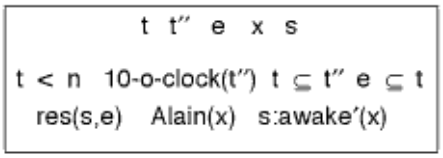


We cannot go into the details of the construction of (35) here. But in any case, the copula construction is only one among many in which predication conditions like awake′(x) have to be transformed into conditions of the form s:awake′(x). In general, such conversions pose a non-trivial problem, not only for adjectives, but also for other non-verbal predicates, such as nouns and prepositions. If we cast the lexical entries of these words in the same mould as (34), with semantic components that take the form of simple predications – e.g. wife′(x,**y**) in the entry for the noun *wife* – then these predications too will often have to be converted into conditions like s: wife′(x,**y**) with one or more additional conditions to locate s. The occurrence of *wife* in (3) provides us with a glimpse of what the problems are that may arise in this connection. In 2.1 we represented the information about x′ being the wife of u simple in the form wife′(x′, u). But this is, strictly speaking, a way of prevaricating on a question that can be raised about (3), and that in certain contexts one might well want to raise: *When* is or was x′ the wife of u – at the time of the event of which (3) speaks, or at the time when the sentences are uttered?

As this example suggests, there are no simple general rules for resolving such ambiguities. The problem, in other words, is not so much that of converting conditions of the form 'wife′(y,x)' into conditions of the form s: wife′(y,x), but to determine the intuitively correct temporal locating conditions for s. For discussion of this problem see Musan (1995), Tonhauser (2000) and Kamp (2001a).

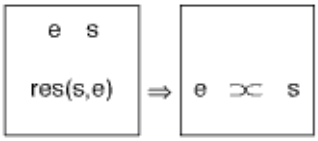
The DRS for (33a) is much like the one we gave in 2.1 for the first sentence of (3), except that (i) there will now be an additional discourse referent t″ representing 10 o'clock, together with the condition that it includes t (t ⊆ t″), and (ii) the new entry (31) for *wake up* imports into the DRS a result state, s′ of the waking up event e, with the conditions s′:awake′(x) and res(s′,e). The DRS is given in (36).

(36)



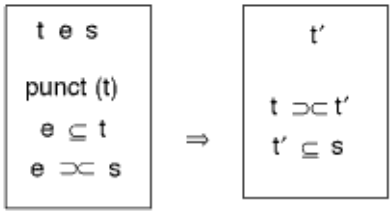
To infer (35) from (36) we need two more principles. The first has been implicit in what has already been said: if s is a result state of e, then s abuts e on the right. Formally:

(37)



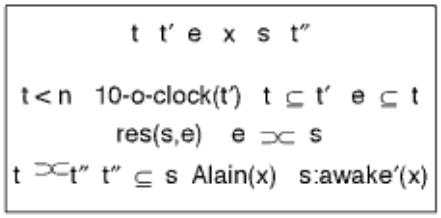
The second principle has to do with the punctual character of the time specification *10 o'clock*. Intuitively such a time t cannot extend beyond the duration of an event e happening at that time. This entails that if e happens at t and s is a state that right-abuts e, then s must include some initial segment of the period that stretches from t into the future. Using "punct" to represent the notion of punctuality that is conveyed by expressions like *10 o'clock*, we can formalise this principle as in (38).

(38)



With the help of (37) and (38), (36) can be modified into (39), from which (34) can be obtained by renaming discourse referents and thinning (i.e. throwing away discourse referents and conditions).

(39)



To infer the DRS for (33c) from that of (33a) a little more is involved. We now need in addition: (i) entries for *asleep* and *unconscious* (which are like (34)) and the meaning postulate (32): (ii) a general principle to the effect that if a state s of a certain type is the result state of an event e, then immediately before e there was a state of the opposite type, i. e. a state s′ which is characterised by the negation of the condition that characterises s. (Often s′ and s are referred to as the *prestate* and *poststate* of e.)

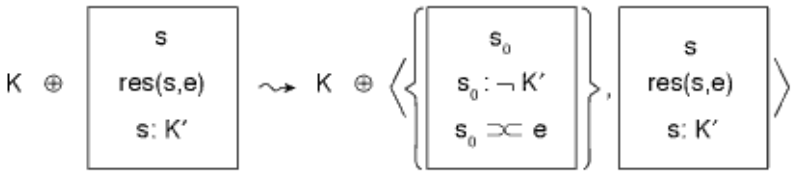
The prestate of an event e will hold at the moment e begins. Sometimes it will last throughout e, but it may also cease before that, in which case the gap between it and the result state will be bridged by some transitional state. However, if we assume that for each state s and interval t included in the duration of s there is a state s′ of the same time as s and with t as its duration, then the Prestate Principle can be formulated simply that there is a state which abuts e on the left and is of a type opposite to e's result state.

Note that the Prestate Principle has the status of making explicit a presupposition. Compare for instance the sentences *Bill left the room* and *Bill didn't leave the room.* For both of these the salient interpretation is that according to which, at the time in question, Bill is inside the room. For some reason the question is raised whether Bill left the room at that time, and the two sentences resolve that issue in opposite ways – the one says that Bill did leave the room and the other that he remained in it. (The negated sentence can be used in relation to a situation in which Bill is not in the room at t, as in *Bill didn't leave the room for the simple reason that he wasn't in the room to begin with at that time.* But

such contexts are marked, and they typically involve information which denies that the pre-state held at the relevant time.)

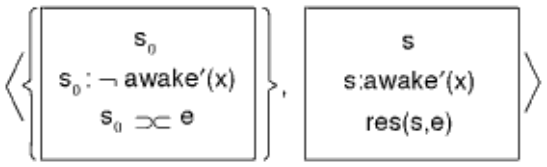
The upshot of this is that the general principle according to which any combination of an event e and a result state s implies the existence of a corresponding prestate s′ must take the form of adding to the representation of event e and result state s a presupposition saying that e is left-abutted by a state whose characterisation is the opposite of that of s. (40) gives the template for adding pre-state presuppositions to arbitrary representations of this kind (i.e. to arbitrary representations introduced by change-of-state verbs). K is a schematic letter for DRSs, K′ for a DRS or a DRS-condition.

(40)

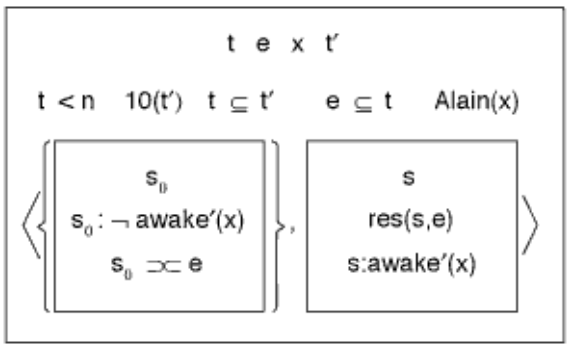


To infer the DRS for (33c) from the DRS (36) for (33a) we first expand the latter by an application of (40) in which K′ is instantiated by the conditon awake′(x). ((41) shows this instantiation of the second term in (40) of the second occurrence of ⊕.) The condition that the event of x waking up was immediately preceded by a sate to the effect that x was not awake, is incorporated into (36) as a presupposition (see (42)). After the presupposition of (42) has been justified (possibly through accommodation), it is available as non-presuppositional information and can be merged with the rest of (42), see (43). At this point we can apply (32) to replace the characterisation awake′(x) of the pre-state s_0 by asleep′(x) ∨ unconscious′(x). Moreover, we can also apply to the state s_0 a principle that is the mirror image of principle (38): if t″ is punctual, e ⊆ t″, and $s_0 \supset\!\prec$ e, then s_0 includes some period of time t‴ that left-abuts t″. With this last application a DRS has been obtained from which the DRS for (33.c) can be derived by renaming and thinning.

(41)



(42)



(43)

t e x t′ s_0 s
t < n 10(t′) t ⊆ t′ e ⊆ t s_0 ⊐⊂ e res(s,e) Alain(x)
s_0 : ¬ awake′(x) s:awake′(x)

The main point of this discussion has been to show how closely the design of the semantic components of lexical entries has to be tied to questions of inference if the inferential support role of the lexicon is taken as seriously as DRT claims it should. Moreover, it isn't just the semantic components of the lexical entries themselves that must be fine-tuned to inferential requirements; the same is true, and perhaps even more emphatically, for the meaning postulates that constitute the Lexical Theory without which the entries would not be able to discharge their inferential obligations. Inferences in the temporal domain provide good illustrations of this intimate connection between inference and the lexicon, but they are in no way alone in this. Therefore, inference always has to be foremost in the mind of the lexical semanticist, no matter what part of the lexicon he is dealing with.

The examples we have discussed bring to the fore two aspects of lexical semantics that DRT-based work has been at pains to do justice to: event structure and presupposition. Presupposition has played its part here only in the form of the pre-state presupposition associated with the change-of-state verb *wake up*. But since pre-state presuppositions are associated with all change-of-state verbs, we accounted for the case that arises in our example by means of the general schema (40) rather than adding the pre-state presupposition explicitly to the semantic part of the lexical entry for the verb *(wake up)* itself (though technically that could have been an alternative way to proceed). However, there are many lexical items which carry presuppositions as an idiosyncratic part of their individual meaning, and in such cases the only natural place for encoding those presuppositions is as part of the semantics of their own lexical entries. An example is the presupposition carrier *again*. (Reasons of space keep us from presenting and discussing its lexical entry explicitly.)

A third important aspect of lexical meaning is *intentionality*. Intentionality is a far more common aspect of lexical meaning than it tends to being given credit for. For instance, we find it in most action verbs, whose default interpretation is that the agent has a certain intention and that the action the verb describes is an attempt to make that intention come true. Representing these intention-related components of lexical meaning puts serious demands on the representation formalism one uses. This has been one reason for the special effort that has been made within DRT to put such a formalism in place. (See Section 6.3 on Propositional Attitudes.)

For the formal logician our discussion carries a different moral. The inferences of which we have offered reconstructions in this section have an appearance of almost embarrassing simplicity. This simplicity has been largely confirmed by the reconstructions we have offered. But these reconstructions also show that a certain amount of inference-like work is involved in these reconstructions nevertheless. That work consists largely in identifying the language-related principles that allow the premise DRS to be transformed or expanded to the point where the entailment relation between it and the conclusion DRS has become fully transparent. In our reconstructions above we coded these language-related principles in the form of meaning postulates; and it was only in

the application of these postulates to the premise representation that the inference rules of classical formal logic came into play. In the examples we have looked at the uses we have made of such rules have been very elementary, and in this respect our examples have been good illustrations of what is involved in such inferences generally: The real action – or there is of it – in such inference processes is in selecting the postulates that make it possible to transform the premise DRS in the ways required. Since the number of meaning postulates that are part of knowing a language is very large, choosing the right ones for a given inferential task could well be a non-trivial problem. It seems however that this is something at which language users are remarkably adept. So, inasmuch as knowing meaning postulates and making the right choices from the set of meaning postulates one knows is arguably part of our *linguistic* competence, the conclusion would seem to be that our inferential abilities depend as much as on our knowledge of language as on a language-independent capacity for abstract formal reasoning.

We conclude this discussion with a word of caution. The inferences reconstructed above were strict, deductively valid inferences. But most of the inferences people draw in the day to day business of real life aren't like that; they are approximate and defeasible. Lexical entries should be such that they can support such inferences too. However, our understanding of how defeasible inferencing works is still fragmentary and tentative. And so long as our grasp of this part of the general problem of inference remains as feeble as it is today, there is no way of telling how well the lexical semantics we propose will stand up in the longer run.

6. Extensions

6.1. Plurals

Natural languages such as English mark the distinction between singular and plural. Plural nouns are as common as singular ones. This in itself would be reason enough to demand of a theory dealing with the semantics of such a language that it can handle plurals as well as singulars. But in the case of DRT there is a special reason for wanting to cover plurals and not only singulars, which has to do with the original motivations for the theory. As noted earlier, one of the main selling points of early DRT was the way it treats the anaphoric relation between pronouns and their indefinite antecedents. A crucial ingredient of that account is the assumption that the interpretation of an anaphoric pronoun always involves a discourse referent that is either made available by the DRS of the preceding discourse or by the DRS of the sentence itself. It is to this discourse referent that the pronoun is then related (often, though not invariably, in the sense of coreference). Plural pronouns, however, do not behave in strict accordance with this principle. They are often interpreted as referring back to elements of the discourse context that are not (yet) represented by discourse referents and that must first be constructed from material that is explicitly contained in the representation.

Our first task in this section will be to review the relevant observations about the behaviour of plural pronouns and DRT's account of them. But the extension of DRT to cover plurals also has another important aspect: By extending DRT so that plurals are covered as well as singulars we move from first to second order logic. This point is not as obvious as it might seem, and requires careful discussion. But it is methodologically

important. We will discuss the two issues – plural anaphora and the expressive power of the extended DRS language – in that order.

Many plural DPs denote sets with two or more members. (Not invariably, see Kamp & Reyle (1993, Ch.4); but in this brief review we will confine ourselves to DPs for which this is the case.) This applies also to anaphoric plural pronouns. But often the sets that these pronouns refer to are not explicitly represented in the discourse representation that should supply the pronoun's antecedent – not, at least, when that representation has been constructed from the antecedent discourse along the lines sketched in Section 2. An example is (44).

(44) Alan took his wife out to dinner. They shared the hors d'oeuvre.

Here the pronoun *they* in the second sentence clearly refers to the pair consisting of Alan and his wife. But if the DRS for the first sentence is constructed according to the standard rules of DRS construction, then it will have no discourse referent representing this pair; it will only have discourse referents – x and y, say – that represent Alan and his wife separately. To obtain a discourse referent that can serve as antecedent for *they* we have to apply the operation of Summation. This application takes the form of introducing a new plural discourse referent Z and adding the condition $Z = x \oplus y$, which defines Z as the sum of x and y.

The possibility of constructing discourse referents that can serve as antecedents for plural pronouns is of methodological interest because it is subject to certain restrictions. This is illustrated by (45).

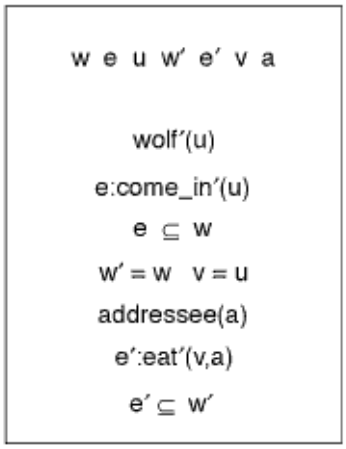
(45) Half of the shareholders were present at the meeting. They learned about what had been said and decided at the meeting only from the newspapers the next morning.

In this sentence *they* can only refer to the half of the shareholders that were at the meeting, even if that interpretation makes little sense in the given context. The interpretation that would make more sense – the one according to which *they* refers to the other half, who were not at the meeting – is blocked: subtraction of one set from another is not an operation that is available for creating pronominal antecedents. (It has been argued that subtraction is possible in certain circumstances, though speakers vary in their judgements about such cases. For extensive discussion of this issue see Nouwen 2003 and Kibble 1997.) Creation of pronoun antecedents is thus not just a matter of logical inference from the DRS representing the given discourse context. Only certain operations, such as the Summation operation that was used to synthesise the Z in constructing a representation for (44), are permitted. (For more details see Kamp & Reyle 1993). Moreover, the restrictions to which this process is subject, and which distinguish it from standard logical deduction, are specific to the interpretation of pronouns: There is no difficulty in referring to the half of the shareholders that were not at the meeting, provided we use a definite description. (In fact, we just did; and in (45) the phrase *the other half* would have done as well.)

The upshot of these considerations: There are a number of principles that can be used to construct antecedents for plural pronouns from material that is explicitly present in the given DRS, but these principles do not exhaust the full power of logical inference.

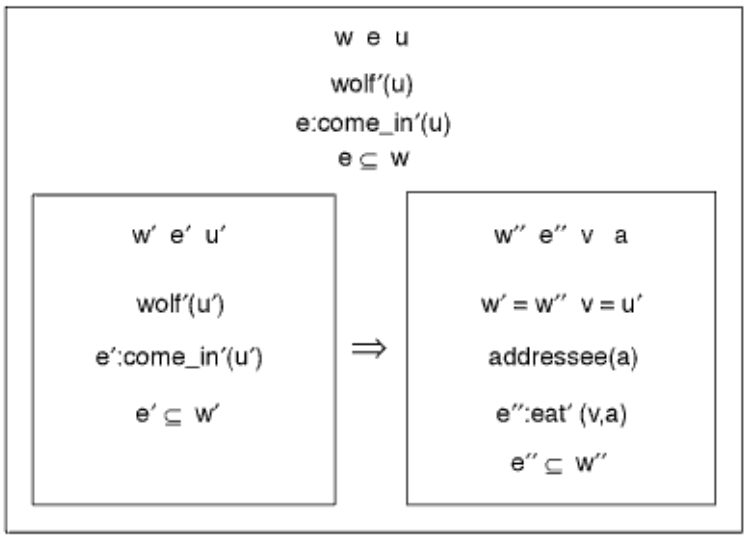
We can extend this DRS with the contribution made by the second sentence of (53) by treating its modal operator *might* as anaphoric to the *might* of the first sentence. The world introduced by the second *might* is identified with the one introduced by the first *might*. This leads to the representation in (55).

(55)



(52) differs from (53) in that its second sentence seems to involve a universal quantification over worlds: Any world in which a wolf would come in would be one in which it would eat you first. As Roberts saw, an adequate semantic representation requires a new interpretation principle (characteristic of modal subordination phenomena) which treats the representation of the first sentence of (52) as the antecedent of a conditional that has the representation of the second sentence as its consequent. The representation is given in (56).

(56)



In more recent times the use of discourse referents for worlds has become more common, notably in the work of Bittner (Bittner 2005; Bittner 2007; Bittner 2008) and Brasoveanu (Brasoveanu 2007). (Just as in Montague Grammar the type-language of Gallin, cf. Gallin 1975, has been adopted by many as replacement of Montague's own Higher Order Intensional Logic, HOIL, see Montague 1970b.)

6.3. Propositional attitudes

The classical treatment of belief, knowledge and other propositional attitudes as it has come to us through the work of Carnap, Montague, Kaplan, Lewis and others treats the objects of the attitudes – that which is believed, known, etc. – to be intensions, as defined in the last subsection. There is one major objection to this kind of analysis, often referred to as the problem of logical omniscience: intensions do not allow for distinctions that are sufficiently fine-grained. In particular, any two sentences that are logically equivalent express the same proposition (i.e. propositional intension). An account that takes intensions to be the objects of belief cannot explain how a person could stand in a relation of belief to a sentence S while failing to stand in that relation to a sentence S′ in cases where S and S′ happen to be logically equivalent, but where this is not so easy to see and the person in question hasn't seen it. If the person professes belief in S but denies belief in S′, then all the theory could say is that she must either be wrong about S or about S′. There is wide (if not universal) agreement that this conclusion is incompatible with the actual aetiology of belief.

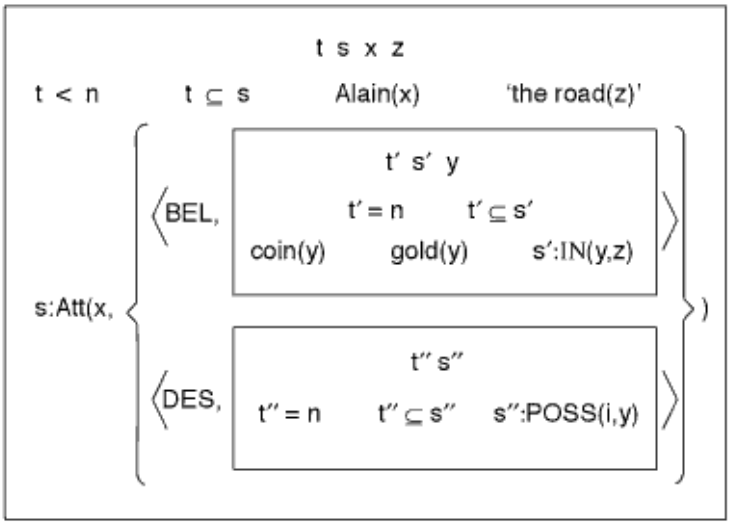
To obtain an ontology of attitudinal objects that is immune to this objection Asher (Asher 1986; Asher 1993) offers a DRT-based account in which the objects of the attitudes are identified as equivalence classes of DRSs. The equivalence relation that generates these classes is defined in terms of the structural properties of DRSs and is substantially tighter than the relation of logical equivalence in classical logic. This approach has the merit of providing an explicit definition of intensional identity that escapes the problem of logical omniscience (at least in its most obvious and unacceptable manifestations). A potential drawback is that it is hard to see which relation of structural equivalence between DRSs gives us the intuitively correct notion of intensional identity. (The problem seems to be in part that intensional identity varies with context.)

A second DRT-based approach, related to Asher's, but different at certain points, was first outlined in Kamp (1990) and subsequently developed in explicit formal detail in Kamp (2003). (See also Kamp 2006 and van Genabith, Kamp & Reyle (to appear).) Here the emphasis is on the development of a representation formalism that is capable of representing not just single propositional attitudes but also combinations of attitudes involving different attitudinal modes – e.g. the combination of a belief and a desire, or of a belief and a doubt. Moreover, it can represent such combinations of two or more attitudes not only for a single agent at a single time, but also combinations of attitudes that a person entertains at different times, or that are held by different persons at the same or at different times. The basic construct of this extension of DRT is a predicate 'Att' whose first argument slot is for the bearer of the represented attitudinal state, while the second slot is for a representation of the attitudinal state that is being ascribed to him. (There is also a third slot, which is reserved for connections between discourse referents occurring in the second slot and objects in the world to which these are anchored, so that these discourse referents function as directly referring terms. For ease of exposition we ignore this slot until further notice; but see the next subsection.) The representations that fill the second slot of 'Att' are sets of pairs consisting of an attitudinal mode indicator (such as BEL for belief, DES for desire, etc.) and a DRS specifying the propositional content of the attitude represented by the pair.

An important feature of this way of representing attitudinal states is that the representations which occur as second members of the pairs may share discourse referents

between them. The meaning of a discourse referent x being shared between the content representation K_1 of one attitude (a belief, say) and the content representation K_2 of another attitude (say, a desire) is that the agent to whom this pair of attitudes is ascribed takes his two attitudes to be about one and the same thing 'x'; and this possibility of taking the two attitudes to be about the same x is independent of whether there exists an external object that can be construed as the common referential target of the two attitudes. An example is given in the DRS in (57).

(57)



(57) represents the case of a person, Alain, who was, at some time t in the past of the current time n, in a mental state which included a pair of connected attitudes – the belief that there was a gold coin lying in the middle of the road and the desire to be in possesion of this coin. Belief and desire are about the same coin, even if both attitudes are based on a phantasy or a mistake and there is no real object (coin or otherwise) that they could be taken to be about. (The discourse referent i in the last DRS represents the self of the agent; this discourse referent is always used in the representation of properties that the agent attributes to himself – in other words, to represent his de se attitudes, see Lewis 1979.)

Enriching DRS-languages with Att opens up the possibility of representing information about attitudinal states of unlimited complexity. For 'Att' may occur in a DRS K that is part of a pair <MOD,K> occurring as an element of the second argument of another occurrence of 'Att' this makes it possible to represent attitudes of one person about the attitudes of another person (or, for that matter about her own attitudes). Such embeddings can be iterated at libitum.

In the model theory for predicational conditions involving 'Att' that is given in Kamp (2003) and van Genabith, Kamp & Reyle (to appear) the possibility of improving on the notoriously problematic ontology of attitudinal objects in terms of classical intensions was given up, partly for the sake of transparency. There would be no difficulty in principle in changing this semantics in favour of one in the spirit of Asher, in which the objects of the attitudes are identified in terms of the syntax of the given DRS language; but other ontological alternatives are in principle possible as well, and a definitive choice should wait until our understanding of the identity conditions for attitudinal objects has improved beyond what it is today.

One important application of the DRT-extension that is obtained by adding the predicate 'Att' is in the semantics of attitude reports (i.e. of the sentences and bits of discourse that are used to ascribe attitudes and attitude complexes to other persons or to oneself). This application requires, in addition to the extension itself, lexical entries for attitudinal predicates - *believe*, *doubt*, *intend*, *learn*, *belief*, *intention*, *acquainted with* – as well as new DRS construction rules for the constituents of the clauses and sentences that serve as complements to such verbs, nouns and adjectives. It should be emphasised, however, that the account we have described is in the first instance an account of the attitudes themselves. More precisely: it is first and foremost an account of mental states that are composed of such attitudes – and only in the second instance of the linguistic forms that natural languages use to describe such mental states and their components.

7. Direct reference and anchors

According to some (we ourselves among them) certain phrases can be used to refer directly. When a phrase α refers directly to an entity d, the link between them guides all possible evaluations of the sentence S to which α belongs, in non-actual circumstances as well as in the actual circumstances in which S is uttered: in each case the evaluation is based on the assumption that α refers to d. In virtue of this direct reference link the proposition expressed by S is a *singular* proposition; it is, to be precise, the *singular* proposition *(expressed by* S *with respect to* α and d), which consists of those worlds w in which d satisfies S when assigned to the argument slot occupied by α.

In DRT terms this can be made explicit as follows. First, let K be a DRS, let x be a discourse referent occurring in the universe of K, $\mathcal{M}$ an intensional model for the DRS language to which K belongs and d an individual of $\mathcal{M}$. Then the *singular proposition expressed in* $\mathcal{M}$ *by* K *with respect to* x *and* d, $[\![K]\!]_{\mathcal{M},\langle x,d\rangle}$ is the set of those worlds w of $W_{\mathcal{M}}$ for which there is an embedding f of the universe of K into the universe of $M(w)$ such that (i) $f(x) = d$ and (ii) f verifies the conditions of K in $M(w)$. (This definition can be generalised straightforwardly to several discourse referents and corresponding individuals in $\mathcal{M}$.)

Second, let K be a DRS for the sentence s and assume that the discourse referent x representing α occurs in the universe of K. Let K′ be the DRS obtained from K by deleting from it all contributions that are due to α, except for the two occurrences of x in (i) the universe of K and (ii) the argument position corresponding to the argument position occupied by α in s. (What these deletions come to takes some spelling out and can be made explicit only given a detailed characterisation of the DRS construction algorithm and the language fragment to which it can be applied. But the operations are basically straightforward.) Then the *(singular) proposition expressed by* S *in* $\mathcal{M}$ *with respect to* α *and* d, *given* K is the proposition $[\![K']\!]_{\mathcal{M},\langle x,d\rangle}$.

This is in essence the standard definition of singular propositions expressed by sentences that contain directly referring expressions. But in DRT we are also concerned with the question how content is to be *represented*. So, how can we represent direct reference and its effect on propositional content? The positive answer that DRT offers to this question is connected with the representation of propositional attitudes via the predicate 'Att' that was described in the last section. As we noted there, 'Att' has a third argument slot, which we decided to ignore for the time being. This slot serves

form in which we retain the contents that we extract from what we hear or read. One important aspect of this, it has been held, is that the very representations that are formed to represent the content of what has been heard or read so far can serve effectively as contexts for interpreting what comes next.

But can DRSs lay any further claim to being psychologically realistic. This continues to be a topic of debate. There have been some psychological experiments to test the roles of discourse referents in mental representations: for instance, how hard or easy is it for human interpreters to retrieve a discourse referent that is needed as antecedent of a given pronoun, depending on such factors as syntactic complexity, distance between pronoun and antecedent or depth of clausal embedding (Gordon & Hendrick 1998). Unfortunately, the predictions that DRT could be seen to make about, for instance, the ease or difficulty of antecedent retrieval seem to be too crude to allow for testing by means of established experimental techniques (e.g. timing experiments). Some more refined models of mental processing of language have been made, however, in which DRT serves as general framework.

8.5. Implementation

From its earliest beginnings DRT was conceived not only as a theory of the representation of meaning but also – and inseparably – as a theoretical foundation for the computation of semantic representations by machine. But articulating the principles of DRS construction on paper is not the same thing as building actual systems that compute semantic representations by applying those principles (and that not only for the reasons to which we just drew attention in our remarks on UDRT).

Toy implementations of DRS construction for small, carefully chosen fragments go back almost as far as DRT itself. But developing systems that construct DRSs from unrestricted text (such as, say, a year's worth of the Wall Street Journal) is incomparably harder. Several efforts to build systems with such large scale capacities have been made over the years, some of them also going back to DRT's early days (e.g. the LILOG project, see Herzog & Rollinger 1991). To date the most successful work of this kind would appear to be that of Bos – see e.g. Bos (2008), Bos (2009) – whose implementations have proved serious contenders in recent text processing and semantic inferencing competitions sponsored by representative AI and Computing Consortia.

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38. Dynamic semantics

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.

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1. Introduction

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 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. Historically, dynamic semantics emerged as a focal point of developments in philosophy, psychology, artificial intelligence, and linguistics.

The interplay between language, meaning, knowledge and belief has become one of the major philosophical themes in the late 19th and the early 20th 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 matters of context and use. In the second half of the 20th 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 a relatively 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 20th 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 20th 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 as well.

(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 'sets the stage' for 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 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 show the need of a dynamic notion of interpretation. They show that one cannot always swap two conjuncts, or reverse a conditional, or repeat a sentence. They show that language depends on context, and that it changes the context, in discourse, but also in sentences themselves.

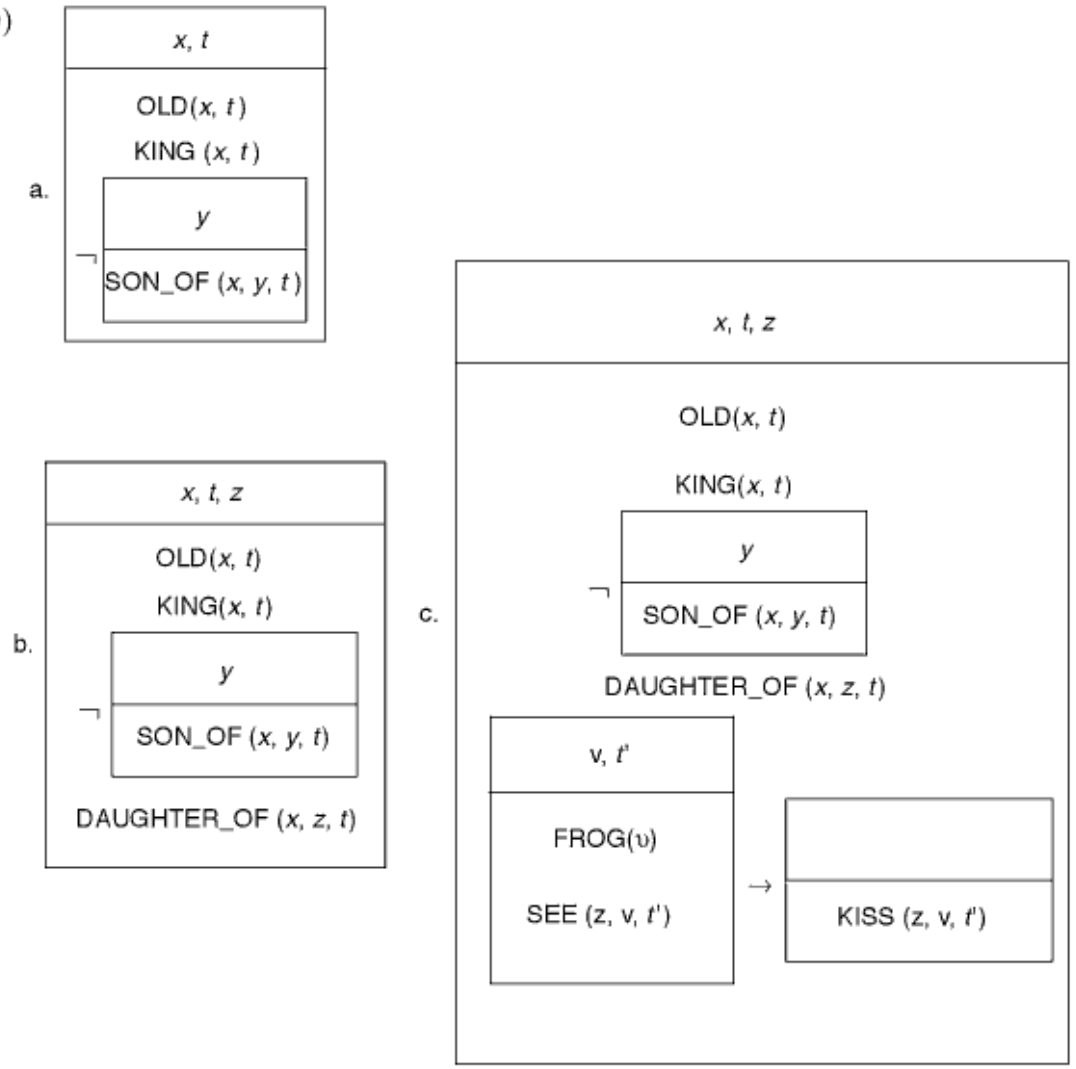
1.3. Discourse representation theory

A dynamic perspective has been adopted in the seminal Kamp (1984), which was intended to bridge the apparent gap between formal logic oriented approaches to the semantics of natural language, and the cognitive models of reasoning from cognitive psychology. To this end, a version of the language of first order predicate logic gets employed as an indispensable 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, it makes up an essential ingredient in the process of interpretation, since already established representations may be key to the understanding of parts which are 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 37 (Kamp & Reyle) *Discourse Representation Theory*.)

By way of illustration, the *DRS*s in (10) serve to 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)



These three *DRS*s represent the contents of the discourse in (9) 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.

1.4. 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 (1988) were the first, independently, to present a formal framework of interpretation for anaphoric phenomena, *DRT* and *File Change Semantics* (*FCS*)

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 a discourse.

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

(11) ✓^{0} Mary borrowed (a copy of *Naming and Necessity*)$_x$ from (a professor in linguistics)$_y$. ✓^{1} (The)$_x$ pages were covered with comments and exclamation marks. ✓^{2} (He)$_y$ must have been studying (it)$_x$ intensively. ✓^{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 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 tests 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 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 of L. 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)

$$[[Rt_1 \ldots t_n]]_M = \{\langle g, h\rangle \mid g = h \text{ and } \langle [t_1]_{M,g}, \ldots, [t_n]_{M,g}\rangle \in I(R)\}$$

$$[[t_i = t_j]]_M = \{\langle g, h\rangle \mid g = h \text{ and } [t_i]_{M,g} = [t_j]_{M,g}\}$$

$$[[\neg\phi]]_M = \{\langle g, h\rangle \mid g = h \text{ and for no } k\text{: } \langle g, k\rangle \in [[\phi]]_M\}$$

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 x in ψ may get *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.
$(\exists x(Fx \wedge \exists y(Dy \wedge Oxy)) \rightarrow Bxy)$

Definition 2 (DPL Truth and Entailment)

- Formula ϕ is true relative to model M and assignment g (written as: $\vDash_{M,g} \phi$) 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: $\phi_1 \ldots \phi_n \vDash \psi$) iff relative to all models M and all assignments g_n, if there are assignments g_0, ... 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 $\vDash_{M,g_n} \psi$.

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)
$\exists x(Mx \wedge Rx) \rightarrow \neg Ax, \exists y(My \wedge Ry) \vDash \neg Ay$

(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)
$\exists x(Mx \wedge DPSAx), \neg\exists y(DPSAy \wedge LDy) \vDash \neg LDx$

The following observation shows that the *DPL* notion of entailment properly corresponds to the *DPL* notion of implication.

Observation 4 (Deduction Theorem)

$$\phi_1, ..., \phi_n \vDash \psi \text{ iff } \phi_1, ..., \phi_{n-1} \vDash (\phi_n \rightarrow \psi) \text{ iff } \vDash (\phi_1 \rightarrow ... (\phi_n \rightarrow \psi) ...).$$

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: $\exists x \phi \vDash \psi$ iff (deduction theorem) $\vDash (\exists x \phi \rightarrow \psi)$ iff (donkey equivalence) $\vDash \forall x(\phi \rightarrow \psi)$.

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.

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. A dynamic perspective on interpretation raises new questions, and discloses an area of semantic research which has not been fully exploited yet. This point is illustrated here by a concise overview of three typical subject areas, exemplifying the pay-off of adopting a dynamic outlook upon interpretation: plurals, updates, and presupposition.

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 37 (Kamp & Reyle) *Discourse Representation Theory* and 46 (Lasersohn) *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.

more involved temporal and modal structure, but also for more intricately structured contextual dependencies. See Roberts (1989), Frank (1997) and Geurts (1999) for empirical details and relevant theoretical discussion. See also Stone & Hardt (1999), Brasoveanu (2006), and Fernando (2007), and article 75 (Geurts) *Accessibility and anaphora.* The main conclusion here is that structural semantic relationships get revealed if one pays due attention to the dynamics of discourse interpretation and that they would have gone unnoticed otherwise.

3.2. Updates in discourse

A dynamic outlook upon interpretation also provides the basis for investigating, detecting, and formalizing various systematic pragmatic aspects of interpretation. 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 may figure here as a shared body of information which is established between a group of interlocutors engaged in a conversation. The point of an assertion then 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 a 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, 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 becomes 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 appears to be hard to formulate such a requirement in the framework of *DRT* or *DPL,* because these systems fail appropriate notions of support (Aloni 2000).

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 of 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 91 (Beaver & Geurts) *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

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.

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39. Rhetorical relations

Abstract

An overview is given of some main positions with respect to rhetorical relations with an emphasis on the open linguistic, philosophical and computational issues and the possibilities for progress. The first part tries to motivate the relations, after which applications to various phenomena and areas are considered. The paper tries to look at rhetorical relations as a single field to which the various models have made important contributions. In this view Rhetorical Structure Theory has discovered the relations, the Linguistic Discourse Model has made grammar out of them and Interpretation by Abduction and Structured Discourse Representation Theory are models of how to recognise them. The proponents of these models as well as many others have analysed the relation between rhetorical relations and phenomena like information structure, pronoun resolution, topic questions, presupposition and temporal reference, have analysed rhetorical relations from various perspectives and developed annotation schemata for them. There is no attempt to treat any approach comprehensively or to choose between approaches.

1. Why study rhetorical relations?

There are two observations that motivate rhetorical relations and rhetorical structure for text. The first is that everybody infers in examples like (1) that what happens in the second sentence is caused by what happens in the first.

(1) His assailants came closer and closer. Jones ducked away behind the couch.

In fact, somebody who failed to make the inference would fail in his understanding of the text. Something would be missing in his competence as an interpreter. But the causality is not expressed by a lexical item or a syntactic construction. Researchers in this area have assumed the following principle, often implicitly.

(2) Connection Principle

In a coherent text, each sentence except the first one is connected to an earlier sentence by a rhetorical relation.

The earlier sentence is very often the last sentence before it, but this is not necessary, witness (3). Here the sentence to which the last sentence has its discourse relation (its PIVOT) is the last but one.

(3) His assailants came closer and closer. There were four of them. Jones ducked away behind the couch.

Pivots can be arbitrarily far away, since the intervening material can be expanded at will.

The second motivating observation is that in texts (and conversations) the sentences come in a meaningful and non-arbitrary order. This contrasts with the notion of a sentence in logic (a formula without free variables) and the notion of a theory (a set of logical sentences). In a logical theory, the order of the sentences is unimportant. In natural languages on the other hand, the order of the sentences is of crucial importance and carries various dimensions of meaning. Rhetorical relations form one of these dimensions, others are anaphoric relations and information structure. It turns out that these dimensions are closely connected with each other, even though they are about very different things. There is little hope for a theory of any one dimension to achieve much in the way of explanation without proper accounts of the other. And little hope for a theory of the meaning of texts that does not bring in all three dimensions. This is the main reason why rhetorical relations are important: without them, a serious account of anaphora and information structure is not possible. It follows that without rhetorical relations, it is hard to even start developing an account of the meaning of natural language sentences, given that sentences are typically part of larger structures like texts and conversations and full of anaphoric elements.

The recipe in (4) (Singh 1970) brings the order out quite clearly. The instructions are meant to be carried out in the order of their occurrence and only make sense in that order. The one rhetorical relation involved is called *Narration* or *Sequence* and the pivot is invariably the immediately preceding sentence.

(4) Soak the rice in cold water for 1 hour. Prepare spices. Divide bird into 8 pieces. Drain rice and leave to dry. Brown the grated onions in butter until all moisture has dried. Put in the chicken and fry over medium heat. Add ginger and cook a further 5 minutes. Add a few tablespoons of yoghourt. Season with salt. Cook on low heat.

The following permutation (5) has an entirely different meaning, to the extent that it can be understood at all.

(5) Add ginger and cook a further 5 minutes. Drain rice and leave to dry. Cook on low heat. Divide bird into 8 pieces. Put in the chicken and fry over medium heat. Soak the rice in cold water for 1 hour. Season with salt. Prepare spices. Add a few tablespoons of yoghourt. Brown the grated onions in butter until all moisture has dried.

What happens in the permutation – next to the temporal reordering – is that the anaphoric elements (add, further, rice, put in, etc.) cannot be resolved anymore to their original antecedents.

2. Which rhetorical relations should be assumed?

Consider (6). In addition to what the sentences mean, the combination also entails that John giving the speech was caused by Bill asking him. Here the extra entailment is marked by the causal marker "because" and the fact that it is the second sentence that

gives the cause of the event referred to in the first sentence seems to come from the fact that the second sentence stands after the first.

(6) John gave the speech. Because Bill had asked him.

If one inserts an extra sentence in between the two as in (7) the causal relation is preferably interpreted as obtaining between the second and the third sentence (or between a combination of the first and the second sentence).

(7) John gave the speech. He gave all the credit to the committee. Because Bill had asked him to.

But also the first and second sentence are related. John's crediting the committee was part of his giving the speech, quite possibly a particular part of the speech. This relation – normally called an *Elaboration* – is mostly not indicated by a specific marker. In fact, nothing much seems to change either, if the causal marker is omitted as in (8). The past perfect seems to be sufficient in this case to infer that Bill asking John to credit the committee must be the cause of John doing so.

(8) a. John gave the speech.
b. He gave all the credit to the committee.
c. Bill had asked him to.

Relations between sentences like *Explanation* and *Elaboration* are known as rhetorical relations (also *discourse relations*) and they form the subject matter of this chapter. It is often assumed that all the sentences in a text (but things do not change much if one switches to dialogue, though it is less appropriate to call the relations "discourse relations" or "rhetorical relations" in that case) are related to other sentences by rhetorical relations. If this is so, marking the relations by labelled arrows and distinguishing between subordinating and coordinating relations gives texts a tree-like structure, referred to as the *rhetorical structure, rhetorical tree* or *discourse tree* of the text. For example, (8) leads to the tree in Fig. 39.1.

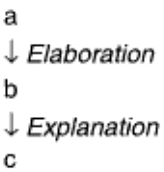


Fig. 39.1: Tree for (8)

A slightly more complex example (Lascarides & Asher 1993) is (9).

(9) a. Guy had a lovely evening.
b. He went to town.
c. He had a good meal.
d. He devoured lots of salmon.
e. He won a dance competition.
f. He caught the bus home at 12.

It is clear that while this gives far fewer than the RST relations, it also splits a number of those relations into two.

Another way of being more principled is given by the Hume–Hobbs–Kehler analysis (Kehler 2002), cf. also article 74 (Kehler) *Cohesion and coherence*, of rhetorical relations based on David Hume's classification of "association between ideas": Similarity, Contiguity in time and place and Cause/Effect. Similarity led Kehler to distinguish the *Resemblance* relations (*List, Formal Contrast, Elaboration*), from the *Causal Relations* (*Explanation, Effect, Justification*) and the *Contiguity Relations* (*Narration*). Kehler (2002) is able to show that the distinction between *Resemblance* and the other relations correlates with important differences in VP ellipsis, differences which correlate with differences in pronoun resolution and temporal anaphora. So it seems that from the perspective of sentence interpretation, this three-way distinction is all one needs. But there are semantic aspects to rhetorical relations that go beyond Hume's distinction and their functional aspects are of the first importance in choosing whether to realise them in a text generation system. These additional semantic and functional aspects cannot be captured without finer-grained distinctions like the distinction between *List, Elaboration* and *Formal Contrast.*

Determining the inventory of rhetorical relations once and for all requires an in depth analysis of all the purposes to which one would put them and the features that are required for those purposes. This does not seem a feasible enterprise at this moment and one has to live with the fact that there are various proposals available for an inventory. Next to the RST proposal, there is an SDRT one and the proposals for discourse annotation (Carlson & Marcu 2001; Webber 2004) have been forced into their own classification under the pressure of having to give precise guidelines to their annotators.

Dialogue brings a number of dialogue specific extra relations like *(Self)-Correction, Answer, Acknowledgement, Denial, Rebuttal* and others. These seem out of place in coherent monologue, but on closer inspection, some of them are there after all. One can answer one's own rhetorical questions, acknowledge and deny suggestions attributed to others, rebut similar suggestions and even correct oneself and others within the boundaries of a text. A reorientation of rhetorical structure research towards dialogue – the real product of the cultural-evolutionary process that created languages, texts, speeches, letters, newspapers and novels – would lead to an inventory of rhetorical relations that has a better claim of being representative of what is possible in interhuman communication.

The enterprise of answering what rhetorical relations there are does therefore not seem to have come to a conclusion. The proposal of Traum (2000) of speech act classification by features could perhaps be adopted for rhetorical relations as well. It would lead to full featural analyses of rhetorical relations and offer a common semantics for all of the current proposals. Another aspect is that making an assertion with a specific rhetorical relation to a pivot would seem a further subclassification of the assertion, i.e. a refinement of speech act anályis.

3. What do rhetorical relations relate?

Above, we let *Cause* and *Elaboration* relate proper sentences (in the typographical sense, a phonological definition is problematic). But in both cases it is quite possible to think of

(13) a. John fell. Bill pushed him. (*Nonvolitional Cause*)
b. John pushed Bill. He was angry. (*Volitional Cause*)
c. John pushed Bill. I saw it myself. (*Justify*)

A special case are also elaborations that give extra information about participants or the location, for the purpose of identification or for motivating or explaining the pivot.

This whole group of relations can – with some charity – be described as relations between the state or event described by the current sentence and the state or event described by the pivot. All other relations are different. They are *Contrast, Concession, Narration* and *List* and seem primarily related to the strategic level: what is reported belongs together because it is relevant to the same issue, but the events and states that are reported are not necessarily related to each other. This does not mean that they cannot have causal, temporal or local relations to each other. *Contrast* and *Concession* often go together with temporal simultaneity and local overlap. The elements of *Lists* also often have non-accidental temporal and local relations to each other. But none of these relations seems to entail any particular temporal, local or causal relationship between the events and states involved. If they nonetheless have a relation of this kind it would be due to their shared relation with an overarching topic. *Narration* (*Sequence* in the list of relations above) is connected with moving through time and will imply temporal succession and that is a reason for distinguishing *Narration* from *List*.

In a *Narration*, a story is told. The pivot event is abandoned and the current sentence reports the next event that is relevant for the story. That is the definitional property for *Narration*: the new event happens after the pivot event. Hobbs (1985) adds another element: the new event is contingent on the pivot event. Contingency should be defined in terms of causality, but it is not obvious how this must be done. The idea is that the pivot event does not itself cause the utterance event, but establishes one of its preconditions. This can be expressed as a counterfactual (14) and an illustration is (15).

(14) If the pivot event had not happened, the current event would not have happened either.

(15) John stepped out of his car and walked up to the door.
contingency: John's stepping out of the car brings him in a state and at a place which makes it possible for him to walk to the door.
counterfactual: If John had not stepped out of his car, he would not have walked up to the door.

Stories are held together not just by temporal succession and contingency, but also by protagonists and locations (the aboutness topic). One can try to express the unity of stories by thinking of them as an *Elaboration* of a single event. Another way of defining the unity of a story tries to see the whole story as an answer to a single question (the story topic) that gets answered by the events that make it up. Unfortunately, clear ideas about the construction of this topic question from the story have not been forthcoming, except for simple constructed cases.

Narration cannot be reduced to a relation between the reported events, not even if with Hobbs one adopts *Contingency*. On the topic view, it is the relation to the event

described by the whole story or the overarching topic question that makes the pivot and the current sentence stand in the *Narration* relation.

Topic questions (see article 72 (Roberts) *Topics*) do a much better job with *Lists*. A *List* (a sequence of sentences connected by the *List* relation) can be seen as an answer in many parts to a single topic question, typically in a situation in which single sentence answers would not do the same job. Here there are algorithms, e.g. Prüst, Scha & van den Berg 1994 that compute the topic question (or a closely related object) for simple cases. *Lists* can also be seen as an answer to the problem that one cannot fully specify binary or ternary relations in a single sentence, unless one is very lucky. For instance, let John love Mary and Sue, Bill Mary and Harriet and Tom only Sue, while there are other boys and girls. It is impossible to give a simple clause which specifies the whole relation, in response to a question: Which boy loves which girl? (16) is true but fails to give the details.

(16) John, Bill and Tom love Mary, Sue and Harriet.

But a *List* like (18) does. Full specification is possible by splitting up the given question into subquestions as in (17) and answering each in turn as in (18) .

(17) Which girls does *x* love?

The *List* in (18) can be seen as a strategy to avoid the problem.

(18) John loves Mary and Sue. Bill Mary and Harriet. And Tom Sue.

Contrast is the topic of ongoing discussions. Umbach (2001) provides a definition for the case when the English "but" or rather the German "aber" does not express *Concession* but what is normally called *Formal Contrast*. The definition runs as follows:

> *A* positively addresses a topic question *Q* which *B* (directly or indirectly) addresses negatively. This is illustrated in (19).

(19) John is tall but Bill is small.
topic question: Are John and Bill tall?
background knowledge: Small implies not tall.

(19) should be contrasted with (20) which requires a different topic question.

(20) John is tall and Bill is small.
topic question: How tall are John and Bill?

The generality of this approach can be undermined however by looking at languages where *Concession* and *Formal Contrast* are expressed by different words. A case in point is Russian, where the expressions *a* and *no* both correspond to English *but* with *no* specialising in the *Concessive* readings (Malchukov 2004).

between constituent clauses in a syntactically integrated complex construction there are exceptions to this principle.

The analysis of many of the markers as listed in Tab. 39.2 is problematic. Good analyses would give an account of the rhetorical relation(s) they can mark. The growing body of research on the semantics and pragmatics of particles is therefore directly relevant for a better understanding of rhetorical relations (see also article 76 (Zimmermann) *Discourse particles*).

Tab. 39.2: Grammaticalised cues for the RST relations

Label	*Grammaticalised markers*
Antithesis	*but*
Background	
Concession	*but, though*
Enablement	
Evidence	*because, since*
Justify	*because, since*
Motivation	*because, since*
Preparation	
Restatement	
Summary	*so*
Circumstance	*while*
Condition	*if*
Elaboration	*namely*
Evaluation	
Interpretation	*so*
Means	
Non-volitional Cause	*because, since*
Non-volitional Result	*so*
Otherwise	*otherwise, else*
Purpose	
Solutionhood	
Unconditional	*anyway*
Unless	*unless*
Volitional Cause	*so*
Volitional Result	*so*
Conjunction	*and*
Contrast	*but, and*
Disjunction	*or*
Joint	
List	*and, also*
Multinuclear Restatement	
Sequence	*then*

4. Where must rhetorical relations be assumed?

The table at the end of section 3. already can serve to make an important point: it is not just the sentences of a discourse that are related by rhetorical relations. Rhetorical relations must also must be assumed within a single sentence as obtaining between coordinated clauses and between main clauses and subordinated clauses. And between subordinate clauses as in the following example (23).

(23) Stepping out of his car and walking to the door John noticed a squirrel in the tree.

Stirling (1993) reports that this is in fact the favourite way of telling a story in switch-reference languages. In Latin – where the case system allows a far more reliable way of tracking the different participants in a sentence than the pronominal systems of many modern languages – multiple participial constructions with rhetorical relations holding between them are much favoured. (24) is from Caesar (1869: book 1,24).

(24) a. ipsi confertissima acie, reiecto nostro equitatu, phalange facta sub primam nostram aciem successerunt
b. they themselves in very close order, after having repulsed our cavalry and formed a phalanx, advanced up to our front line.

In (24), the relation of *Narration* between throwing back the cavalry and forming a phalanx, both expressed by an absolute ablative is only expressed by the linear order.

This raises the question how deep one should go into syntactic structure for applying rhetorical relations. Very far it seems. Any subordinate predication can in principle be related by a rhetorical relation to another predication, although not to any other predication. Predications have to be related to other ones, since the speaker has put them there for a reason and the hearer needs to figure out why the material was deemed useful by the speaker. An exception is material that is used for the purpose of identification, but also such material can be simultaneously used to give *Causes* or *Justifications.*

(25) a. The angry farmers blocked the road. (*Volitional Cause*)
b. Pushing the button, John blew up the wall. (*Means*)
c. Holding the flowers in his arm, John crossed the road. (*Circumstance*)
d. When he reached the crossing, he turned right, following Mary's instructions. (*Volitional Cause*)

One can even quite legitimately ask the opposite question. How much of the semantic connections expressed by lexical and syntactic means are in fact rhetorical relations? As it turns out many are. Typically all the connectors between sentences have a semantics that is reminiscent of a rhetorical relation. The thematic relations expressed by case and word order have to be analysed by the proto-thematic properties following the analysis of Dowty (1989). And those are suspiciously reminiscent of rhetorical relations: *Cause, Volition, Affected, Beneficiary, Result, Instrument.* Complement sentences can be related to *Elaborations.* On this perspective, one could say that there are fundamental semantic relations for natural language which should be recognised in interpretation and that

their nuclei next to each other on the tree, satellites hang below the nucleus in a nucleus-satellite relation. In other frameworks, a number of relations can be classified as coordinating, while others are subordinating. In some cases, the decision is not simple, e.g. for *Restatements*. The RFC makes one strong prediction:

(29) Prediction
No third person pronoun can be bound in S_2 from S_0 if S_0 is coordinated with S_1 and S_1 is coordinated with S_2.

This still allows the possibility that antecedents in S_0 bind pronouns in S_2 by an intermediate reference to the antecedent in S_1, but it rules out many potential antecedent-anaphora bindings. The RFC makes a precise statement about when anaphora to antecedents that are further away than the last clause can be allowed to a pivot P: when the interrupting material is subordinated to P.

Importantly, the RFC can be generalised to other kinds of anaphora and ellipsis, to tense and even to bridging. The other kinds of anaphora include anaphoric expressions such as *so, one, such, other, there, thereby, then* and *meanwhile* in this way and many others. If they have antecedents that do not come from the current utterance, the pivot must refer to these antecedents as well.

Tense seems to constitute a problem but this is only on the popular view going back to Reichenbach (1947) that tense is a temporal anaphor, like *soon* or *meanwhile*. That view is hard to maintain when one is not like Hinrichs (1986), the first full development of the anaphoric view, looking exclusively at western novelettes for one's data. Contrastive pairs and lists form clear counterexamples to the claim that the past tense is a temporal anaphor: no temporal relation is inferred. If one wants to infer a relation, overt temporal anaphors are necessary and clearly none of the three possibilities listed in (30) is already implicated.

(30) Jones went to work. (Soon/meanwhile/then) Smith started off towards the city center.

On Kehler's view (Kehler 2002), derived from Comrie (1999), tense just marks the relationship to speech time while other temporal relations between the events in the connected sentences, if any, depend on the inferred rhetorical relation. Here *Narration* and *Result* entail $e_1 < e_2$, and *Explanation* $e_2 < e_1$. The *Similarity* cases do not impose temporal constraints. This implies that tense itself is not subject to the RFC. In Kehler's view (presumably also the view of Lascarides & Asher 1993) the real temporal anaphors are the discourse relations themselves and they trivially obey the RFC.

There is a second generalisation with the same domain as the RFC: parallelism. It is here formulated without restriction and it will soon be clear why it must be restricted.

(31) Parallelism Constraint
Maximize the parallelism between pivot and current utterance

This gives the prediction that where it is possible subject pronouns should have subject antecedents, that optional constituents should be incorporated in ellipsis resolution, that

generation (another area for which useful generalisations have emerged is in NP selection, i.e. pronoun resolution in NL interpretation). Rhetorical relations come in in two different ways. In the first place, as an approach to the problem of presenting more information than will fit in a single sentence. That means that several sentences have to be formed which must be linearised in some way. How to do this? The standard solution is to construct a text plan where messages (corresponding to clauses) and connected blocks of such messages are connected by rhetorical relations. Later processing takes care of how the relations are expressed and of the linear order.

Second, rhetorical relations provide a basis for deciding which messages to put in and the reason for putting them in: context selection and text planning. For example, an inventory of relations can be checked one by one to decide if it is necessary to add further motivation, to provide further elaboration, to generate a concessive clause etc. In practice, this is difficult and often avoided, though it can play a role in local decisions (e.g. whether to insert further detail in a given text plan).

Pioneering work in natural language generation was the background to Rhetorical Structure Theory (RST) (Mann & Thompson 1988; Mann & Matthiessen 1985). These are the first publications about rhetorical relations (if one does not count classical rhetorics, in which rhetorical structure is important but rhetorical relations much less). They are still worth reading. Taboada & Mann (2006) gives an overview and useful discussion of the research in the RST tradition.

In RST rhetorical relations are defined in terms of constraints on the relata and their combination and specify the effect they have, when they are assumed. The constraints can be seen as giving limitations on when the relation can be assumed. The effect is typically the perlocutionary effect: what is the speaker hoping to achieve with the utterance bearing this relation to the pivot. The connection with the perlocutionary effect is important: it makes the connection between rhetorical relations and speech acts. One can say that an utterance in a text, bearing a rhetorical relation to a pivot is just a special kind of speech act: one that tries to achieve something which – in a way specified by the rhetorical relation – depends on the pivot (a point also made in Asher & Lascarides 2003). The perlocutionary effect or rather the speaker's goal of attaining certain perlocutionary effect gives the motive for the speech act and can be identified with the speaker intention of Grice (1957). If it is possible to pursue the programme of identifying particular perlocutionary goals with rhetorical relations, RST becomes a theory of speech acts in which one new parameter is the identity of the pivot and another one the particular relation the pivot bears to it. The perlocutionary effect in principle also provides an interface with text planning. The proper text planner should be able to reason about what perlocutionary effects the generator wants to achieve on the user and to be able to realise these with rhetorically related utterances.

The views on rhetorical structure have not changed much since RST started. So much of the general picture is already there that one starts wondering what the last 30 years have brought. In fact, that is quite a lot. Conspicuously absent in early RST is the RFC and in general the relation between pronominal, temporal and ellipsis resolution and rhetorical relations. Or the relation between information structure and rhetorical structure. The most important shift seems however wanting to deploy rhetorical structure in the study of text interpretation.

5.3. Information structure

There is a seemingly opposite school in the study of rhetorical structure represented by scholars like von Stutterheim & Klein (1989) and van Kuppevelt (1995). In this approach, the starting point is the task of the speaker, conceived as a question. The structure of a text is then a complex answer to this question. This immediately leads to a distinction between partial answers to the question and satellites to such partial answers (which answer questions of their own, raised by their nucleus). The question of a text also leads to the fixation of the topic and foci of the partial answers and the fixation and movement of the referential parameters in these texts. This leads to interesting parallels with treatments of discourse semantics such as Discourse Representation Theory.

One can say from the perspective of this school that RST is just a classification of a set of natural relations that arise in the goal-directed enterprise that is telling a story or producing an overview of some states of affairs or to provide an extended explanation.

A difference with RST is that the question immediately makes a connection with the task of the text as a whole. Moreover, it is possible to develop an account of especially those discourse relations that seem to be governed by information structure rather than by semantic relations almost directly on the basis of the questions structure: especially van Kuppevelt works out this connection and treats both information structure and text structure in terms of questions. This makes it possible to link up with areas such as theories of topic-focus articulation (cf. article 71 (Hinterwimmer) *Information structure* or Grosz, Joshi & Weinstein 1995 on centering).

The theory seems to have the potential to serve as a foundation for rhetorical relations and rhetorical structure. Any element of a text needs to be assigned a role with respect to the question of the text or with respect to one of its answers. If this role can be expressed as another question, specific for the particular element, this question will determine both the rhetorical relation and the pivot.

5.4. Text interpretation

While rhetorical relations started in text generation as a theory of how to structure texts, section 5.1. should have made it clear that there is quite a lot of semantic mileage in having a grasp on rhetorical relations in interpretation. The main obstacle for achieving such a grasp is the fact that rhetorical relations quite commonly are not overtly marked at all.

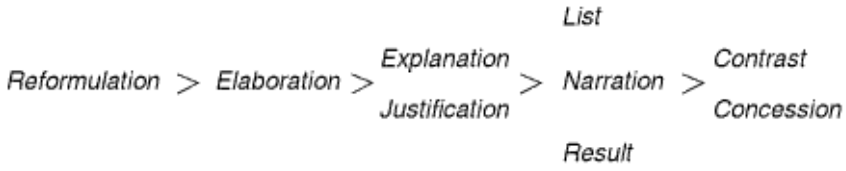
Two remarks are in order. First of all, it is quite normal that there is not a marker in NL for all the conceptual distinctions that are expressed in the sense that speakers are aware of the distinction and hearers are supposed to figure out what it is. The many meanings of common prepositions in English like "with", "of" or "in" are a clear case in point. A natural language understanding system faces the task of filling in the blanks there, if it is aiming for understanding that is comparable with what humans get out of the language input. A lot of ambiguity resolution is necessary.

The second remark is that nonetheless NL is full of markers for rhetorical relations and that texts are full of these markers: various coordinating and subordinating connectors express one or more rhetorical relations, many particles at least rule out some rhetorical relations. (Webber et al. 2003 argues for what seems to be the correct view: the

and conjunctions, the question when to deploy these devices in a text generator is still not well understood. It seems that knowing the meaning is not enough, one also needs a proper description of the triggering conditions beyond meaning. For an area that is as central as rhetorical structure, the research investment so far has been very small indeed. As compared e.g. to the investment in the syntax of sentences where hundreds if not thousands of researchers are active there are maybe 75 people altogether who have contributed to the area of rhetorical structure and for a few of them only it has been a substantial part of their career. The intellectual interest of the two problems is hard to compare, but theoretical syntax seems to have only a minor impact on natural language understanding and generation and the potential of rhetorical structure seems to be far greater for both of these areas.

I would gamble on two new impulses into the area in the coming years. One is the advent of corpora that are annotated with rhetorical structure. Such corpora have already been developed and annotation schemes have been provided. For useful references, see http://www.isi.edu/ marcu/discourse/. More recent is the Penn Discourse Treebank (http://www.ldc.upenn.edu). They can be combined with the development of more semantic understanding within the stochastic paradigm in NLP in combination with logical techniques. This will lead within the coming years to the possibility of estimating the plausibility of a given interpretation in a context and preferring the most plausible interpretation. This will also allow the recognition of rhetorical relations and thereby liberate research on rhetorical structure from the fixation on the problem of asyndetic expression, a problem outside the reach of current technologies. While these new possibilities will help considerably in other areas of semantics and pragmatics, the improvement of rhetorical understanding will have strong repercussions on the overall quality of semantic and pragmatic understanding.

A second promise is optimality theory. Both generation and interpretation can usefully be seen as a choice between alternatives where the choice is guided by principles, i.e. as optimisation problems. Both generation and interpretation also need blocking and blocking is typical for optimisation problems. Certain interpretations may be obscured by other and better ones, certain possible realisations may be blocked by preferred other realisations. Two interpretational constraints seem directly relevant to rhetorical structure and define defaults there. The first is a principle that maximises the givenness of any element of an interpretation, called *NEW, DOAP, *ACCOMMODATE by different authors. This creates defaults in the interpretation of rhetorical relations as indicated in the following diagram, taken from Zeevat & Jasinskaja (2007).



The principle also underpins the default in pivot identification: the lowest element on the right frontier that fits.

A good thing about the area of rhetorical relations is that, while schools have been formed, they have not led to divisions other than in general ideology. The Right

Frontier Constraint, the general picture of rhetorical structure and most of the analysis of empirical data is shared by all. Where divisions occur, they seem to be about issues that transcend rhetorical structure: How much structure can be captured with unification or tree adjoining grammar? What is the correct way to deal with non-monotonic reasoning? Should the inference of rhetorical structure be entirely situated in semantic representation?

The exciting questions in the field seem concerned with extending the empirical coverage of rhetorical structure, the application of rhetorical structure to linguistic and cognitive problems and the foundational questions about rhetorical structure: where does it come from and why is it the way it is? And the issues connected with the enterprise of further developing the technological potential of rhetorical structure.

7. References

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