The State of the Art in Computational Semantics:
Evaluating the Descriptive Capabilities of Semantic Theories

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This document contributes to an assessment of the state of the art in Computational Semantics. It addresses the question how different semantic theories perform in the task of modelling important semantic phenomena occurring in natural language data. We will examine how the phenomena and linguistic examples presented in D2 ("Specification of Linguistic Coverage") and D7, Chapter 3 ("Some Basic Linguistic Data and Their Importance") by the different semantic theories described in D8 ("Describing the approaches"), i.e., Discourse Representation Theory, Dynamic Semantics, Situation Semantics, Property Theory, and Monotonic Semantics.

We look into the different classes of phenomena specified in D2 and D7 in turn, and illustrate and comment on the performance of the respective theory for each of these classes. Detailed analyses are provide, where a theory makes a substantial contribution to the treatment of a class of data. In many cases, just a sketch of the treatment or a short comment is given. In some cases the phenomena are presented as having no special treatment, either because of systematic reasons, or just because it has not been worked out, so far. Proceeding in this bottom-up fashion, we hope to provide a fairly clear and detailed picture not only of the coverage of each theory, but also of their strengths and weaknesses.

Sections 2 - 12 contain comments on the treatment of the following natural language phenomena:

- Generalised Quantifiers and Scope (section 2);
- Plurals (section 3);
- Anaphora (section 4);
- Ellipsis (section 5);
- Adjectives (section 6);
- Comparatives (section 7);
• Temporal Reference (section 8);
• Verbs (Aspects and Intensionality) (section 9);
• Attitudes (section 10);
• Questions (section 11);
• Events (section 12).

The prerequisites for understanding the notions and formal equipment used in this document are mostly given in D8, and it is assumed that the reader is to some degree familiar with the descriptions of the theoretical approaches given there.

Some additional assumptions, definitions, and notation conventions for Situation Semantics, Property Theory, and Monotonic Semantics are provided in the first section. As far as the DRT analysis is concerned, we do not say much about particular DRS-construction rules but rather concentrate on completed representations. Unless stated otherwise the construction rules employed are those of [Kamp and Reyle, 1993].

Two appendices are added, one giving some more formal detail for the use of dependent types in Property Theory, the other giving the Situation Semantics grammar rules.

Note that some references are referring to deliverable 8 “Describing the Approaches”, by adding ”D8” to the reference number.

1 Basic Assumptions and Definitions

1.1 Situation Semantics

1.2 General Comments

The Situation Semantics treatment is quite closely related to the recreation of Gawron and Peters’ fragment in terms of EKN style situation theory that we presented in deliverable D8. However, there are some important differences to the Gawron and Peters fragment. These include:

• a variant of Gawron and Peters’ account of quantifier scope and binding to allow for underspecified meanings

• the introduction of Montague style compositional techniques using abstraction, e.g. treating noun-phrase contents as abstracts which require a property as argument. This facilitates the treatment of conjunction and intensional verbs.

• a revision of Gawron and Peters’ treatment of tense in order to allow for the treatment of a greater variety of tense phenomena than they handle
the addition of a treatment of the attitudes and naked infinitive perception complements

1.2.1 Notation and Operations

Parameter Sorts  The letters and symbols used for parameters in the grammar encode information about their sort, according to the following conventions:

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Sort</th>
</tr>
</thead>
<tbody>
<tr>
<td>S, MS</td>
<td>situation (mental state)</td>
</tr>
<tr>
<td>T</td>
<td>time</td>
</tr>
<tr>
<td>X, Y, X_i</td>
<td>individual</td>
</tr>
<tr>
<td>P</td>
<td>(([X] → proposition) → proposition)</td>
</tr>
<tr>
<td>Prpn</td>
<td>proposition</td>
</tr>
<tr>
<td>P</td>
<td>[X] → infon</td>
</tr>
<tr>
<td>Q</td>
<td>[X] → proposition</td>
</tr>
<tr>
<td>MProp</td>
<td>[S, T] → proposition</td>
</tr>
</tbody>
</table>

i.e., type of situations and times, a “Montague proposition”

The sortal restrictions on parameters could be expressed by including propositions like (Prpn : proposition) as restrictions, but adopting the convention above makes the notation easier to read.

Index Assignments  If \( \zeta \) is an abstract with role indices \( r_1, \ldots, r_n \) then \( f \) is an index assignment for \( \zeta \) if \( \{ r_1, \ldots, r_n \} \subseteq \text{dom}(f) \), \( f \) is 1–1 and for any \( r \in \text{dom}(f) \), \( f(r) \) is a parameter which is not a parameter of \( \zeta \). An example of an index assignment for

\[
\text{desc-sit} \rightarrow S \cdot \langle \text{rt}, u \rangle \rightarrow T
\]

is:

\[
\left[ \begin{array}{l}
\text{desc-sit} \rightarrow S' \\
\langle \text{rt}, u \rangle \rightarrow T
\end{array} \right]
\]

If \( Z \) is a set of abstracts, \( f \) is a minimal index assignment (MIA) for \( Z \) iff \( f \) is an index assignment for each \( \zeta \in Z \), and \( \text{dom}(f) = \bigcup_{\zeta \in Z} \text{roles}(\zeta) \), the union of the role indices of each
Application to partial assignments  In order to make the rules easier to read we introduce an abbreviation for application to partial assignments, i.e. those assignments that don’t provide a value for all the roles of an abstract. This abbreviation, which is discussed in [Barwise and Cooper, 1993], is defined in terms of the normal notion of application to total assignments.

If $\text{dom}(f) \cap \text{roles}(\zeta) \subseteq \text{roles}(\zeta)$ (i.e., the assignment only supplies values for a proper subset of the roles), then we write $\zeta.f$ for $\lambda f''(\zeta,f'')$ where $f''$ is an extension of $f$ which assigns unique parameters other than those in $f$ or $\zeta$ to each role in $\text{roles}(\zeta) - \text{dom}(f)$ and $f''$ is $f'$ restricted to $\text{roles}(\zeta) - \text{dom}(f)$.

For example,

$$
\text{desc-sit} \rightarrow S, (rt,u) \rightarrow T
$$

\begin{array}{c}
\text{S} \\
\text{meet}(s,k,T)
\end{array}

\rightarrow [(rt,u) \rightarrow t]

is

$$
\text{desc-sit} \rightarrow S
$$

\begin{array}{c}
\text{S} \\
\text{meet}(s,k,t)
\end{array}

Conventions for non-abstracts and empty assignments  We will adopt the following conventions. Let $\zeta$ be an abstract. Then

- $\zeta.f = \zeta$ if $\text{dom}(f) \cap \text{roles}(\zeta) = \emptyset$
- $\lambda \theta \zeta = \zeta$
  Where $\emptyset$ is the empty assignment.
- if $f'$ is a restriction of $f$ to the roles of $\zeta$, then $\lambda f \zeta = \lambda f' \zeta$

This will allow us to give general definitions where in some cases we want to apply a type to an assignment (in order to obtain content from meaning) and in other cases there will be no abstraction over context parameters. According to this convention a proposition may also be regarded as a zero-place type and the result of applying it to any assignment will be the proposition itself.
**Combination (“Linguistic application”)** Let $\alpha$ and $\beta$ be abstracts. Then the combination of $\alpha$ and $\beta$, written $\alpha\{\beta\}$, is defined as follows:

$$\alpha\{\beta\} = \lambda f(\alpha.f[\beta.f])$$

where $f$ is a mia for $\{\alpha, \beta\}$

1.3 **Property Theory**

In most cases of the PT contributions, just a sketch of the treatment is given. PT is a weak formalism in which some existing treatments may be implemented. The use of PT as a formalism for natural language semantics does not result in a commitment to particular interpretations or representations. There are many possible representations of linguistic phenomena in PT, and many different ways of obtaining the truth conditions. This does not mean that no unified approach is possible. However, different styles of representation in PT may facilitate the exposition of different phenomena, especially in such a brief document.

Perhaps the strength of PT lies in the fact that different theories can be expressed within a uniform formalism. To give a flavour of this, it can be shown that ‘worlds’ can be added to the theory [Chierchia, 1991b]. Thus a possible worlds style analysis of modality, for example, can be adopted by PT. We can add a class of properties $W$ corresponding to worlds. Each of these properties holds of the propositions true in that world. This allows the conventional treatment of modality:

$$\square p =_{df} \forall w(Ww \rightarrow wp)$$

It is also possible to have an accessibility relationship between worlds. It can capture more than just the (set-theoretically) ‘first-order’ frames as two worlds need not be equated if they have the same propositions true in them. The theory is weaker than Intensional Logic: worlds need not be complete for example. The representation of intensionality and modality are distinct. The subsection on anaphora (section 4.4) elaborates on a dependent type analysis of NL. This provides an illustration of how existing semantic theories can be incorporated into a unifying theory.

Not all terms of the appropriate form correspond with propositions. This fact is used to avoid the logical paradoxes, but it also offers a means of characterising felicitous discourse. Also, there is no requirement that propositions be expressed in terms of standard logical operators; the previous section has already mentioned a treatment of underspecification which makes use of this.

1.4 **Monotonic Semantics**

The way that monotonic interpretation can be applied to the semantic phenomena in D2 will be illustrated by the analyses actually assigned by SRI’s Core Language Engine (CLE).

For implementation and historical reasons, the QLF notation used within the CLE differs in certain minor respects from that described in Deliverable D8: the order of the term/form
index and category arguments are reversed; categories are represented by means of fixed arity functors (the arguments are the values of positionally identified features); application of a predicate to arguments is written using square brackets, i.e. \([\text{Pred}, \ldots, \text{Args} \ldots]\) rather than \(\text{Pred}(\ldots, \text{Args} \ldots)\); certain abbreviatory devices are used for representing term referents, e.g. \(\text{ent}(\text{john})\) in place of \(X^X=john\); meta-variables and, initially, term and form indices are represented as (Prolog) variables.

The CLE is a wide coverage system that has been built up over the course of time. As a result, the implemented treatment of some phenomenon may not always in line with what we can, with the benefit of hindsight, see as being a better analysis. Where these discrepancies arise we will adopt a policy of being honest: we will show what the implemented analysis gives, and only following that suggest what a better treatment would be.

By focusing on the mapping from sentence and context to meaning, monotonic semantics allows a degree of flexibility in the underlying model theory. For an implementation, such as the CLE, model-theoretic decisions have to be made one way or the other. For example, is temporal reference to be handled by means of tense operators, explicit quantification over times, quantification over times and events,...? In this particular case the CLE opts for quantification over time and events, but this should not be taken as indicating a commitment on the part of monotonic interpretation.

Where choices like these have to be made, there has been a tendency to defer as much of the decision as possible to the way that particular forms or terms get resolved. For example, unresolved QLFs in the CLE represent information about tense and aspect by means of the values of certain features present in categories on verb forms. Resolution then imposes event-based resolutions on these forms, though alternative treatments would also be possible. This division of labour permits a certain theory neutrality for (unresolved) QLFs, which can often be useful.

In addition, there is a tendency to be conservative about the analyses implemented. This is partly to illustrate that by placing due emphasis on the mapping from sentence plus context to meaning, one can avoid some of the model-theoretic complications introduced in other treatments for dealing with context-sensitivity.

Finally, QLF analyses of specific phenomena will be presented in one or more of three forms (i) the unresolved QLF produced from a sentence on the basis of syntactic analysis alone, (ii) possible instantiations of the QLF brought about by resolution (resolved QLFs), and (iii) an expression in a ‘target reasoning language’ (TRL) that is truth conditionally equivalent to the resolved QLF. TRL expressions are derived from resolved QLFs essentially through applying the semantic interpretation rules for QLF. TRL is a predominantly first-order language, though with a limited range of higher-order constructions. It is better suited to automatic inference than QLF, which contains (logically) redundant category information. Rather than introduce the TRL language explicitly here, we will describe certain aspects of it where necessary.
2 Generalised Quantifiers and Scope

2.1 Discourse Representation Theory

Generalized quantifiers\(^1\) are interpreted as relations between two sets: the first set is defined as the set of objects satisfying the restrictor part of the quantifier while the second set corresponds to the set of objects satisfying the nuclear scope part of the quantifier.

The DRT treatment of generalized quantifiers is outlined in (38 in D8) - (41 in D8). It is defined in terms of extensions of partial assignment functions (verifying embeddings) and requires that every verifying embedding of the restrictor DRS can be extended into a verifying embedding of the nuclear scope DRS.\(^2\) This is the formal reflex of the intuition that the nuclear scope DRS somehow extends the situation described by the restrictor DRS. This intuition is supported by the fact that anaphoric pronouns in the nuclear scope can be bound by antecedents in the restrictor but not vice versa. The definition encapsulates the quantificational structure in the sense that it prevents anaphoric reference from outside the structure into it.\(^3\) The interpretation of generalised quantifiers in terms of extended embeddings effectively entails that the quantifier relation holds between tuples of objects referred to in the universe of the restrictor DRS and tuples satisfying the nuclear scope DRS. This results in an unselective notion of binding and has been discussed in the literature under the heading of the proportion problem c.f. [Kadmon, 1987], [Chierchia, 1991a]. Selective binding quantifies over objects satisfying the (complex) properties defined by the restrictor and nuclear scope part of the quantifier. Currently it is not clear whether quantifiers are systematically ambiguous between selective and unselective binding and/or whether and to which extent this is subject to contextual factors.

2.1.1 Variety of Generalized Quantifiers

The quantifiers contained in the fragment

\[
\begin{align*}
\text{Most}/\text{Few}/\text{A few}/\text{Many}/\text{No}/\text{All}/\text{Every}/\text{Each}/\text{A}/ \\
\text{Some}/\text{Three}/\text{At most three}/\text{At least three}/ \\
\text{Most of the}/\text{Few of the}/\text{Each of the}/ \\
\text{At least three and at most five}
\end{align*}
\]

(1) representative(s) left.

\^1\ Strictly speaking: generalized determiners. Here we simply follow common practice (abuse) and refer to generalized determiners as generalized quantifiers.

\^2\ The definition guarantees that generalized quantifiers are conservative.

\^3\ In DPL/DMG terminology: a generalized quantifier is internally dynamic but externally static.
dent quantifiers (*few, many*); weak *a, one, few, several* and strong quantifiers *the, all, every, most* etc.

One of the central assumptions in classical Montague grammar is that all NPs including proper names are semantically treated as quantifiers in that they denote sets of properties. While this move yields a certain uniformity in the treatment of NPs it fails to do justice to the distinct potential of definite, indefinite and “properly” quantificational NPs particularly with respect to anaphoric properties. DRT assumes a more fine-grained NP typology. It distinguishes between *definites, indefinites, cardinality quantifiers* and *proportional quantifiers*. The distinction between cardinality and proportional quantifiers goes back to [Partee,88] and amounts to a distinction between quantifiers that can be reduced to a property of the intersection of the two sets they relate and those which cannot. A cardinality quantifier expresses a condition on the size of a set. A sentence like

(2) Smith ordered more than 10 computers.

may be paraphrased as

(3) The set of computers which Smith ordered contains more than 10 elements.

In DRT this can readily be represented in terms of the set abstraction mechanism \( \eta = \Sigma x : K \) introduced in section 1.1.5.2 in D8.

From a purely truth conditional point of view (4) is equivalent to

The important point, however, is that under the analysis in (4) cardinality quantifiers not only introduce an individual discourse referent \( x \) into the argument positions of verbs they occupy but crucially also introduce a further discourse referent \( \eta \) which is not already bound by some quantificational structure and thus available for binding. In this respect cardinality
quantifiers pair up with indefinites. This is borne out by the fact that only indefinites and cardinality quantifiers (and neither definites nor proportional quantifiers) can appear in *there* insertion contexts\(^4\) which seem to assert existence of denotation of the “inserted” NP. In DRT the existence predication simply falls out in terms of discourse binding, i.e. existential closure of the discourse referents in the universe of the top level DRS.

By contrast, proportional quantifiers always introduce individual discourse referents \(x\) which are “properly” bound by the quantificational structure introduced by the quantifier. In the representations this is accounted for in terms of tripartite structures (in DRT: duplex conditions) as in:

\[
\begin{array}{c}
\text{representative}(x) \\
\text{all} \\
\text{left}(x)
\end{array}
\]

which is the representation\(^5\) associated with

\[
\text{(7)} \quad \text{All representatives left.}
\]

Some quantifiers are context dependent. Cases in point are *many* and *few*. Currently there is no formally worked out account of this kind of context dependency in DRT.

\[\text{2.1.2 Semantic Properties of Natural Language Quantifiers}\]

Work on generalized quantifiers (c.f. [Barwise and Cooper, 1981], [Keenan, 1987], [Westerstähl, 1989]) has postulated a significant number of substantive constraints on possible natural language quantifier denotations. These constraints simply carry over to the DRT analysis pretty much intact.

The semantic interpretation of duplex conditions representing generalized quantifiers in (41 in D8), for example, guarantees that such quantifiers are *conservative*, i.e. generalized quantifiers express a relation between two sets where the first set corresponds to the denotation of the restriction part while the second set corresponds to the intersection of the denotation of the restriction with the nuclear scope part of the quantifier.

*Monotonicity* properties of natural language quantifiers manifest themselves in (and licence) inference patterns involving such quantifiers. Under the relational perspective, a generalized quantifier \(Q\) is right monotone increasing (\(\text{MON}^+\)) if for any sets \(A, B\) and \(B'\), if \(B \subseteq B'\) and \(Q(A, B)\) then \(Q(A, B')\). \(Q\) is right monotone decreasing (\(\text{MON}^-\)) if for any sets \(A, B\) and \(B'\),

\[\text{4}A \text{ similar argument can be provided for NP final each.}\]

\[\text{5Plural quantifiers, collective and distributive readings etc. will be discussed in greater detail in the sections below.}\]
if $B \subseteq B'$ and $Q(A, B')$ then $Q(A, B)$. $Q$ is left monotone increasing ($\uparrow$ MON) if for any sets $A$, $A'$ and $B$, if $A \subseteq A'$ and $Q(A, B)$ then $Q(A', B)$. $Q$ is left monotone decreasing ($\downarrow$ MON) if for any sets $A$, $A'$ and $B$, if $A \subseteq A'$ and $Q(A', B)$ then $Q(A, B)$.

All is ($\uparrow$ MON), some is ($\downarrow$ MON):

(a) All representatives left quickly.
   $\vdash$ All representatives left. $(\uparrow$ MON$)$

(b) All representatives left.
   $\vdash$ All ITEL representatives left. $(\downarrow$ MON$)$

(c) Some representatives left quickly.
   $\vdash$ Some representatives left. $(\uparrow$ MON$)$

(d) Some ITEL representatives left.
   $\vdash$ Some representatives left. $(\downarrow$ MON$)$

No is ($\downarrow$ MON):

(a) No representative left.
   $\vdash$ No representative left quickly. $(\downarrow$ MON$)$

(b) No representative left.
   $\vdash$ No ITEL representative left. $(\downarrow$ MON$)$

Most is (MON) but neither ($\uparrow$ MON) nor ($\downarrow$ MON):

(a) Most ITEL representatives left.
   $\nvdash$ Most representatives left. $(\neg \uparrow$ MON$)$

(b) Most representatives left.
   $\nvdash$ Most ITEL representatives left. $(\neg \downarrow$ MON$)$

Monotonicity patterns licence more complex inference schemata like

\[ Q(A, B) \]
\[ \frac{\text{all}(B, C)}{Q(A, C)} \]

where $Q$ is (MON).

which is instantiated by
Most representatives attended the meeting.

(12) Everybody who attended the meeting supported the proposal.
Most representatives supported the proposal.

2.1.3 Scope Ambiguity and Scope Constraints

In the standard version of DRT which is based on the DRS construction algorithm outlined in section 1.2.1 in D8 The Top-Down Construction Algorithm above scope ambiguity is accounted for in terms of non-determinism in the construction algorithm. The construction algorithm maps scopally ambiguous sentences into a set of disambiguated representations. The required non-determinism can be achieved in two ways: either the order of application of construction rules is relaxed or particular construction rules are reformulated.

Given a sentence of the form

(13) Every representative attended a meeting.

on the first approach we would process (13) applying the construction rules in the sequence CR.EVERY ⊃ CR.ID (i.e. processing the quantified subject NP before the indefinite object NP) resulting in

\[
\begin{array}{c}
\text{representative}(x) \\
\forall x \\
\text{meeting}(y) \\
\text{attend}(x, y)
\end{array}
\]

(14)

or, alternatively, apply the construction rules in the sequence CR.ID ⊃ CR.EVERY (i.e. processing the indefinite object NP before the quantified subject NP) yielding:

\[
\begin{array}{c}
\text{meeting}(y) \\
\forall x \\
\text{attend}(x, y)
\end{array}
\]

(15)

In the precise formulation of the construction algorithm which incorporates a flexible order of rule application special care has to be taken to block unwanted anaphoric references such as between pronouns in subject positions and antecedents in object positions. The sentence

(16) He met a customer who employed Jones.
does not have a reading where \textit{he} is anaphoric to \textit{Jones}. This reading can be blocked by integrating syntactic constraints (e.g. \textit{c-command relations}) into the construction algorithm (cf. [Roberts, 1987], [Frey, 1993] and [Berman and Hestvik, 1994]).

The second approach does not relax the processing order but involves a reformulation of each of the scope inducing construction rules. Essentially, such construction rules are associated with two alternative sets of construction operations. The first set of operations is simply the one defined in the original formulation of the construction rules. The second set effectively incorporates some material in the DRS constructed up to the point where the construction rule is applied. To give an example: the second set of construction operations of the reformulated CR.EVERY\textsubscript{scope} applies to universally quantified NPs in object position. It removes the discourse referents and conditions introduced by the subject NP from the DRS and incorporates them into the nuclear scope DRS in the resulting duplex condition. If, as is assumed in the standard version of the construction algorithm, it is required that pronouns are resolved as soon as their discourse referents are introduced into the DRS the revised construction rule approach does not suffer from the problems discussed with respect to example (16). However, the precise formulation of the revised construction rule is remarkably ugly. It involves destructive operations on DRSs and complicated indexing mechanisms. For this reason and due to the fact that syntactic constraints need to be integrated into the construction algorithm for independent reasons anyhow, in standard DRT the first option is usually preferred.

Syntactic constraints play an important role in the determination of possible anaphoric dependencies and in the determination of scope possibilities. It is often argued that relative clauses in English set up scope islands for genuinely quantificational NPs.

\begin{itemize}
\item[(a)] The representatives of every software company came to the meeting.
\item[(b)] The representatives who worked for every software company came to the meeting.
\end{itemize}

It is claimed that (17) (a) has a reading where \textit{every software company} takes wide scope over \textit{the representatives} which is lacking in (17) (b) because of the presence of the relative clause. On this view\footnote{This view is not undisputed. Compare: \textit{The slush fund that every minister needs is kept by his secretary} [Pereira, 1990].} (17) (a) corresponds to the following (simplified) representations\footnote{Here we only give some of the possible distributive and collective readings of the definite plural NP.}
Depending on the context indefinite NPs can be endowed with a variety of interpretations.
They can be employed for the purposes of non-specific (indefinite) reference (i.e. interpreted existentially), they can assume the quantification force of an embedding quantifier (e.g. have universal import in “donkey”-sentences) or be used to refer to a particular object. This last use is often referred to as the *specific use* of indefinite NPs. Specific uses of indefinite NPs act as referring terms. Often long and descriptively informative indefinite NPs like *a representative who knows Smith* in

\[ \text{(20)} \quad \text{Every customer talked to a representative who knows Smith.} \]

are interpreted specifically. In the case of (20) the revised construction algorithm will assign both a specific (wide scope) and a non-specific (narrow scope) interpretation to the indefinite NP. However, the construction algorithm does so indiscriminately, i.e. it will also map the indefinite in *every customer talked to a representative* into both a specific and non-specific interpretation. At the moment there is simply no precise formulation of what exactly constitutes a long and descriptively informative indefinite NP.

The revised construction algorithm will not in general be sufficient in cases where a specific indefinite NP is processed inside a sub-DRS in some DRS. In order to express specific reference the indefinite needs to introduce its discourse referent and associated condition into the universe of the main DRS. The construction procedure needs to be changed accordingly. There is further evidence that indefinite NPs in object position may scope over their corresponding subjects without receiving a fully specific interpretation. To give an example, the sentence:

\[ \text{(21)} \quad \text{If every customer to whom every representative sells a certain product is satisfied the product is useful.} \]

has a reading corresponding to

\[ \text{(22)} \]

Technically this means that the representations associated with indefinite NPs may in principle turn up at different levels of embedding in the sub-DRSs of a DRS. The precise locations are constrained by the fact that such indefsines must be accessible for anaphoric reference and by the requirement that argument positions in a DRS are properly bound (free variable
constraint. The construction algorithm has to take account of this.

Often definite descriptions single out a unique referent. In such cases the definite description is not in the scope of any other scope inducing element in a discourse. Sometimes, however, definite descriptions do not single out a unique referent. Often such descriptions involve relative clauses containing anaphoric elements coreferential with a quantified NP in some other part of the sentence.8

(23) Every manager promoted the representative who supported his decision.

This sentence has a reading where each manager promoted a separate (possibly unique) representative which ignoring the uniqueness presupposition corresponds to the following representation

Apart from quantificational structures the logical connectives ∨, ⇒ and ¬ can give rise to scope ambiguities. First we briefly consider ambiguities induced by the interaction of connectives and then we consider the interaction between quantificational structures and logical connectives.

A sentence like

(25) Smith and a manager or a representative called a meeting.

is ambiguous between an interpretation which groups the subject NP constituents as in (Smith and a manager) or a representative and the interpretation Smith and (a manager or a representative). In the DRT framework ambiguities of this sort give rise to different syntactic analyses which are subsequently mapped onto their corresponding semantic representations.

In contrast most cases of scope ambiguity between quantificational structures and logical connectives are accounted for on the level of the DRS-construction algorithm. The syntactically unambiguous sentence

8Or the definite description itself is in some sense anaphoric (e.g. functionally related) to a quantified NP: In every computer the CPU sits on the motherboard.
(26) Everybody didn’t sign up.

is mapped into the following two DRSs:

\[ \neg \frac{x}{\text{person}(x)} \quad \forall x \quad \text{sign-up}(x) \]

\[ \frac{x}{\text{person}(x)} \quad \forall x \quad \neg \text{sign-up}(x) \]

The standard DRS-construction algorithm will generate the second reading. To get the first reading as before we could either relax the processing order so that the negation (CR.NEG) is processed before the quantificational structure (CR.EVERY) or stick to the fixed processing order but introduce a disjunction of operations in (CR.NEG).\(^9\) Example (26) illustrates scope ambiguity between a subject NP and do supported verb phrase negation. The picture is complicated by scope interactions between object NPs and negation. E.g. the sentence

(28) Smith doesn’t own a laptop.

with an indefinite NP in object position does not have a natural narrow scope reading for the negation where there exists some laptop such that Smith does not own that laptop. On the other hand, narrow scope readings of the negation (corresponding to wide scope of the indefinite) are possible in the case of specific readings of indefinite NPs (which as we pointed out above are often favoured in the case long and descriptively rich indefinite NPs) like in

(29) Smith didn’t process an order placed by her manager.

which has an interpretation which involves some particular order.

In the case of universally quantified NPs in object position narrow scope readings for the negation seem to be almost impossible:

(30) Smith didn’t process every order.

(30) does not have an interpretation where Smith processed no order.

---

\(^9\)This latter option is the one pursued in [Kamp and Reyle, 1993].
The extended DRS-construction algorithm outlined above is essentially a more non-deterministic version of the standard algorithm. The non-determinism either pertains to the order of application of construction rules or to disjunctive reformulations of sets of construction operations. It incorporates a variety of syntactically (e.g. c-command relations) and semantically (e.g. free variable constraint) motivated constraints. The extended DRS-construction algorithm treats scope ambiguity in essentially the following way: the mapping between a sentence (discourse) and its semantic representation is relational (i.e. a single semantically ambiguous sentence corresponds to a number of disambiguated semantic representations) while the interpretation of each disambiguated semantic representation is functional.

By contrast, in the UDRS approach the mapping from a semantically (not syntactically) ambiguous sentence to its semantic representation is functional and the interpretation of an underspecified representation is functional too (each underspecified representation is associated with a set of its corresponding disambiguated representations where the elements in this set are interpreted disjunctively). The first order UDRS fragment has a sound and complete proof theory which operates directly on the underspecified representations without the need to consider cases. The UDRS approach is further detailed in section 1.1.8 in D8 Underspecification and we give an outline of an HPSG-style UDRS syntax-semantics interface in section 1.2.4 in D8 above. Here we will simply give an example of an underspecified treatment of one of the examples given above and briefly recapitulate some of the advantages of the UDRS approach with respect to the scope ambiguity problems and the extended DRS-construction algorithm as discussed above.

As our example we pick the interaction between connective and quantificational structure scope in (26). On the UDRS approach (26) is mapped into

\[
\text{(31) } \quad \frac{\text{x} \quad \forall \text{x} \quad l_{22} \quad l_1}{l_{1}, \neg \Box l_{21} \quad l_2 \quad \text{sign} = \text{up(x)} \quad l_3}
\]

which leaves the scope relation between negation and the quantifier underspecified. The interpretation of (31) corresponds to the disjunction of the two disambiguated representations given in (37).

(31) is a graphical representation of a UDRS. As a textual specification the UDRS is a pair \((\mathcal{L}, \mathcal{D})\) consisting of a set \(\mathcal{L}\) of subordination constraints and a set \(\mathcal{D}\) of labeled UDRS conditions such that the subordination constraints form an upper semi-lattice. In the case at hand (for some suitable labeling) we have the UDRS

\[
\text{(32) } \quad \langle l_1 \leq l_{17}, l_2 \leq l_{17}, l_3 \leq l_{21}, l_3 \leq l_{12} \rangle,
\]

28
\[
\{l_1 : l_1 \circ l_{22}, \ l_{11} : x, \ l_2 : \neg l_{21}, \ l_3 : \text{sign} - up(x)\}\}
\]

Addition of further subordination constraints from a variety of sources (syntax, semantics, pragmatics) may transform (31) into one of the disambiguated representations in (27). \(\mathcal{L} \cup \{l_2 \leq l_{22}\}\) results in the narrow scope reading of the negation in (26) while \(\mathcal{L} \cup \{l_1 \leq l_2\}\) results in the wide scope reading.

The UDRS approach (e.g. in the guise of the HPSG-style syntax-semantics interface) provides a uniform framework for stating such constraints. To start with indefinite NPs\(^{10}\), e.g., are required to have scope over the semantic representation of verbs they are arguments of. This constraint is ensured by the Closed Formula Principle. Unless further constrained indefinites may take arbitrary wide scope in the resulting representation.\(^{11}\) Thus the resulting representation is undecided between specific and non-specific (or indeed intermediate readings) of indefinite NPs as discussed e.g. in relation to (28), (29), (20) and (21). Proper names, \(\pi\), always take wide scope with respect to any other scope inducing elements in a discourse. This is marked in the lexicon by \(l_\pi : \pi\). If we assume a constraint that the scope potential of a properly quantificational structure is clause bounded - like e.g. if we assume that relative clauses set up scope islands (c.f. the discussion relating to (17)) - this will be enforced by a constraint of the form \(l_{\text{quant}} \leq l_{\text{clause}}\).

The UDRS framework is monotonic in that (i) the addition of subordination constraints reduces the set of meanings and (ii) in contrast to the extended construction algorithm outlined above the UDRS framework does not involve any destructive manipulations on the representations.

### 2.1.4 Quantification and Coordination

In this section we consider the interaction between quantification and verb, NP and N-bar co-ordination.

**Verb co-ordination:** Whether a quantifier gets wide scope over conjoined verbs sometimes seems to depend on the verb: In (33) the same computer is developed and manufactured\(^{12}\) (conjunction of two referentially transparent verbs). In (36) ITEL may have wanted a specific consultant but had to hire someone else, or had no specific consultant in mind (conjunction of a transparent and opaque verb).

(33) ITEL developed and manufactured a computer.

---

\(^{10}\)Like any other argument of a verb.

\(^{11}\)The only further initial restriction is that they are weakly subordinated to the \(\top\) element in the upper semi-lattice defined by the resulting representation. This is marked in the lexical entry of the indefinite determiner by the subordination constraint \(l_{\text{ind}} \leq l_\top\) where \(l_{\text{ind}}\) is the distinguished label associated with the UDRS-condition induced by the indefinite.

\(^{12}\)In the case at hand this is probably the pragmatically preferred reading. There is another reading which involves two computers, c.f. ITEL sold and bought a computer.
As it stands the DRS-construction algorithm does in fact map (33) into the following two representations.\(^{13}\)

\[
\begin{array}{|c|c|}
\hline
x & y \\
\hline
itel(x) & computer(y) \\
develop(x, y) & manufacture(x, y) \\
\hline
\end{array}
\]

\((a)\)

\[
\begin{array}{|c|c|}
\hline
x & y \\
\hline
itel(x) & computer(y) \\
develop(x, y) & itel(z) \\
computer(v) & manufacture(z, v) \\
\hline
\end{array}
\]

\((b)\)

In order to exclude reading (34) (b) the construction algorithm (i.e. construction rule CR.AND) would have to be made sensitive to the type of verbs in verb conjunctions. As things stand both

(35) APCOM wants and needs a computer.

and

(36) ITEI wanted and hired a consultant.

are mapped into representations corresponding to (34) above.

**NP co-ordination:** here we briefly consider conjunctions of quantified NPs and quantified NPs and proper names. Coordinating two quantified NPs does not create scope ambiguities: (37), for example, does not have two readings, one in which *most executives* takes wide scope, the other in which *a few customers* takes wide scope.

(37) Most executives and a few customers attended the meeting.

This prediction is accounted for by the DRS-construction algorithm. In the case of “properly” quantificational NPs (involving proportional quantifiers introducing duplex conditions) a sentence of the form \([\ldots NP_i and NP_j\ldots]\) is effectively interpreted as

---

\(^{13}\)The fact that (34) (b) contains two discourse referents and associated conditions pertaining to ITEI is an artefact of the DRS construction algorithm. On the interpretation that ITEI is proper name both refer to the same “individual”. In the following we will ignore this complication.
\([\ldots NP_i \ldots] \text{ and } [\ldots NP_j \ldots]\). (37) is thus mapped into\(^{14}\)

\[
\begin{array}{c}
x \\
\text{the meeting}(x) \\
y \\
\text{executive}(y) \\
\downarrow \text{most} \\
y \\
\downarrow \text{attend}(y, x) \\
y \\
\text{customer}(y) \\
\downarrow \text{few} \\
y \\
\downarrow \text{attend}(y, x)
\end{array}
\]

(38)

The next example involves cardinality quantifiers. In contrast to proportional quantifiers they do not introduce duplex conditions in the representation and may admit of both collective and distributive interpretations.\(^{15}\) The DRS-construction algorithm maps

\[(39) \quad \text{Three executives and two customers attended the meeting.}\]

into the following representations

\(^{14}\text{Note that it is assumed that genuinely quantificational NPs in subject position only admit of a distributive reading.}\)

\(^{15}\text{That is to say cardinality quantifiers themselves do not introduce duplex conditions. A distributive interpretation of a cardinality quantifier, of course, may introduce duplex conditions.}\)
The DRS in (40) (a) gives the reading where the executives and customers collectively attend the meeting; (b) gives the reading where the executives collectively attend the meeting and the customers collectively attend the same meeting; (c) the reading where each of the members in the set of customers and executives “individually” attend the same meeting and (d) the reading where each of the members in the set of executives “individually” attend the meeting and each of the members in the set of customers “individually” attend the very same meeting and (e) and (f) were we distribute over the customers but not the executives and vice versa, respectively. One may wonder as to whether and in what sense the readings given in (40) really amount to separate readings of (39). In the case at hand the readings do not seem to make that much of a difference. This is due to the fact that (i) the object NP is a definite NP which does not enter into scope ambiguities with respect to the distributive readings and (ii) there seems to be a strong preference to interpret a verb like attend collectively.

The next example involves a conjunction of a proper name and a quantified NP.

(41) Prof. Smith and most customers attended the meeting.
The DRS-construction algorithm yields the following representation:

\[
\begin{array}{c}
\text{\(x\ y\)} \\
\text{\(\text{prof\ smith}(x)\)} \\
\text{\(\text{the\ meeting}(y)\)} \\
\text{\(\text{attend}(x, y)\)} \\
\text{\(\text{most}\)} \\
\text{\(\text{customer}(z)\)} \\
\text{\(\text{attend}(z, y)\)}
\end{array}
\]

\text{(42)}

\text{N-bar co-ordination: there are some restrictions on the available readings:}

\text{(43) Every representative or client was at the meeting.}

\text{(43) only has the reading according to which every person who was either a representative or a client attended the meeting, and cannot be interpreted as it was either the case that every representative was at the meeting, or it was the case that every client was at the meeting.}

\text{(44) As it stands, however, the DRS-construction algorithm only yields the reading which is supposed to be ruled out}

\text{(45) The reason for this is simply that the disjunction rule indiscriminately projects disjunctions of constituents of category XP into sentential disjunctions.}

\text{Sentence (46) involves a conjunction of N-bar constituents in the subject NP.}
Every representative and client was at the meeting.

In contrast to (43), (46) can be paraphrased either as every person who was both a representative and a client was at the meeting or as every representative was at the meeting, and every client was at the meeting. Both readings are produced by the DRS-construction algorithm. Unlike the disjunction rule, the conjunction rule may in fact map a conjunction of categories of type XP into a conjunction of any dominating constituent of type YP.

Examples like (48) which have both the N-bar and the sentential disjunction readings complicate matters.

Our sales manager or head of research will go to the meeting.

In the case of examples (49) and (50) there is a strong tendency to read the conjunction as N-bar conjunction. The construction algorithm, however, will treat both along the lines outlined with respect to (46) above.

Our sales manager and head of research will go to the meeting.

Our sales manager and highest paid executive will go to the meeting.

In the presence of a disambiguating verb cluster e.g. has gone or have gone the construction algorithm will yield a singular or plural reading only.
VP Co-ordination: example (51) is ambiguous between a sentential reading of the disjunction or a reading (preferred) which confines the disjunction to the level of the VP.

(51) Every representative wrote or telephoned.

The readings are given in

\[
\begin{align*}
&\text{(a)} & &\begin{array}{c}
\forall x \\
\text{reps}(x) & & \triangledown & & \text{write}(x) & & \lor \\
x & & \end{array} \\
&\text{(b)} & &\begin{array}{c}
\forall x \\
\text{reps}(x) & & \triangledown & & \text{write}(x) & & \lor \\
x & & \end{array}
\end{align*}
\]

Of these the construction algorithm yields (52) (b).

2.1.5 Possessives

Possessive NP’s come in two forms: either a possessive pronoun followed by a nominal (a proper noun or some N-bar construction) like her account or some NP followed by ’s followed by a nominal like for example Smith’s account.

Possessive NPs specify some relation between two entities. Therefore it seems natural to interpret the possessive ’s (which in the case of possessive pronouns in English has been absorbed into the morphology of the pronoun) as the natural language counterpart of the relation in question. In the paradigmatic case this relation is a relation between possessor and possessee. More often than not, however, the precise nature of the relation in question can only be determined in context and involves a considerable amount of inferencing. The NP Smith’s account e.g. can refer to the account Smith owns, the account Smith is working on, the account Smith is in charge of etc. The situation is different in the case of relational nouns like father, friend etc. NPs like Smith’s father are rarely interpreted as some father Smith owns, takes care of etc. but rather as the person who stands to Smith in the relation of father to son. The picture is further complicated by the fact that some possessive NP’s may carry uniqueness presuppositions.

Possessive pronouns are subject to the constraint that they cannot be anaphorically linked to the discourse referent introduced by the following N-bar constituent. In the syntactic literature this has often been expressed as follows: possessives cannot be anaphoric to elements
in their minimal binding domain which is the smallest NP that contains the possessive as a constituent.\textsuperscript{16}

As it stands in DRT there is currently no formally worked out account of how the precise nature of the relation expressed by possessive NPs is determined.\textsuperscript{17} The “possessive” relation is simply indicated in terms of a dummy predicate ‘s so that the sentences

\begin{itemize}
  \item[(a)] Jones filed Smith’s report.
  \item[(b)] Jones filed every customer’s report.
  \item[(c)] Smith signed his name on his report.
\end{itemize}

are mapped into the following DRSs:

\begin{align*}
\text{(a)} & \quad \begin{array}{c}
  x \quad y \quad z \\
  jones(x) \\
  smith(y) \\
  report(z) \\
  's(y, z) \\
  file(x, z)
\end{array} \\
\text{(b)} & \quad \begin{array}{c}
  x \\
  jones(x) \\
\end{array} \quad \begin{array}{c}
  y \\
  \forall \quad y \\
  customer(y) \\
\end{array} \quad \begin{array}{c}
  z \\
  report(z) \\
  's(y, z) \\
  file(x, z)
\end{array}
\end{align*}

\begin{align*}
\text{(c)} & \quad \begin{array}{c}
  x \quad y \quad z \\
  smith(x) \\
  name(y) \\
  report(z) \\
  's(u, y) \\
  's(w, z) \\
  u = x \\
  w = x
\end{array}
\end{align*}

Partitive constructions consist of a determiner followed by a prepositional of-phrase whose NP is usually definite. The embedded NP denotation provides a set which restricts the domain of quantification of the determiner: if the determiner is a proper quantifier the NP denotation provides the domain of quantification; if the determiner is an indefinite it either provides the

\textsuperscript{16}In this respect they are similar to non-reflexive pronouns which cannot be bound in the smallest clause containing the pronoun.

\textsuperscript{17}In principle, the machinery required to do that (representation of context and inferencing) is available in DRT.
domain of quantification or contains the set that acts as the value of the determiner as a subset:

(55) Most of the customers complained.

is mapped into

```
+---+   +---+   +---+   +---+
| X |   | the |   | the |
|    |   | customer(X) |   | customer(X) |
```

(56)

```
+---+   +---+   +---+   +---+
| x |   | most |   | complain(x) |
|    |   | x ∈ X |   |   |
```

2.1.6 ‘Non-Quantificational’ NPs

Under the heading ‘Non-Quantificational’ NPs we will discuss proper names and definite descriptions. In DRT indefinite NPs and cardinality quantifiers are also regarded as non-quantificational. This is mainly due to the fact that unlike properly quantificational NPs they can set up discourse referents which are not bound by the NP itself. Indefinite NPs and cardinality quantifiers are discussed elsewhere in the present document.

Most proper names are ambiguous in that in principle they can refer to a number of individuals. In a given context, however, proper names pick out a single determined individual. Thus a proper name \( \pi \) is not synonymous with the complex NP \( \text{someone called } \pi \). Proper names do not (usually) pick out a certain individual by virtue of some descriptive content but rather in terms of some (arbitrary) act of labeling. In order to account for this DRT has adopted a formal device referred to as (external) anchor. An external anchor represented \( \{\{x, a\}\} \) is a function which maps some discourse referent \( x \) to some individual \( a \) in the domain of interpretation. It constrains the (partial) variable assignments used in the definition of verification of DRSs. The simple sentence

(57) Smith left.

is represented as

```
+---+   +---+   +---+   +---+
| x |   | smith(x) |   | left(x) |
|    |   | \{x,a\} |   |   |
```

Given \( \mathcal{M} = \langle \mathcal{U}, \mathcal{T} \rangle \), (58) is true in \( \mathcal{M} \) if and only if there exists a \( g \) such that \( \text{dom}(g) = \{x\} \) and \( \{\{x, a\}\} \subseteq g \) where \( a \in \mathcal{U} \) and \( g \) verifies (58) in \( \mathcal{M} \).
The Russellian account of definite descriptions can be straightforwardly translated into DRT. On this account the function of a definite description is to provide a uniquely specifying description of a single individual. A description of the form the N-bar is proper if and only if the predicate representing the N-bar phrase is true of exactly one individual; otherwise it is considered an improper description. On this analysis a sentence like

(59) The manager attended a meeting.

is mapped into

\[
\begin{array}{ccl}
  x & z \\
  \text{manager}(x) \\
  y & \forall y & x = y \\
  \text{manager}(y) \\
  \text{meeting}(z) \\
  \text{attend}(x, z)
\end{array}
\]

If there is no unique manager in the domain under consideration (60) will simply come out false. It has often been objected that uniqueness and existence are presupposed rather than simply asserted and that improper definite descriptions involve presupposition failure rather than flat falsity.

A further problem with the Russellian approach to definite descriptions is that it simply doesn’t seem to apply to the majority of actual uses of definite descriptions. Cases in point are

(61) (a) A man and a woman applied to APCOM. The man was turned down.
    (b) Smith went to the bank and to the post office.

In both (61) (a) and (b) on any realistic account the predicates man, bank and post office are satisfied by large numbers of individuals. What seems to be needed is some notion of a local domain under consideration within the domain at large from which the definite description selects its unique referent.

A more realistic account of definite descriptions (which tallies better with how definite descriptions are actually used) would thus account for the fact that a definite description singles out a unique individual relative to a given context. Thus (60) should probably be augmented to something like
(62) \[
\begin{array}{c|c}
 x \land z & X \\
 \hline
 x \in X \\
 \text{manager}(x) \\
 \end{array}
\]
\[
\begin{array}{c|c}
 y & y \in X \\
 \hline
 \text{manager}(y) \\
 \end{array}
\]
\[
\forall y \quad x = y \\
\]
\[
\text{meeting}(z) \\
\text{attend}(x, z) \\
\]

where \( X \) is a representation of some currently salient context set. As yet there is no formally worked out account of saliency tracking of the sort required in (62) in DRT.

(61) (a) illustrates an anaphoric usage of definite descriptions where the anaphoric relation is one of simple identity. Often, however, this relation is considerably more complex:

(63) Smith’s computer is not working. The keyboard malfunctions.

Here \textit{the keyboard} is understood as the keyboard of Smith’s computer. The anaphoric relation between the definite description in the second sentence and its antecedent in the first is functional (in the sense that a keyboard is functionally related to a computer or part of a computer) rather than simply coreferential.

Definite descriptions provide clear illustrations of the difference between \textit{restrictive} and \textit{non-restrictive} uses of relative clauses. A restrictive relative clause contributes directly to the determination of the denotation of the NP of which it is a constituent. A non-restrictive relative clause (orthographically set apart by commas) provides a further assertion about (constraint on) the denotation of the NP without the relative clause. That this can actually make a difference can be seen in the following two examples:

(64) (a) The customer who bought APCOM was insufferable.
(b) The customer, who bought APCOM, was insufferable.

For (64) (a) to come out true there can be more than one customer but there has to be exactly one customer who bought APCOM. For (64) (b) to come out true there must only be one customer and this customer also bought APCOM. This is reflected in the corresponding DRSs:
2.2 Update and Dynamic Semantics

To see how non-standard quantifiers such as *most*, *at most half*, *at least seven*, etcetera, can be treated dynamically, let us first look at the treatment of the quantifiers that we already have in the fragment of Section 2.2 in DS: *every* and *no*.

<table>
<thead>
<tr>
<th>expression</th>
<th>category</th>
<th>translates to</th>
<th>type</th>
</tr>
</thead>
<tbody>
<tr>
<td>every</td>
<td>DET(i,*)</td>
<td>( \lambda P \lambda Q(\eta x_i; P(x_i)) \Rightarrow Q(x_i) )</td>
<td>( ((e,T),((e,T),T)) )</td>
</tr>
<tr>
<td>no</td>
<td>DET(i,*)</td>
<td>( \lambda P \lambda Q(\eta x_i; P(x_i); Q(x_i)) )</td>
<td>( ((e,T),((e,T),T)) )</td>
</tr>
</tbody>
</table>

Working out an example like *Every man walks* on the basis of this gives the following representation: 

\( (\eta x; \text{man} x) \Rightarrow \text{walk} x \). The treatment of *every* creates the impression that the quantificational force resides in the dynamic implication \( \Rightarrow \).

Trying to extend this approach to non standard quantifiers, one would hope that special variants of dynamic implication would work here. One might for instance want to analyse 1 along the lines of 2.

1 Most farmers who own a dog feed it.
(2) \( (x; y; \text{farmer}(x); \text{dog}(y); \text{own}(x, y)) \Rightarrow_m \Rightarrow \text{feed}(x, y). \)

The semantics that goes with this is:

- \( M, s, s' \models D_1 \Rightarrow_m \Rightarrow D_2 \) iff for most assignments \( s' \) with \( M, s, s' \models D_1 \) there is an assignment \( s'' \) with \( M, s', s'' \models D_2 \).

Unfortunately, this analysis does give the wrong truth conditions. In the example case, it quantifies over farmer–dog pairs instead of individual farmers. In a situation where there are five kind farmers who each own one dog and feed it, and one mean farmer who neglects each of his ten dogs, the analysis makes sentence 1 false, while intuitively it should be true in this situation.

The problem (called the proportion problem in the literature) suggests that generalized quantifiers be added explicitly to the representation language. We would then get:

<table>
<thead>
<tr>
<th>expression</th>
<th>category</th>
<th>translates to</th>
<th>type</th>
</tr>
</thead>
<tbody>
<tr>
<td>most'</td>
<td>DET(i.*)</td>
<td>( \lambda x \forall y (M\text{OST} u_i(P(u_i), Q(u_i))) )</td>
<td>((e,T),(e,T),T))</td>
</tr>
<tr>
<td>at least ( n )</td>
<td>DET(i.*)</td>
<td>( \lambda x \forall y (M\text{AT LEAST} n u_i(P(u_i), Q(u_i))) )</td>
<td>((e,T),(e,T),T))</td>
</tr>
</tbody>
</table>

The intended interpretation of this also takes care of the ‘internal dynamics’ of the quantification. We use \( s[x] \) for an assignment which differs at most from \( s \) in the value assigned to \( x \), and \( M, s \models D \) for truth in \( M \), given \( s \).

- \( M, s, s' \models Q x (\pi_1, \pi_2) \) iff \( s = s' \) and the set of assignments \( s[x] \) for which \( M, s[x] \models \pi_1 \) is \( Q \)-related to the set of assignments \( s[x] \) for which \( M, s[x] \models \pi_1; \pi_2 \).

For the example sentence, this clause gives the following meaning: for most farmers who own a dog it holds that they feed at least one dog that they own. This is certainly a reading that the sentence has, but there might also be cases where we want something stronger:

- \( M, s, s'' \models Q x (\pi_1, \pi_2) \) iff \( s = s' \) and the set of assignments \( s[x] \) for which \( M, s[x] \models \pi_1 \) is \( Q \)-related to the set of assignments \( s[x] \) for \( M, s[x] \models \pi_1 \Rightarrow \pi_2 \).

This would get the so-called strong reading. In our example case: for most farmers who own a dog it holds that they feed all the dogs that they own.
2.3 Situation Semantics

2.3.1 Proper Names

We follow Gawron and Peters in assuming that proper names contribute a restricted parameter to the content of the utterance. However, we use EKN style restrictions instead of putting the restriction directly on the parameter, as Gawron and Peters do. Our basic meaning for proper names includes two parameters in addition to that for the discourse situation: the referent and the resource situation which provides the information that the referent is called by the proper name. We differ from Gawron and Peters also in that the content of the proper name which is provided when all the context roles are fixed is a Montague style generalized quantifier of the form $\lambda[P](P[a])$ (where $a$ is the referent provided by the context). We do this in order to facilitate a straightforward treatment of NP conjunction which mixes proper names and generalized quantifiers such as every representative. The basic meaning for a proper name $\alpha$ is

\[
\text{ds} \rightarrow DS, \langle \text{ref}, u \rangle \rightarrow X, \langle \text{exploits}, u \rangle \rightarrow R
\]

Gawron and Peters also impose a constraint on the circumstances, namely, that they must include an action of referring to $X$ with the NP; this could easily be added – it’s not essential for the analysis.

We also differ from Gawron and Peters in that we put proper names in store. There are two reasons for this. One reason has to do with NP conjunction. The conjunction will be constructed in the store and this will ensure that conjoined NP’s always scope together. Also our treatment of intensional verbs will ultimately allow for different readings to be obtained depending on whether the proper name is within the scope of an intensional verb or not.\textsuperscript{18}

The storage is represented by an infon of the form

\[
\begin{array}{c}
\text{ref}(u, X) \\
\text{res}(u, R) \\
\text{DS} \\
\text{named}(X, \alpha)
\end{array}
\]

\textsuperscript{18}This gives a more refined treatment that Montague did since for Montague the different scopes of proper names relative to intensional verbs did not yield a meaning difference.
quant\((u, q)\)

where \(u\) is the utterance which expresses the quantifier and \(q\) is the quantifier, i.e. what we called the basic NP meaning above. We will define a quantifier resolution operation which will take an unresolved meaning with quantifiers represented in this way and quantify in the quantifier over the parameter which is the value of the role \(\langle \text{par}, u \rangle\) in the following rule. We will look first at generalized quantifiers before we give the details of resolution.

Here is the lexical rule for proper names.

**LEX-PN1** If \(u\) is a use of type \([\text{NP } \alpha]\) and \(\alpha\) is a proper name, then

\[
[u] = Y
\]

\[
\text{quant}(u, P[X]) \quad \begin{array}{c}
\text{ds} \rightarrow DS, \langle \text{par}, u \rangle \rightarrow Y \\
\text{DS} \\
\text{ref}(u, Y)
\end{array}
\]

\[
\text{ds} \rightarrow DS, \langle \text{ref}, u \rangle \rightarrow X, \langle \text{exploits}, u \rangle \rightarrow R \\
\text{P} \\
\text{R} \\
\text{named}(X, \alpha) \\
\text{DS} \\
\text{ref}(u, X) \\
\text{res}(u, R)
\]

\[
\text{res}(u, R)
\]

\[
\text{named}(X, \alpha)
\]

\[
\text{ref}(u, X)
\]

\[
\text{ds} \rightarrow DS, \langle \text{par}, u \rangle \rightarrow Y
\]

2.3.2 **Definite**

Definite descriptions are assigned a meaning that is a cross between the meaning of indefinites and the meaning of pronouns. We adopt for definites the treatment proposed in DRT [Heim, 1982], but, as in the case of pronouns, we use parameters to encode the familiarity condition. We shall treat the meanings of definites as being exactly like those of indefinites, except that a **ref** role is introduced instead of **indef**. Thus the meaning of \([\text{the}_1 \text{ representative}_2]_3\) will be:
The meaning of the determiner the is given by the following rule:

**LEX-DEF-ART** If \( u \) is a use of type \([\text{Det} \text{the}]\), then

\[
[u] = \frac{\text{ds} \rightarrow DS, \text{par}, u_3 \rightarrow Y}{P[X]}
\]

\[
Q[X]
\]

\[
\text{ref}(u, X)
\]

Using \text{ref} rather than \text{indefref} means that we have a hibind rather than a lobind role—so definites will not get captured by the quantification closure rules. It also means that nounphrases with definite articles could be made to covary with other NPs in the same way that pronouns do, although we will not spell out the rules to do this here.

### 2.3.3 Indefinites

Situation semantics can be used both for a generalised quantifier-style treatment of definites and indefinites, and a DRT-style one. The content of an indefinite noun-phrase like \( a \) repre-
sentative in a Montagovian framework could be represented in EKN in the following fashion (see, e.g., Cooper’s PTQ in EKN draft and [Cooper, 1993a]):

However, we adopt here, following Barwise and Perry [1983] and Gawron and Peters [1990], the DRT treatment of definites and indefinites, according to which (in)definites are not quantificational, but introduce elements (discourse markers in DRT) that can be ‘bound’ by other operators. One of the motivations is that this treatment offers a way of dealing with anaphoric expressions.

The meaning of \[ a_1 \text{ representative}_2 \]_3, where the subscripts correspond to the subscripts on the u’s in the meaning, is:

This meaning is obtained by the rule for combining the lexical meaning for the indefinite article with a common noun. Here is the lexical rule for the indefinite article:

**LEX-INDEF-ART** If \( u \) is a use of type \([\text{Det}\ a]\), then
The common noun meaning is specified by \textbf{LEX-CN}. The rule for combining them is:

\textbf{PS-NONQUANT-NP} If \( u \) is a use of type \([\text{NP} \ [\cdot \text{quant}] \ N]\) with intermediate constituents \( u_1, u_2 \), respectively, then

\[
[u] = \begin{array}{c}
ds \rightarrow DS <\text{indref}, u > \rightarrow X \\
Q \\
P \\
[u] = P[X] \\
\begin{array}{c}
DS \\
\text{indref}(u, X) \\
Q[X]
\end{array}
\end{array}
\]

where \( f \) is a mia for \([u_1], [u_2]\)

The meaning of \textit{left}_4 is:

\[
[u] = \begin{array}{c}
ds \rightarrow DS <\text{par}, u > \rightarrow Y \\
\begin{array}{c}
DS \\
\text{ref}(u, Y) \\
\end{array}
\end{array}
\]

\[
[u] = \begin{array}{c}
\text{quant}(u, \lambda f([u_1]; f([u_2]; f))) \\
\end{array}
\]

And the meaning of the sentence [[\text{representative}_2] _3 \text{left}_4]_5 is obtained by \textbf{PS-S1}:
If $u_5 \models \langle \text{scope-over}, u_3, u_5 \rangle$ we can resolve this meaning to:

If this is the entire discourse then the discourse interpretation rule will apply to the result of creating a type from this meaning. The meaning of the entire discourse will be:
The discourse interpretation rule that achieves this is:

**DISC-RULE** If \( u \) is a discourse \( u_1, \ldots, u_n \), then

\[
[u] = \exists \text{lobind}(\forall f_1 \ldots \forall f_n \cdot S)(S : [u_1], f \land \ldots \land [u_n], f))
\]

where \( f \) is a mia for \([u_1], \ldots, [u_n]\).

We can compare the resolved meaning of a representative left with that of \([[Smith]_1 \ [left]_2]_3\).

This is:
The important difference between \textit{Smith} and a representative is that the referent role for the proper name is \texttt{ref} whereas that for the indefinite is \texttt{indefref}, which is declared to be a \texttt{lobind} role. When the discourse rule applies, it existentially closes over any \texttt{lobind} roles but will leave \texttt{ref} roles introduced by proper names as context roles.

The fact that indefinites may take narrow scope with respect to other operators means that the \texttt{lobind} roles they introduce can be quantified over at various levels of embedding, and not just by existential closure at the discourse level. This is why \texttt{qresolve} invokes $\exists_{\text{lobind}}$ when a quantificational NP is quantified in. For example, the two readings of [[Every$_1$ company$_2$]$_3$ \texttt{hired}_4\texttt{a} \texttt{representative}_c]$_7$$_8$$_9$ (ignoring ambiguities arising from tense and ignoring some restrictions on DS and the utterances) in which the indefinite takes narrow scope and the one in which the indefinite takes wide scope will be represented as in (66a) and (66b), respectively:

\begin{align*}
\text{\texttt{ds} = DS}, \texttt{<sit-time}> = U, \texttt{<ev-time}> = T, \texttt{<exploit-u_4>} = R, \texttt{<ref-u_6>} = X, \texttt{desc-sit} = S
\end{align*}
2.3.4 Generalized Quantifiers

Determiners in quantified NPs correspond to binary relations between unary types of individuals and unary properties of individuals. Thus we allow ourselves propositions such as

\[ \forall Y \exists X \text{ every}(X, Y) \]

\[ \forall X \exists r \text{ manager}(X, r) \]

\[ \forall X \exists t \text{ leave}(X, t) \]

In previous work by Cooper [Cooper, 1993a] determiners have been treated as relations between types, but here we follow Gawron and Peters more closely in treating them as relations between types and properties. This gives us the advantage of having more control over the situation which supports the infon in the second argument. We will illustrate this in the distinction made between every and each below. Also it will allow us to treat VP negation as infonically negation rather than propositional negation.

For each determiner relation \( \alpha \) there is a corresponding set theoretic relation between sets \( \alpha^* \) of the familiar kind from generalized quantifier theory. The \( \alpha \) and \( \alpha^* \) relations can be related in the following way:

\[ \exists s [s \models \langle \alpha, r; 1 \rangle] \iff \exists s' \alpha^*(\{x \mid x \models r\}, \{x \mid s' \models r\}) \]

\[ \exists s [s \models \langle \alpha, r; 0 \rangle] \iff \neg \exists s' \alpha^*(\{x \mid x \models r\}, \{x \mid s' \models r\}) \]

Suppose that there is some situation \( s \) which supports the quantificational infon
corresponding to *most managers* (in situation \( r \)) *work out*. This will be true just in case there is some situation \( s' \) (which may or may not be the same situation as the one which supports the quantificational infon) such that

\[
\text{most}^*(\{x \mid r \models \langle \text{manager}, x \rangle\}, \{x \mid s' \models \langle \text{work-out}, x \rangle\})
\]

that is, most* holds between the set of managers in situation \( r \) and the set of individuals who work out in situation \( s' \). In other words, most of the managers in the resource situation \( r \) which identifies the range of the restricted quantification work out in situation \( s \). Cooper [1] examines various kinds of motivation for resource situations. Here we can note that it plays an important role in fixing the domain of quantification when the quantified infon is negative. Suppose that there is some situation \( s \) which supports the quantificational infon

\[
\langle \text{every}, X \mid r \models \langle \text{manager}, X \rangle, \text{work-out}(Y) : 0 \rangle
\]

corresponding to *not every manager* (in situation \( r \)) *works out*. This will be true just in case there is *no* situation \( s' \) such that

\[
\text{every}^*(\{x \mid r \models \langle \text{manager}, x \rangle\}, \{x \mid s' \models \langle \text{work-out}, x \rangle\})
\]

Here every* is, of course, the subset relation as is standard in generalized quantifier theory. This says, then, that there is no situation in which all the individuals who are managers in the resource situation \( r \) work out. This is not the only way of working out negated quantification in situation semantics, but it is a way that meets the common intuition that negative quantification makes a stronger claim about the world (represented by the negated existential quantification over situations) than positive quantification. (cf. the discussion of *John does not own a car* in Cooper and Kamp [1]). Note, however, that the range of the quantifier determined by the resource situation remains unaffected by the negation.

For *every* the above constraints will be equivalent to

\[
\exists s[s \models \langle \text{every}, \tau, r; 1 \rangle] \iff \exists s' \forall x (x : \tau \rightarrow s \models \langle r, x \rangle) \\
\exists s[s \models \langle \text{every}, \tau, r; 0 \rangle] \iff \neg \exists s \forall x (x : \tau \rightarrow s \models \langle r, x \rangle)
\]
Consider how this applies to a sentence like *every delegate left*. Why do we allow the situation which supports the infons about the individual delegates leaving to be distinct from the situation which supports the quantificational info? In Cooper [] it is argued that this accounts for the fact that someone can see every delegate leave without seeing each individual leaving event. Imagine the situation where you are presenting a lecture to a large group of delegates and there is suddenly a fire alarm and a general scramble for the door. The lecturer may indeed see the general scramble without being able to truthfully say that she saw the leaving events of all the particular individuals. This seems to contrast with _each_. Seeing each delegate leave does seem to require that you saw all the individual leavings. For this reason, Cooper [] suggests that _each_ requires that the connection between the quantificational info and the individual infons be closer, namely that they be supported by the same situation. Thus, in addition to the constraints above for _each_ we should add:

$$\forall s[s \models \langle \text{each}, \tau, r, 1 \rangle \iff \forall x[x : \tau \rightarrow s \models \langle r, x \rangle]$$

The basic meaning of a use $u$ of an NP *every representative*, where $u_1$ is the use of *every* and $u_2$ is the use of *representative* is the following (which will go in the store):

The meaning of the NP with the basic meaning in store looks as follows:
Here the utterance of the NP keeps track not only of the quantifier but also of the meaning of the common noun *representative*, indicated using Gawron and Peters’ terminology of *ascribed type* (asc-type). The reason we keep the ascribed type in the store in addition to the quantifier is so as to allow ourselves one kind of solution to the proportion problem in the treatment of donkey anaphora where the ascribed type is conjoined with the second argument of the determiner relation. This will be discussed further below.

This meaning is obtained compositionally by combining the meaning of the determiner *every* with the translation of the common noun *representative*. Here is the lexical rule for quantificational determiners such as *every*.

**LEX-QUANTDET** If \( u \) is a use of type \([\text{Det} \, \alpha] \) where \( \alpha \) is a quantificational determiner and \( \alpha' \) is the situation theoretic relation corresponding to \( \alpha \), then

---

\[  \]
The lexical rule **LEX-CN** for common nouns gives a role both for a resource situation and a temporal argument to each nominal predicate. Here it is:

\[
[u] = \begin{array}{c}
\text{LEX-CN} \\
\text{If } u \text{ is a use of type } [N \alpha] \text{ and } \alpha' \text{ is the situation theoretic property corresponding to } \alpha, \text{ then}
\end{array}
\]

\[
[\alpha'(Q,P)] = \begin{array}{c}
\text{ds} \rightarrow DS \\
Q \\
P \\
\alpha'(Q,P) \\
\text{disc-sit}(u,DS)
\end{array}
\]

The temporal argument of a nominal predicate, much as the temporal argument of a verbal predicate, could be either referential or existentially quantified over. To keep matters simple, we ignore the issue here; we will illustrate how this can be made to work when discussing VPs.

The phrase structure rule which combines quantified determiners and common nouns does four things. It existentially quantifies over any indefinite roles that may be in the meaning of the common noun. This is relevant if the common noun, for example, contains a relative clause, but has no effect in the simple cases we are discussing at the moment. It also keeps track of the meaning of the common noun, storing it under the label ‘asc-type’. This becomes important for the treatment of donkey anaphora so that the common noun can be “copied” into the second argument of the quantifier in order to avoid the proportion problem. Again this is not relevant for simple examples. It applies the determiner meaning to the noun meaning (passing up the context roles to be context roles of the NP meaning) and it places this resulting meaning in the store as the quantifier associated with the NP utterance. Here is the rule:

\[
\text{PS-NP If } u \text{ is a use of type } [\text{NP Det } N] \text{ with constituents } u_1, u_2 \text{ respectively, then}
\]

54
2.3.5 Quantifier scope resolution

According to Gawron and Peters, the scope of quantifiers is determined by the circumstances. They formalize retrieval or discharge from the store in terms of a function called Closure, applied to obtain the meaning of those utterance constituents where discharge can take place. We adopt a variant of their proposal. Whereas Gawron and Peters use the circumstances situation to support inferences concerning quantifier scope we will use the utterance situations which are the utterances over which the quantifiers take scope. It is convenient and intuitive to do things this way, though no great claim hangs by it.

We first give a theory of the kinds of facts about quantifier scope that utterances can support.

If \( u \) is an utterance then:

1. If \( u \) supports the fact that \( u_1 \) has scope over \( u_2 \) then \( u \) is either a sentence, a verb-phrase or a common-noun-phrase (\( N \)) and \( u_1 \) and \( u_2 \) are noun-phrases. In symbols:
   \[
   \exists u_1, u_2, u \models \text{ scope-over, } u_1, u_2 \rightarrow \quad u \models \text{ cat, } u, \text{ s } \lor \text{ cat, } u, \text{ vp } \lor \text{ cat, } u, \text{ cn } \]
   \[
   u_1 \models \text{ cat, } u_1, \text{ np } \]
   \[
   u_2 \models \text{ cat, } u_2, \text{ np } \]

   The constraints on the category of \( u \) represent the kind of phrase that can be quantified in over. This corresponds exactly to Montague's three kinds of quantification rules — over sentences, verb-phrases (IV-phrases) and common nouns (CN-phrases). We will concentrate on sentence quantification in what follows but it could be extended in the routine way to cover the other kinds of quantification. We also assume, as this states, that only NP's get quantified in, which in a more detailed treatment need not necessarily be the case.
2. If \( u \) supports the fact that \( u \) itself scopes \textit{in situ} then \( u \) is a noun-phrase.

\[
\begin{align*}
\vdash \langle \text{scope-in-situ, } u \rangle & \rightarrow u \vdash \langle \text{cat, } u, \text{ np} \rangle \\
\end{align*}
\]

We include this clause in order to allow NPs to scope within intensional verbs.

3. If \( u_1 \) scopes over \( u_2 \) in the utterance \( u \) then \( u_1 \) is a constituent of \( u \) (not necessarily an immediate constituent). This means, that a noun-phrase that is quantified into an utterance has to be a constituent of that utterance. \( u_2 \) is either \( u \) itself or another noun-phrase which is quantified into \( u \) and whose scope is within that of \( u_1 \). We take the fact that \( u_1 \) scopes over \( u_2 \) to mean that there is no \( u_3 \) which takes scope between \( u_1 \) and \( u_2 \).

\[
\begin{align*}
\vdash \langle \text{scope-over, } u_1, u_2 \rangle & \rightarrow u \vdash \langle \text{constituent-of, } u_1, u \rangle \\
& \text{and } (u_2 = u \text{ or } u \vdash \langle \text{constituent-of, } u_2, u \rangle) \\
\end{align*}
\]

4. If \( u_1 \) scopes over \( u_2 \) in \( u \) then there’s no other \( u' \) that it gets quantified into and no other \( u_2' \) which it takes scope over. (Remember that we are dealing with actual utterance events here, not utterance types and that we take “scopes over” to mean takes immediate scope over.)

\[
\begin{align*}
u \vdash \langle \text{scope-over, } u_1, u_2 \rangle & \rightarrow \neg \exists u', u_2' \text{ such that } u' \vdash \langle \text{scope-over, } u_1, u_2' \rangle \\
\end{align*}
\]

5. If \( u \) takes scope \textit{in situ} then it doesn’t scope over anything.

\[
\begin{align*}
u \vdash \langle \text{scope-in-situ, } u \rangle & \rightarrow \neg \exists u', u'' : u' \vdash \langle \text{scope-over, } u, u'' \rangle \\
\end{align*}
\]

6. An utterance \( u \) is completely specified with respect to quantifier scope just in case for all its NP constituents \( u_{NP} \) there’s some utterance which supports either a fact that \( u_{NP} \) scopes over something or a fact that \( u_{NP} \) scopes \textit{in situ}.

\[
\begin{align*}
u \text{ is completely specified with respect to quantifier scope iff:} & \\
\forall u_{NP} \vdash \langle \text{constituent-of, } u_{NP}, u \rangle & \rightarrow \langle \exists u', u'' : u' \vdash \langle \text{scope-over, } u_{NP}, u'' \rangle \rangle \\
& \text{and } \forall u_{NP} \vdash \langle \text{scope-in-situ, } u_{NP} \rangle \\
\end{align*}
\]

Our basic semantic rules produce meanings where quantifiers are stored. However, given sufficient scope information of the kind described above, we can reason our way towards meanings where the quantifiers are discharged from the store and take scope in the conventional sense. We define an operation on meanings called \textit{qresolve} which obtains meanings which are resolved to the extent that there is sufficient information about scoping supported by the utterance to enable it. \textit{qresolve} is a one-place operation which takes a meaning and produces a new resolved meaning. Intuitively it works from the outside in taking the NP which is specified to have widest scope and quantifying it into to the result of resolving whatever it is quantified into. \textit{qresolve} is defined in terms of another two-place operation \textit{qresolve}' whose arguments are utterances and NP-utterances and which is to be read so that \textit{qresolve}'(\( u, u_i \)) is to be the resolution of \( u \) from \( u_i \) inwards (i.e., ignoring any NPs which have wider scope that \( u_i \)).

We now present the definition of \textit{qresolve}.

1. If, according to \( u, u_i \) is the unique NP with widest scope, then \textit{qresolve}(\( u \)) is \textit{qresolve}'(\( u, u_i \)), i.e. the result of doing resolution as far out as \( u_i \).
If \( u_i \) is unique utterence such that \( \exists u_j \models \langle \text{scope-over, } u_i, u_j \rangle \) (\( u_j \) may be \( u \) itself) and \( \neg \exists u_k \models \langle \text{scope-over, } u_k, u_i \rangle \), and there are \( u_1, \ldots, u_n \) such that:

\[
\begin{align*}
    u &\models \langle \text{scope-over, } u_i, u_1 \rangle, \\
    &\langle \text{scope-over, } u_1, u_2 \rangle, \\
    &\ldots, \\
    &\langle \text{scope-over, } u_{n-1}, u_n \rangle, \\
    &\langle \text{scope-over, } u_n, u \rangle,
\end{align*}
\]

then \( \text{qresolve}(u) = \text{qresolve}'(u, u_i) \)

2. If \( u \) scopes in situ then \( \text{qresolve}(u) \) is the generalized quantifier meaning retrieved from the store, except that all the lobind context roles (i.e. those introduced by indefinites are existentially closed)

If \( u \models \langle \text{scope-in-situ, } u \rangle \land \langle \text{quant, } u, q \rangle \) then

\[
\text{qresolve}(u) = \lambda f' \left( \begin{array}{c}
P \\
\exists_{\text{lobind}}(\lambda f(q.f.[P])).f' \end{array} \right)
\]

where \( f \) is a mia for \( \{q\} \) and \( f' \) is a mia for \( \{\exists_{\text{lobind}}(\lambda f(q.f.[P]))\} \)

3. Otherwise \( \text{qresolve}(u) = [u] \).

We include here a definition of the existential closure operation \( \exists_{\text{lobind}} \) which is used in the in situ clause above. This operation will also play an important role in the definition of \( \text{qresolve}' \) to follow. It existentially quantifies over roles which are designated as “lobind”, those introduced by indefinites, and passes the remaining context roles up as context roles of the result.

**Existential closure**

If \( \zeta \) is a type abstract and \( \ell \subseteq \text{roles}(\zeta) \) and \( g \) is an index assignment for \( \zeta \) with domain \( \ell \) then

\[
\exists_{\ell}(\zeta) = \lambda f(\exists^* \lambda g(\zeta.g.f))
\]

where \( f \) is a mia for \( \zeta.g \)

\( \exists_{\text{lobind}}(\zeta) \) is the special case where \( \ell = \{p|p \in \text{roles}(\zeta) \land \text{lobind}(\ell)\} \)

We now define \( \text{qresolve}' \)

1. First we deal with the case where the NP takes scope over the sentence directly without any intervening scope-taking NP. There are two subcases: one where the NP is quantificational and the other where it is not (i.e. has the article \( a \) or \( the \) as determiner).
If $u_1$ is quantificational NP (e.g. with determiner *every*) as is indicated by the fact that it supports an infon of the form $\langle \text{asc-typ, } u_1, \tau \rangle$ and it scopes over a sentence utterance $u$, then the resolution of $u$ up to $u_3$ is obtained by applying the quantifier stored in $u_1$ to an abstract of the form $\lambda[X]([\phi])$ where $X$ is the parameter which is the content of $u_1$ and $\phi$ is derived from (leaving aside a few details) conjoining $\tau[X]$ and the meaning of $u$ and existential closing the lobind roles in this conjunction. Here is the precise representation in symbols.

If $u \models \langle \text{scope-over, } u_1, u \rangle \land \langle \text{cat, } u, s \rangle$ and $u_1 \models \langle \text{quant, } u_1, q \rangle \land \langle \text{asc-type, } u_1, \tau \rangle$ then

$$\text{qresolve}'(u, u_1) = \lambda f - \{\langle \text{par, } u \rangle, \zeta \}$$

$$\exists_{\text{lobind}}(\lambda f'([u], f') \cdot \tau, f', [y]) \cdot f$$

where $f'$ is a mia for $\{\tau, [u]\}$ and $f$ is a mia for $\{q, [u_1], \exists_{\text{lobind}}(\lambda f'((\tau, f' \land [u], f')))\}$ and $f(\langle \text{par, } u \rangle) = \zeta$.

Otherwise (i.e. if $u_1$ is not a quantificational NP and therefore does not support an infon of the form $\langle \text{asc-type, } u_1, \tau \rangle$), if $u \models \langle \text{scope-over, } u_1, u \rangle \land \langle \text{cat, } u, s \rangle$ and $u \models \langle \text{quant, } u_1, q \rangle$ then

$$\text{qresolve}'(u, u_1) = \lambda f - \{\langle \text{par, } u \rangle, \zeta \}$$

$$\exists_{\text{lobind}}(\lambda f'([u], f') \cdot [u] \cdot f)$$

where $f$ is a mia for $\{q, [u_1], [u]\}$ and $f(\langle \text{par, } u \rangle) = \zeta$.

2. The second case is where there is an intervening NP which takes scope between the NP being quantified in and the sentence being quantified into. This divides into two subcases for quantificational and non-quantificational NPs as before.

If $u \models \langle \text{scope-over, } u_1, u_2 \rangle \land \langle \text{cat, } u, s \rangle$ and $u_1 \models \langle \text{quant, } u_i, q \rangle \land \langle \text{asc-type, } u_1, \tau \rangle$, and $\text{qresolve}'(u, u_i) = p$, then

$$\text{qresolve}'(u, u_i) = \lambda f - \{\langle \text{par, } u \rangle, \zeta \}$$

$$\exists_{\text{lobind}}(\lambda f'([u], f') \cdot p, f') \cdot \tau, f', [y] \cdot f$$

where $f'$ is a mia for $\{\tau, p\}$ and $f$ is a mia for $\{q, [u_1], \exists_{\text{lobind}}(\lambda f'((\tau, f' \land p, f')))\}$ and $f(\langle \text{par, } u \rangle) = \zeta$, $Y = [u_1], f$. 

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Otherwise, if \( u \models \langle \text{scope-over, } u, u_j \rangle \land \langle \text{cat, } u, s \rangle \) and \( u_i \models \langle \text{quant, } u_i, q \rangle \) and \( \text{qresolve}'(u, u_j) = p \) then

\[
\text{qresolve}'(u, u_i) = \lambda f - \{\langle \text{par, } u \rangle, \zeta \} \left( Y, \left[ \begin{array}{c}
Y \\
p.f
\end{array} \right] \right)
\]

where \( f \) is a mia for \( \{q, \llbracket u_i \rrbracket, p\} \) and \( f(\langle \text{par, } u \rangle) = \zeta \), \( Y = \llbracket u_i \rrbracket \cdot f \).

Our semantic rules derive unresolved meanings with quantifiers in store. They do not specify the scope facts that are supported by the utterances. This information must come from another source than that provided by the grammar. However, we can specify how to obtain resolved meanings to the extent that information is provided by the context. We do this by defining an interpretation function \( \llbracket \cdot \rrbracket_{\text{res}} \) which is like \( \llbracket \cdot \rrbracket \) except that it requires that \( \text{qresolve} \) (and, in a complete treatment, whatever other resolution operators there might be) is applied recursively to all the constituents that are interpreted.

We define a function \( \llbracket \cdot \rrbracket_{\text{res}} \) which is like \( \llbracket \cdot \rrbracket \) except that where \( \llbracket \cdot \rrbracket \) yields unresolved meanings; \( \llbracket \cdot \rrbracket_{\text{res}} \) yields resolved meanings to the extent that the utterance and its constituents provide appropriate information for the resolution.

\( \llbracket \cdot \rrbracket_{\text{res}} \) is defined exactly like \( \llbracket \cdot \rrbracket \) except that \( \llbracket \cdot \rrbracket \) is replaced by \( \llbracket \cdot \rrbracket_{\text{res}} \) throughout, and \( \rho \) is applied to the result where \( \rho \) is \( \ldots \circ \text{qresolve} \). For our present purposes we take \( \rho \) to be identical with \( \text{qresolve} \). If other kinds of resolution were included in the treatment then \( \rho \) would be a composition of all of these.

e.g. If \( \llbracket u \rrbracket = \lambda f[\llbracket u_1 \rrbracket \cdot f, [\llbracket u_2 \rrbracket \cdot f] \rangle \), where \( f \) is a mia for \( \{[u_1], [u_2]\} \) then

\( \llbracket u \rrbracket_{\text{res}} = \rho(\lambda f[\llbracket u_1 \rrbracket_{\text{res}} \cdot f, [\llbracket u_2 \rrbracket_{\text{res}} \cdot f] \rangle), \) where \( f \) is a mia for \( \{[u_1]_{\text{res}}, [u_2]_{\text{res}}\} \)

Let us take as an example the rule for combining NPs and VPs to form sentences, which we introduce here.

**PS-S1** If \( u \) is a use of type \( [S \ NP \ VP] \) with constituents \( u_1 \) and \( u_2 \), respectively, then

\[
\llbracket u \rrbracket = \lambda f[\llbracket u_2 \rrbracket \cdot f, [\llbracket u_1 \rrbracket \cdot f] \rangle
\]

where \( f \) is a mia for \( \{[u_2], [u_1]\} \).

The corresponding rule for obtaining the resolved meaning will be:

**PS-S1-res** If \( u \) is a use of type \( [S \ NP \ VP] \) with constituents \( u_1 \) and \( u_2 \), respectively, then

\[
\llbracket u \rrbracket_{\text{res}} = \rho(\lambda f([u_2]_{\text{res}} \cdot f, [\llbracket u_1 \rrbracket_{\text{res}} \cdot f]) \rangle
\]

where \( f \) is a mia for \( \{[u_2]_{\text{res}}, [u_1]_{\text{res}}\} \).
We will illustrate how the rules above interact with resolution with an example. The sub-utterances associated with an utterance of \([\text{Every representative}_3 \text{ left}_4]_5\) (D5-1) are associated by the grammar above with the following contents:

1. \([\text{every}_1]\): as specified by \textbf{LEX-QUANTDET}, i.e.

\[
\begin{array}{c|c}
Q & DS \\
\hline
P & DS \\
\end{array}
\begin{array}{c}
\text{every}'(Q, P) \\
\hline
\text{disc-sit}(u, DS)
\end{array}
\]

2. \([\text{representative}_2]\): as specified by \textbf{LEX-CN}, i.e.

\[
\begin{array}{c|c}
X & DS, (rt, u) \rightarrow T, (\text{exploits}, u) \rightarrow R \\
\hline
R & DS \\
\end{array}
\begin{array}{c}
\text{representative}'(X, T) \\
\hline
\text{res}(u, R) \\
\text{ref-time}(u, T)
\end{array}
\]

3. \([\text{every representative}_3]\): as in (68) on Page 53.

4. \([\text{Every representative left}_4]\):
If $u_5 = \{\text{scope-over, } u_3, u_5\}$ we can resolve this meaning to:
2.4 Property Theory

The representation of generalised quantifiers in Property Theory (as opposed to modelling their behaviour) is quite trivial. As an example, the sentence:

\[ \text{Every representative left.} \]

can be represented with a PTQ-like analysis as:

\[ \Theta x (\text{representative}'x \Rightarrow \text{left}'x) \]

If this is a proposition, then its truth conditions will be given by:

\[ \forall x (T(\text{representative}'x) \rightarrow T(\text{left}'x)) \]
The alternative underspecified semantics would represent the sentence as:

\[ \text{left'}(\text{all'}(\text{representative'})) \]

Additional axioms allow the same truth conditions to be obtained.

Finally, in a dependent type analysis to be introduced in section 4.4, the sentence can be represented by:

\[ \text{IIrepresentative'}(\lambda x. \text{left'}x) \]

The intended interpretation of this term is explained more fully in that section. Notice that axioms could be used to obtain the truth conditional behaviour of this representation from the underspecified form.

If we have a theory of plurals (as outlined in section 1.1.5.2 in D8), the truth conditions associated with the use of the determiner “all” can be given in terms of the supremum of the extension of a property, like the definite descriptor. The truth conditions of the sentence:

\[ \text{All representatives left.} \]

would involve the predication:

\[ \text{left'}(\sigma x \text{representative'}x) \]

where \( \sigma x p x \) is the supremum of the property \( p \).

It is not clear whether use of “all” should inherit the existence presuppositions of the definite descriptor, but it probably lacks the definite descriptors anaphoric behaviour.

So-called ‘second order’ quantifiers in principle can be represented in a computationally tractable manner, because sets in PT are defined by properties, which are first-order objects in PT. The example:

\[ \text{Most representatives left.} \]

can be represented using the underspecified form:

\[ \text{left'}(\text{most'}\text{representatives'}) \]

When this is scoped, its truth conditions may contain the term:

\[ \text{most'}\text{representatives'}(\lambda x. \text{left'}x) \]

where the quantifier is typed. The exact behaviour of such expressions can be governed by additional axioms. For example, the desired monotonic inferences can be obtained directly by adding an axiom:

\[ T(\text{most'}q(\lambda x.p x)) \& T(\Theta x p x \Rightarrow rx) \rightarrow T(\text{most'}q(\lambda x.r x)) \]

thus allowing inferences of the form:
Most representatives attended the meeting
Everyone who attended the meeting supported the proposal.
Most representatives supported the proposal.

There is currently no special treatment of partitive constructions (such as "each of the"), nor of constraints on scoping, in PT, although the constraints might be expressible as axioms in the theory.

A treatment of coordination is given in [Fox, 1993]. Essentially, full distribution over conjunction can be performed in the syntactic analysis. This distribution (scoping) could be performed directly in the semantics, via additional axioms, but this is not done in [Fox, 1993], as it complicated the presentation of other issues which were being addressed. Concerning VP conjunction, given the sentence:

\textit{Intel developed and manufactured a computer.}

the grammar parses this into one of the following terms

\[(\text{developed}'(\text{a'computer}'))\text{itel}' \oplus (\text{manufactured}'(\text{a'computer}'))\text{itel}' \]

\[(\text{developed}' \oplus \text{manufacture}')(\text{a'computer}')\text{itel}' \]

The weak typing of PT allows us to conjoin terms of any sort with the summation operator \(\oplus\). Assuming that the second interpretation is the desired one, and that it is a proposition, then axioms allow the truth conditions:

\[\exists x (T(\text{computer}'x) \& T(\text{developed}'\text{itel}') \& T(\text{manufactured}'\text{itel}'))\]

to be found.

Concerning NP coordination, with the sentence:

\textit{Most executives and a few customers attended the meeting.}

the truth conditions would create reference to two collections, one consisting of most executives, the other of a few customers. These collections then attend the meeting. This means that neither quantifier outscopes the other.

In [Fox, 1993], N-bar coordination is performed by the grammar. The noun phrase in:

\textit{Every representative and client was at the meeting.}

can be represented by one of:

\[\lambda p.p(\text{every}'\text{representative}') \oplus p(\text{every}'\text{client}')\]
\[\lambda p.p(\text{every}'(\text{representative}' \oplus \text{client}'))\]
where ⊕ in the second interpretation gives rise to the intersection of the properties in the truth conditions.

Extra constraints would be required to rule out the first interpretation in the case of disjoined N-bar categories, as in:

\[ \text{Every representative or client was at the meeting.} \]

in order to avoid reading this as “every representative was at the meeting, or every client was at the meeting”.

So-called intermediate distribution over a conjunction can be subsumed by a collective representation, as suggested by Link and Lønning [Link, 1991], or, alternatively by a generalised, context-dependent distribution operator [Schwarzschild, 1990; Schwarzschild, 1992].

Some other categories (such as adjectives and adverbs) can partially distribute across conjunction, but then only to adjacent phrases in a conjunction.

In one PT implementation, possessives, (and the verb “have”) are modelled with a three place relation “of”, giving the two individuals which are related and some aspect of their relationship [De Roeck et al., 1991a; De Roeck et al., 1991b]. The noun phrase:

\[ \text{John's manager.} \]

is represented by:

\[ \text{of}(j^{'}, \text{manager}', m^{'}) \]

where \( m' \) is John’s manager. This prevents some problems with a two place possessive relation, \( \text{of}(j', m') \), because we might also have that \( m' \) is not John’s employer, in which case we would obtain the contradictory \( \neg \text{of}(j', m') \). The extra argument effectively functions as a guise or role [Landman, 1989; Fox, 1994]. In:

\[ \text{Smith signed his name on his report.} \]

Smith made a mark on his report, which was his as a report, but it may not have been his piece of paper upon which it was printed.
2.5 Monotonic Semantics

2.5.1 Background

A generalized quantifier $Q$ is a relation between two sets, a restriction set $R$ and a body set $B$.\(^{20}\) As argued by [Barwise and Cooper, 1981], generalized quantifiers occurring in natural language are such that the relation expressed by $Q$ is dependent only on the cardinality of the restriction set and the cardinality of the intersection of the restriction and body set. This means that a quantifier can be characterised as a predicate on two numbers $\lambda n \lambda m. Q(n, m)$, where $n$ corresponds to the cardinality of the restriction, $|R|$, and $m$ to $|R \cap B|$.

For the sake of dealing with (collective) plurals and amount terms, two additional kinds of quantifier are introduced. In time-honoured tradition (e.g. [Scha, 1981]) plural collectives can be treated as sets of objects (and singular entities as singleton sets). Collective (or set) quantifiers are represented as $\text{set}(\lambda n \lambda m. Q(n, m))$. Here $n$ correspond to the cardinality of the union of all the items satisfying the restriction, and $m$ to the cardinality of some subset of this union satisfying the body. Amount quantifiers are similar $\text{amount}(\lambda n \lambda m. Q(n, m)$, measure) except that measure indicates some way of measuring the size of the sets other than cardinality (e.g. in terms of length, weight, etc). Set quantifiers could alternatively be represented as $\text{amount}(\lambda n \lambda m. Q(n, m)$, cardinality). Plurals and amount terms will be discussed at greater length in the section on plurals below.

The QLF semantics assumes that all noun phrase quantification, and indeed all noun phrases, can be treated in terms of generalized quantifiers. In this section, we will primarily address the question of how noun phrases are mapped onto quantifiers, but will also present some arguments against distinguishing between quantificational and non-quantificational NPs.

2.5.2 Variety of Quantifiers

QLF terms all contain a field indicating the quantifier associated with the term; in unresolved QLFs derived on the basis of syntactic structure alone, this field is typically uninstantiated. Resolution instantiates the quantifier through the saliency relation connecting the term category, restriction and context at large to the quantifier. Usually the restriction and wider context contribute little to the saliency relation, so that there is a fairly direct mapping from term categories onto quantifiers.

Basic Quantifiers  To illustrate the quantifier mapping for simple determiners, here is the QLF term (before resolution) corresponding to the noun phrase (*every man*):

\[
\text{term}(q(\text{tpc,every,sing}), D, E^*[\text{man},E], \quad -- --)
\]

\(^{20}\) $Q$ is more properly called a generalized determiner. We will follow a common abuse of terminology by calling it a quantifier, however.
The category, \( q(tpc, every, sing) \), identifies the term as corresponding to a ‘quantified’ noun phrase in subject or topic position (\( tpc \)), with a singular determiner expression \( every \). This is followed by the term’s index \( D \) (represented here as a prolog variable), and then by the restriction \( \lambda x.\text{man}(x) \). The underscores represent meta-variables for the quantifier and contextual restriction of the term. Resolution instantiates meta-variables in accordance with the category, restriction, context and salience relation. Two possible resolutions are

\[
\text{term}(q(tpc, every, sing), D, E^\text{[man,E]}, \\
\text{forall, qnt(D)})
\]

\[
\text{term}(q(tpc, every, sing), D, E^\text{[man,E]}, \\
\text{set(forall), qnt(D)})
\]

The quantifier meta-variable has been instantiated to \text{forall} (distributive) or \text{set(forall)} (collective), where \text{forall} is an abbreviation of \( N^M[eq,N,M] \).

The referent \( \text{qnt}(D) \) indicates the lack of any contextual restriction on the quantification.\(^{21}\)

For other determiners, like \text{} \text{a}, \text{most}, \text{some}, \text{three} \, the category of the term will differ from the above, e.g. \( q(tpc, a, sing) \) or \( q(tpc, most, plur) \). This leads to different quantifiers being appropriate resolvents, e.g. \( N^M[gt,M,1] \) or \( N^M[ratio,geq,M,N,1,2] \) (i.e. at least half: the ratio of the body plus restriction cardinality to the restriction cardinality is greater or equal to the ratio of 1 to 2). In the case of singular determiners like \( a \), a collective set version of the quantifier is not available as a resolution.

In some cases the choice of quantifier cannot be read so directly from the surface determiner / term category. Examples are \text{} \text{many} or \text{} \text{few}, where what counts as many or few can be highly context dependent.\(^{22}\)

**Quantifiers with Internal Structure** Determiners may also have a complex structure, e.g. ‘three or four’. In these cases, a QLF expression is built up as the value of the determiner feature in the \text{} \text{term} category. So, for example:

\[
\text{term}( \ q(tpc, \\
B^C^\text{form}(conj(det,or),_), \\
D^[:D,[eq,C,3],[eq,C,4]], \\
_\text{plur}), \\
A^:\text{man,E}, \\
_\text{,_,})
\]

\(^{21}\text{qnt}(D)\) is an abbreviation for the property \( X^D[eq,B,X] \). Recalling that the semantic evaluation rule for terms discharges an index like \( D \) to a variable bound by the quantifier, this corresponds to a null contextual restriction to objects that are self-identical.

\(^{22}\text{QLF allows the possibility of mapping the determiner onto a variety of different quantifiers during resolution. In practice, it is hard to discern how the appropriate quantifier varies with context (and its restriction), and so the resolution of such vague determiners is rather simplistic in the CLE.\)
Here, the determiner value \( E^C \text{form} (...) \) — represents a disjunction of two determiners, roughly: \( n^m \lor m \) (or \( m = 3, m = 4 \)). The value is a QLF expression, containing a disjunctive form requiring resolution (in this case trivially to \( \lor \)). This determiner value provides the basis for the quantifier resolution, which is essentially the determiner value after the disjunctive forms resolved, perhaps with an additional operator to create a set quantifier.23

The CLE handles a variety of other complex determiners, including ordinals (the first three/the last three), measure phrases (three litres of). These are not discussed here.

**Partitives and Possessives**  
Partitives and possessives gives rise to terms with complex restrictions rather than to terms with complex categories. The treatment of the two is similar, since both constructions are in turn related to the genitive: *John’s mother/the mother of John; the mother of the men/each of the men.*

The possessive *John’s mother* receives the following kind of analysis (before contextual resolution):

\[
\text{term}(q(tpc, \text{poss\_some}, \text{sing}), A, \\
C^-
\text{[and, [mother, C],} \\
\text{form(possessive, B}, \\
D^-[\text{and, [mother, C],} \\
\text{[D, C, term(proper\_name(ntpc), E}, \\
E^-[\text{name, E, 'John'], -..}]])], \\
-..)
\]

There are two main contextual issues: how the possessive relation in the possessive form is to be resolved, and how the possessive quantifier is to be resolved.

While *John’s mother* is relatively unambiguous (the person who gave birth to John, or perhaps raised him from childhood), other possessives like *John’s report* admit of a variety of interpretations (e.g. the report about John, the report John wrote, or the report John possesses). These correspond to different predicates chosen to resolve the possessive form. It is not clear what, if any, constraints should be placed on the range of predicates that can be used to resolve possessives. The paraphrases given above for possessives (“the report about John” etc) suggest that the quantificational force of possessives is similar to that of definite determiners.

Genitivess, like *the mother of John*, are treated as genitive PPs modifying noun phrases. Semantically, though they are closely related to possessives

23This example highlights a slight fudge about the determiner feature in term categories. For simple determiners like each, every or all, the value (each, every or all) reflects the surface determiner. All of these correspond to an underlying universal, but with different propensities towards scoping and collective/distributive interpretations. For complex determiners, the value is a logical expression forming the basis of teh corresponding quantifier. In principle, these two roles should be kept distinct, e.g. by having two separate features for surface and logical determiner. In practice, no harm comes of running the two together.
The difference between the possessive and the possessive genitive form is that the possessive genitive allows a narrower range of possible resolvable: it selects predicates expressing some sort of functional relationship between the head and genitive noun.

Partitive noun phrases, like each of the men are treated as a different kind of genitive, where the genitive PP modifies a determiner acting as a pronoun, each

Rather than resolving the bare determiner NP each in the normal way as an anaphor, the initial semantic analysis forces it to be quantificational by instantiating the term referent. The genit(sub) form is resolved to give the property of being an element that is partof the denotation of the (group denoting) NP argument (i.e. being one of the men).

2.5.3 ‘Non-Quantificational’ NPs

The CLE treats all noun phrases as quantificational, including proper names, pronouns, definites and indefinites. However, they may be resolved to quantify over objects contextually restricted to be identical to some salient individual or set of individuals.

For example, the noun phrase John gives rise to a term

If there is some individual salient in context who has the name “John”, then the term can be resolved to give an existential quantifier over objects identical to this individual:
term(proper_name(tpc), A, E'[name,E,'John'],
exists,ent(john smith))

(where ent(john smith) is an abbreviation for \(\exists X \forall x (x = \text{john smith})\). If there is no such salient individual, the name can be treated as a straight existential quantifier over objects named "John":

term(proper_name(tpc), A, E'[name,E,'John'],
exists,qty(A))

Note that when a name is resolved to quantify over objects identical to a specific individual, the scope of the existential relative to other universal or plural quantifiers is immaterial: the quantifier always behaves as though it had wide scope.

Pronouns, definites and indefinites are treated in a similar way, although we will defer discussion of this to the section on anaphora.

2.5.4 Monotonicity

Monotonicity inferences can be accounted for by appeal to the usual properties of generalised quantifiers. In practice, though, this is not quite what happens in the CLE, where inference is performed on a target reasoning language (TRL), derived in a systematic way from resolved QLFs. TRL only employs universal and existential quantification, but allows for quantification over sets. Generalised quantifiers lead (where simplification is not possible) to higher-order cardinality predications on the sets being quantified over. (For example, the TRL formula resulting from a sentence like *five men are married* is (ignoring tense)

\[
\exists X, \text{cardinality}(X, N^N(N=5), Y \land \text{man}(Y) \land \text{married}(Y)))
\]

where \(X\) is some set of objects, \(N^N(N=5)\), is a property that describes the cardinality of this set, and \(Y \land \text{man}(Y) \land \text{married}(Y)\), is a property that describes the individual elements of the set \(X\).)

2.5.5 Scope Constraints

We have already addressed two scope constraints—vacuous quantification and the free variable constraint— in a previous section. There is nothing in the treatment of quantification in QLF to impose a third scope island constraint, though such a constraint can be imposed as an ad hoc extra if necessary. Following Pereira [Pereira, 1990], we suspect that there are too many violations of scope islands for it to count as a constraint: it is just a strong preference on preferred scopings.
Besides the repeated ‘violation’ of scope islands by definites and indefinites occurring in relative clauses, violations involving obviously quantification noun phrases are not that unheard of:

*The answer that each panelist gave was written down. Three of the panelists agreed with the contestant’s answer, so he was asked to appear again on next week’s quiz.*

Without scope islands, there is less reason to declare definite and indefinite noun phrases to be non-quantificational. Which is as well, given that QLF treats all noun phrases as being quantificational. However, we should still say something about why definites and indefinites are much more likely than other noun phrases to violate scope island preferences than

With definites an explanation is readily forthcoming. In

*Every representative who worked for the software company came to the meeting*

the definite noun phrases can be resolved to (universally?) quantify over all object identical to a particular company. Even if the definite quantifier is given narrow scope with respect to *every representative*, it will still refer to just this one contextually salient company. So one can have what looks like an island violation without assigning the definite wide scope.

This line of argument will not do for indefinites, as in

*Every representative who worked for a software company came to the meeting*

(Indefinites are not usually resolved to refer to specific individuals). An informal explanation lies in saying that the purpose of a relative clause is to give sufficient information to narrow down the range of objects satisfying the nominal restriction, preferably to some unique individual or set of individuals. If universal quantifiers within a relative clause are given wide scope, the number of objects satisfying the nominal restriction tends to increase rather than decrease. But giving an indefinite wide scope, as above, does not tend to multiply the number of representatives.

### 2.5.6 Quantification and Coordination

**Verb Conjunction** The unresolved QLF for *ITEL developed and manufactured a computer* is (simplified)

\[
\text{form}(\text{conj}(v, \text{and}), - ,
   \text{A}^*[A, \text{form}(\text{verb}(\text{past}, \text{no}, \text{no}, \text{no}, \text{y}), B),
   \text{C}^*[C, \text{develop}, B),\ldots]
\]

The repetition of the object term \((a \text{ computer}, \text{index } G)\) in both conjuncts permits two readings. If \(G\) is given wide scope over the conjunct, the same computer is developed and manufactured. Alternatively, if \(G\) is scoped twice, each within its own conjunct, different computers are involved.

The subject term \((\text{index } D)\) only occurs once, and in the second verb conjunct only the index occurs. This forces a wide scope reading for the subject (though since the subject will presumably resolve to refer to a single individual, in this case it does not much matter what scope it gets). It is not obvious that this is correct: arguably there is a reading of \(A \text{ private company runs the railways and the postal system}\) where different companies are involved. To get this possibility, we would need to repeat the entire subject term in both conjuncts.

The traditional view of verb conjunction is that there is a difference between conjoining intensional and non-intensional verbs: intensional verbs permit different entities being referred to by the object, non-intensional verbs do not. As with scope islands, we feel there are too many counter-examples to this for it to count as anything other than a strong preference on scoping.

**NP Conjunction** Coordination of most other constituents is handled analogously to that of VPs. However, noun phrase conjunction is handled slightly differently, since one needs to produces a conjoined term rather than a conjoined form. An NP like \(\text{every man, every woman and every child}\) gets the following QLF:

```plaintext
term(conjdet(and,np),K)
  A^\text{[partof,}A
  term(conjgrp(and,np,K),B
  C^\text{form(conj(and,np),J}
  D^\text{[D,[E]:[partof,C,}
  term(q(...every..),E,
    F^\text{[man,F],}_-,_])],
  [D,[G]:[partof,C,}
  term(q(...every..),G,
    H^\text{[woman,H],}_-,_])],
  [I]:[partof,C,}
  term(q(...every..),I,
    J^\text{[child,J],}_-,_]])],
_,_F),
```
Resolution instantiates the form meta-variable, F, to and (or or if the categories had specified this as the conjunction). The quantifier resolvent Q may be resolved either to forall or set(forall) to give a distributive or collective reading of the conjunction. This construction builds a group denoting term, B such that every child is included within the group, every woman is included within the group and every man is included within the group. This is embedded within the restriction of the main term K, which quantifies/distributes over parts of the group. Additionally, the group term, B, must be given wide scope over the distributive term K.

Nbar Conjunction  Noun phrases that appear to have conjoined Nbars, e.g. every representative and client are treated as being ambiguous between (i) genuine nbar conjunction, i.e. everyone who is both a representative and a client, and (ii) an NP conjunction where the determiner of the second conjunct is elliptical, i.e. every representative and every client. This ambiguity is confined to those cases where the conjunction is ex. With or, only nbar conjunction is permitted.

Apparent counterexamples to the nbar conjunction only treatment of or include NPs like a/our sales manager or head of research, since this seems to be equivalent to a/our sales manager or a/our head of research. However, this equivalence follows from the fact that the NP refers to a single object, and this object must satisfy one or other property.

The elliptical type of nbar conjunction needs to be handled with care. For while every man and woman is equivalent to every man and every woman, ten men and women is not equivalent to ten men and ten women. The QLF therefore builds up a group term whose members comprise men and women, and then quantifies over ten members of the group term.

![QLF representation](image-url)  

Arguably there is one reading of the NP supporting this equivalence, but we are focusing on the reading where there are ten people in total, consisting of both men and women.
3 Plurals

3.1 Discourse Representation Theory

In section 1.1.5.2 in D8 we presented an extended DRS-language to deal with plural NPs. Both from a linguistic (syntactic) and a semantic point of view plural NPs pose a number of special problems not encountered in the core fragment outlined in sections 1.1.1 in D8 and 1.1.2 in D8. To mention but a few, syntactic (morphological) and semantic plurality do not always coincide. Plural NPs can have singular interpretations (dependent plurals) and sets of singular NPs can contribute to a plural denotation (e.g. conjunctions of singular NPs or, in the case of anaphoric reference, NPs spread out over different argument positions of verbs (in possibly different sentences)). From a semantic point of view plural NPs can refer to collections of individuals (collective readings), and may then also involve predication over such collections of individuals or simply correspond to quantification over individuals along the lines outlined in sections 1.1.1 in D8, 1.1.2 in D8 and 1.1.5.1 in D8 (distributive readings) or indeed be ambiguous between the two interpretations.

In order to account for some of these complexities the DRS-language is extended with singular and plural discourse referents noted $at(x)$ and $nonat(x)$ respectively and a summation and an abstraction operation. The summation operation noted $x = y_1 \oplus \cdots \oplus y_n$ constructs plural discourse referents out of singular (and plural) discourse referents while the abstraction operation noted $x = \Sigma y : K$ constructs plural discourse referents whose members satisfy DRSs abstracted over. Models for the extended DRS-language provide singular and plural objects in terms of a structured universe isomorphic to a powerset algebra. In the following we will adopt a somewhat more informal notation where lower case letters $x$ refer to singular, upper case letters $X$ to plural and lower case Greek letters $\eta$ to neutral discourse referents.

3.1.1 Indefinite, Definite and Quantified Plurals

Definite plural NPs tend to have universal force. Under this interpretation the object NP in

$$\text{(69)} \quad \text{The minutes listed the people who attended.}$$

denotes the maximal set of objects (or on a distributive reading a universal quantifier over the elements in the maximal set of objects) satisfying the property denoted by the N-bar constituent. Indefinite plural NPs like the object NP in

$$\text{(70)} \quad \text{The minutes listed some questions raised.}$$

---

25. The language also contains part of and cardinality statements noted $x \in y$ and $|x| = n$ for $n \in \{1, 2, \ldots\}$.

26. This move loses us axiomatizability of the consequence relation.

27. This is context dependent and may admit of exceptions, e.g.: Juliet hates the Montagues.

28. Relative to some context.
denote some set of objects (or on a distributive reading a universal quantifier over the elements in this set of objects) satisfying the property denoted by the N-bar constituent.

As it stands the maximality condition often associated with definite plurals is only accounted for informally \((\text{the } N(X) \text{ as opposed to } N(x))\) in the representations (here we only give the collective interpretations for (69) and (70), respectively):

\[
\begin{array}{|c|}
\hline
x \ Y \\
\hline
\text{the minutes}(x) \\
\text{the people}(Y) \\
\text{attend}(Y) \\
\text{list}(x,Y) \\
\hline
\end{array}
\]

(71)

\[
\begin{array}{|c|}
\hline
x \ Y \\
\hline
\text{the minutes}(x) \\
\text{questions}(Y) \\
\text{raised}(Y) \\
\text{list}(x,Y) \\
\hline
\end{array}
\]

(72) The minutes listed most questions raised.

is represented as

\[
\begin{array}{|c|}
\hline
x \\
\hline
\text{the minutes}(x) \\
\hline
\end{array}
\]

\[
\begin{array}{|c|}
\hline
y \\
\hline
\text{question}(y) \\
\text{raised}(y) \\
\hline
\end{array}
\begin{array}{c}
\diamond \\
\text{most} \\
\hline
y \\
\end{array}
\begin{array}{|c|}
\hline
\text{list}(x,y) \\
\hline
\end{array}
\]

(73)

In the next example we have a dependent bare plural which enforces a distributive interpretation of the definite plural NP.

### 3.1.2 Existential Bare Plurals

Bare plurals are a notoriously difficult phenomenon to treat. In subject position they often carry a generic interpretation which is about \textit{typical} instances in the set of all objects satisfying the plural NP.
Mainframes are expensive.

Currently generic readings are simply represented in terms of a generic quantifier:

\[
\begin{array}{c}
\text{Gen} \\
x \\
\text{expensive}(x)
\end{array} \quad \begin{array}{c}
x \\
\text{mainframe}(x)
\end{array}
\]

For the semantics/logics of this quantifier (i.e., for the verification conditions of duplex conditions like (75)), it is possible to adopt one of the currently available proposals (e.g., [Asher and Morreau, 1991], [Morreau, 1992]).

Some occurrences of bare plurals admit of a somewhat more straightforward treatment, though. Cases in point are dependent bare plurals as in

(76) Most representatives have cars.

which is truth conditionally equivalent to

(77) Most representatives have one or more cars.

Dependent bare plurals are considered in more detail in section 3.1.3 below. The next example is already more involved.

(78) ITEI sold personal computers to APCOM.

In contrast to (76) which features a state denoting verb (78) contains an event denoting verb. The sentence admits an episodic reading where ITEI sold some personal computers to APCOM and a habitual reading where over a certain period of time there existed a “practice” of ITEI selling personal computers to APCOM. In either case the semantic import of the bare plural is existential. This is reflected in the following representations:

---

29Here $e$ is an event type discourse referent, $n$ refers to utterance time and $t$ to some period of time.
In (79) (b), of course, we cheated. First, as it stands the DRS-construction algorithm would only derive (79) (a); second, we helped ourselves to a predicate $HAB(t, \lambda e.K)$ which means that events $e$ of type $K$ happen regularly or habitually within the interval of time specified by $t$. Exactly what the truth conditions for such predicates are is a difficult matter (and not to be settled by standard model theoretic considerations).

3.1.3 Dependent Plurals

Dependent plurals are occurrences of bare or definite plural NPs (often but not always in object position) whose interpretation depends on the presence of a licencing plural NP in the same clause. A characteristic feature of dependent plurals is that the syntactic plurality of the NP is not necessarily matched by semantic plurality. Thus a sentence

(80) All the sales representatives have company cars.

is regarded true in a situation where each of the representatives owns one or more company cars. In the representations this is accounted for in terms of neutral discourse referents denoted by small letters in the Greek alphabet which are undecided between singular and plural reference:
Example (82) is a variation of (80) involving a dependent definite plural NP in object position and a plural anaphor in a reduced relative clause modifying the dependent plural NP. As was the case for dependent bare plural NPs dependent definite plural NPs require a licencing plural NP in the same clause. Furthermore, the discourse referent introduced by the licencing NP needs to be accessible to the neutral discourse referent introduced by the dependent definite NP. In general, however, definite NPs exhibit a strong tendency to take wide scope with respect to other material in the representation. Exceptions to this rule are provided by definite NPs containing elements which are anaphoric on some other element in the representation. In the case at hand

(82) Most customers got the computers they wanted.

we have an anaphoric relation between a plural pronoun and the licencing NP. Indeed, it seems difficult to get dependent readings for definite plural NPs which do not contain an element anaphoric to the licencing NP.

\[ x \text{ customer}(x) \quad \text{most} \quad x \]

\[ y \xi \]

\[ \eta = \Sigma y : \]

\[ \text{computer}(y) \]

\[ \xi = x \]

\[ \text{want}(\xi, y) \]

\[ \text{get}(x, \eta) \]

3.1.4 Collective and Distributive Readings and Scope Ambiguity

The following two sentences are ambiguous between distributive and collective readings:

(84) Smith and Jones signed two contracts.

(85) Smith and Jones left London.

(84) is mapped into the following representations:
(86) (a) gives the reading where both subject and object NP are interpreted collectively, (b) where Smith signed two contracts (interpreted collectively) and Jones signed two (possibly different) contracts (interpreted collectively), (c) where Smith and Jones collectively signed each of two contracts, (d) where Smith signed each of two contracts and Jones signed each of two (possibly different) contracts and (e) where Smith and Jones each (i.e. interpreted distributively) signed a collection of two contracts.30

30 Note that strictly speaking (84) still has further readings (which are also generated by the DRS-construction algorithm). In addition to (86) (b) and (d) there are two further readings where we distribute over contract(Y) but not over contract(U) or vice versa:
Likewise (85) can refer to a situation where Smith and Jones left London together or to a situation where the two protagonists left separately. The DRS-construction algorithm yields:

\[
\begin{array}{c|c}
\begin{array}{c|c|c|c|c}
 x & Y & z & U \\
\hline
 smith(x) & jones(z) & london(u) \\
\hline
 Y = x \oplus z \\
 leave(Y, u) \\
\end{array} & \begin{array}{c|c|c|c|c}
 x & Y & z & U \\
\hline
 smith(x) & jones(z) & london(u) \\
\hline
 leave(x, u) & leave(z, u) \\
\end{array}
\end{array}
\]

Example (88) is of particular interest since it has a reading where the conjoined subject NP is distributed over the first VP but interpreted collectively in the case of the second VP. In other words it has an interpretation where Smith and Jones left separately but met collectively.

(88) Smith and Jones left London and met in Edinburgh.

The reading in question can indeed be obtained in terms of the DRS-construction algorithm if we first process the subject NP and apply summation over the discourse referents introduced by its conjuncts. We then process the VP constituent splitting it into its conjuncts and apply (optional) distribution to the first conjunct. The resulting representation is:

\[
\begin{array}{c|c}
\begin{array}{c|c|c|c|c}
 x & Y & z & U \\
\hline
 smith(x) & jones(z) & london(u) \\
\hline
 Y = x \oplus z \\
 leave(Y, u) \\
\hline
 y & y \in Y \\
\hline
 sign(x, y) \\
\hline
\end{array} & \begin{array}{c|c|c|c|c}
 x & Y & z & U \\
\hline
 smith(x) & jones(z) & london(u) \\
\hline
 Y = x \oplus z \\
 leave(Y, u) \\
\hline
 y & y \in Y \\
\hline
 sign(x, y) \\
\hline
\end{array}
\end{array}
\]

Such readings will be discussed at greater length with respect to example (93) below.

31 Actually, in addition to (87) (b) the construction algorithm also yields the logically equivalent:

\[
\begin{array}{c|c}
\begin{array}{c|c|c|c|c}
 x & Y & z & u \\
\hline
 smith(x) & jones(z) & london(u) \\
\hline
 Y = x \oplus z \\
\hline
 y & y \in Y \\
\hline
 sign(x, y) \\
\hline
\end{array}
\end{array}
\]

32 As far as the second VP is concerned the collective interpretation is the only available one. The first VP is genuinely ambiguous between a collective and a distributive reading. Since the collective - collective reading of (88) can be obtained straight forwardly by the DRS-construction algorithm here we only consider the distributive - collective reading.
The following set of example sentences (90) - (101) illustrate the interaction of collective and distributive readings with scope. In the case of (90) the object NP is either a dependent (bare) plural or an indefinite NP.

(90) ITEL, APCOM, GFI and CRC hired consultants/a consultant.

Dependent plurals are discussed further in sections 3.1.2 and 3.1.3 above. Here we focus on the version with singular indefinite object NP. The indefinite may either take narrow scope or wide scope with respect to a distributive interpretation of the complex subject NP. In the case of the collective interpretation of the subject NP scope issues do not arise.
In (91) (a) we have a collective hiring of some consultant, (b) represents individual hireings of possibly different consultants and (c) individual hireings of (at least) one particular consultant by each of the companies.

Floating quantifiers like *each* force a distributive interpretation. The DRS-construction algorithm accounts for this in that it makes distribution obligatory. Thus

\[(92) \quad \text{ITEL, APCOM, GFI and CRC each hired a consultant.}\]

is mapped into (91) (b) and (c) only.
Finally we briefly consider examples involving cardinal NPs in both subject and object position. A sentence like

\[(93)\] Five departments own 15 mainframes.

has a quite bewildering number of possible readings. The differences between those readings become more prominent if we shift from a state denoting to an event denoting verb like `supply':

\[(94)\] Five departments supplied 15 mainframes.

The interpretation involving collective readings of both the subject and the object NP is given by

\[
\begin{array}{|c|c|}
\hline
X & Y \\
\hline
\text{department}(X) & |X| = 5 \\
\text{mainframe}(Y) & |Y| = 15 \\
\text{supply}(X,Y) & \\
\hline
\end{array}
\]

Distribution over the subject NP results into two further options for an interpretation of the object NP in the scope of the subject NP. Either we interpret the object collectively or distribute over it:
The representation in (96) (a) corresponds to the reading where each of the five departments ordered a set of 15 mainframes such that in each case the 15 mainframes were ordered in a single ordering event. (96) (b) corresponds to the reading where for each of the five departments there are 15 mainframes such that each of the mainframes was ordered separately. Both readings involve 5 departments and between 15 to 75 mainframes.

Two further readings can be obtained by having both subject and object NP occupy positions in the top level DRS and distributing over the object NP and either have a collective or a distributive interpretation of the subject NP in the scope of the distributed object NP:
The readings represented in (97) involve 5 departments and 15 mainframes. (97) (a) correspond to the reading where each of the mainframes in some specified set of 15 mainframes was ordered collectively by all departments while (97) (b) represents the reading where each of the 15 mainframes in the set was ordered by each of the departments separately.

In each of the representations in (96) the object NP is interpreted inside the scope of the distributed subject NP. Conceivably there could be a further reading where the subject NP is interpreted entirely inside the scope of the distributed object NP:
The readings corresponding to (98) would involve 15 mainframes and anything between 5 and 75 departments. Although in principle these readings could be obtained in terms of the extended non-deterministic DRS-construction algorithm outlined in section 2.1.3 above (94) does not seem to admit of such readings.

In addition to the readings given in (95) to (97) it is sometimes argued that a sentence like (94) has a further cumulative reading which essentially requires that (i) for each element in the denotation of the subject NP there is at least one element in the denotation of the object NP such that these elements stand in the relation specified by the verb and (ii) for each element in the denotation of the object NP there is at least one element in the denotation of the subject NP such that these elements stand in the relation specified by the verb. The truth conditions associated with this reading would be captured by the following DRS:

\[ Y \]
\[ mainframe(Y) \]
\[ |Y| = 15 \]

\[ X \]
\[ department(X) \]
\[ |X| = 5 \]
\[ supply(X, y) \]

\[ y \]
\[ y \in Y \]

\[ \forall y \]

\[ X \]
\[ department(X) \]
\[ |X| = 5 \]
\[ supply(x, y) \]

\[ x \]
\[ x \in X \]

\[ \forall x \]

\[ Y \]
\[ mainframe(Y) \]
\[ |Y| = 15 \]

\[ X \]
\[ department(X) \]
\[ |X| = 5 \]
\[ supply(x, y) \]

\[ x \]
\[ x \in X \]

\[ \forall x \]

\[ c.f. [Scha. 1981]. \]
As it stands the DRS-construction algorithm does not produce the structure in (94). However it could straightforwardly be extended to map conditions of the form $\text{verb}(X, Y)$ into the quantificational structures required by a cumulative reading of (95). It is worth mentioning that (95), (96), (97) and (99) do not yet exhaustively cover the set of possible readings of (95). In (99) we effectively distribute over the subject and the object NP denotations in the quantificational structures designed to capture the cumulative reading. On this analysis the cumulative reading requires that individuals satisfy the “cumulative” condition expressed by the two quantificational structures. Intuitively, however, (95) would be true in a situation where subsets of departments in addition to individual departments in the set of departments own subsets of mainframes or individual mainframes in the set of mainframes such that the subsets together with the individuals exhaust the original sets in each of the quantificational structures in the cumulative reading.

The discussion with respect to (95) equally applies to sentences:

(100) 4 men installed 3 computers.

(101) 4 men installed 4 computers.

Here we simply point out that (101) has a bijective reading as a special case.

### 3.1.5 Reciprocals

Superficially reciprocals like each other appear similar to floating quantifiers (e.g. each as discussed with respect to (92) above) in that (i) they require the presence of a licencing plural NP and (ii) they force some kind of distribution over the licencing NP. In the case of a
reciprocal this “distribution” involves pairs of non-identical elements from the denotation of the licencing NP. In simple cases where the licencing NP has a two-element or a three-element set denotation as e.g. in

\( (102) \quad \text{Two representatives spoke to each other.} \)

the truth conditions are readily given by those associated with\(^{34}\)

\[
\begin{array}{c|c|c}
X & \text{representative}(X) & |X| = 2 \\
\hline
x & \forall \ x \in X & \forall \ y \in X \\
\hline
x \neq y & \text{\textit{speak to}}(x, y)
\end{array}
\]

\( (103) \)

The picture is considerably more complicated if we look at licencing NP denotation sets which contain more than 3 elements. It seems difficult to assign necessary and sufficient truth conditions to a sentence like

\( (104) \quad \text{The representatives spoke to each other.} \)

if the set of representatives contains, say, some 20 members or so. For (104) to come out true do really all possible representative pairs \((x, y)\) such that \(x \neq y\) in the set need to stand in the \textit{speak to} relation?\(^{35}\) These problems if anything are even more involved in the case of some genuinely quantificational licencing NPs such as

\( (105) \quad \text{Most of the representatives spoke to each other.} \)

\(^{34}\)In fact this already is a simplification. The truth conditions associated with (103) obtain in the case of \textit{symmetric} verb clusters like \textit{talk to} etc. Here the semantic import of the reciprocal effectively amounts to the conjunction \(v_{\text{sym}}(a, b) \land v_{\text{sym}}(b, a)\) where \([a, b]\) is the interpretation of the licencing NP. In the case of an \textit{asymmetric} verb cluster like \textit{put on top of} as in

\[\text{Put those two chairs on top of each other.}\]

the reciprocal amounts to the disjunction \(v_{\text{asym}}(a, b) \lor v_{\text{asym}}(b, a)\).

\(^{35}\)The problem is resolved if a floating quantifier like \textit{all} is applied to the licencing NP:

\[\text{The representatives all spoke to each other.}\]
Here it is not clear whether we are quantifying over non-identical pairs satisfying the symmetric *speak*–*to* relation with respect to the set of all possible non-identical pairs or over the size of the set of representatives which satisfy the *speak*–*to* relation with respect to the size of the set of all representatives etc.

### 3.2 Update and Dynamic Semantics

A dynamic perspective on plurality distinguishes between singular and plural type variables, and treats them both dynamically, along the lines of the next section. See Van der Does [1992] for a static formal theory of plurality that provides a suitable starting point for this. The result of this dynamic shift for plurals would come quite close to the DRT treatment of plurality. (Again, Dynamic Semantics has a perspective to offer here rather than off the shelf solutions.)

### 3.3 Situation Semantics

The Situation Semantics grammar does not deal with plurals. A simple way to provide a minimal coverage for plurals would be to adopt Link’s assumptions about the structure of the domain of individuals, and possibly a ‘pluralizing’ operator so that a predicate like *representative* would have groups of representatives in its denotation. For example, *Smith signed two contracts* could be analyzed as in (106). This would still leave open the major issues in the semantics of plurals, such as representing the collective/distributive ambiguity, the semantics of bare plurals, etc.

\[
\begin{array}{c}
\text{ds} \rightarrow D \{\text{sit-time}, n\} \rightarrow X, \quad \text{descri-sit}, n \rightarrow S, \quad \text{rt}, n \rightarrow T \\
\text{do}, n \rightarrow Y, \quad \text{exploits}, n \rightarrow R \\
\text{contract}^*(X) \\
\#(X) = 2 \\
\text{sign}(Y, X, T) \\
\text{named}(Y, \text{"Smith"}) \\
\text{T} \rightarrow \text{N}
\end{array}
\]

(106)

### 3.4 Property Theory

To treat plurals and mass terms in PT, a Boolean algebra-like structure can be added to those terms which can be referred to by natural language [Fox, 1993; Fox, 1992]. As a consequence of sets being defined in terms of properties, such structures axiomatised in PT are naturally *definably complete* [Lonning, 1989], and hence first-order. To elaborate on this, it seems desirable to use *complete lattices* to model plurals so that there are terms which represent any
collection of individuals; a lattice is *complete* (in a lattice-theoretic) sense if the supremum of each set in the relevant domain exists. To express this as an axiom requires universal quantification over arbitrary sets. Such an axiom is not complete (in a model-theoretic sense) with respect to any general model, and is thus truly second order. L"unken suggests that in practice we may only need to form the supremum of sets which can be denoted by natural language expressions; this is what he means by definable completeness. Such a weakened axiom is complete with respect to a general model, and in effect only has the power of a first-order statement. In PT, we can refer to, and quantify over, only those sets which are defined in terms of properties. This means that an axiom that apparently expressing lattice-theoretic completeness within PT is really expressing a form of *definable* completeness. It is possible to give a general model for such an axiom given in PT, so it is in effect a first-order axiom.

3.4.1 Definites

As with Link's treatment, definite descriptors are taken to refer to the supremum of a property in a lattice [Link, 1983]. The sentence:

*The minutes listed the people who attended.*

would have something like the following truth conditions:

\[(\text{listed'}\sigma x \text{people-who-attended'}x)\sigma x \text{minutes'}x\]

where \(\sigma x px\) is the supremum of the terms \(t\) such that \(T(pt)\). The property \(p\) may be singular (in which case it will not distribute to the proper parts of any terms which it holds of).\(^{36}\)

In PT, not all expressions of the appropriate form represent propositions. This is an essential aspect of its treatment of paradoxical terms. It may be possible to use this notion to model felicity in discourse. This is mentioned in connection with the treatment of anaphora, given in section 4.4.2, with the example:

*Every man walked in. He whistled.*

The second sentence cannot be properly typed. This could be generalised to other cases felicitous discourse, and presupposition. As an example of the latter, we can set up the axioms in such a way that sentences whose presuppositions are not met cannot be proven to be propositions. This can be illustrated with definite descriptors.\(^{37}\) We can define a class of natural language denotable properties \(\text{Pty}_\Delta\), and natural language denotable individuals \(\Delta\). Given \(p\) in \(\text{Pty}_\Delta\) and \(s\) in \(\Delta\), then we can prove that \(ps\) is a proposition using the following axiom:

\[\text{(Pty}_\Delta(p) \& \Delta s) \rightarrow P(ps)\]

\(^{36}\)In the current example, the representation is neutral as to whether "minutes" is a plural count noun, a singular count noun, or a mass term.

\(^{37}\)This section is largely based on work in [Fox, 1993].
We may require that a definite descriptor $\sigma x q x$ (the $x$ such that $T(q x)$) is only provably in $\Delta$ if $q$ has an extension in $\Delta$:

$$\exists y (\Delta y & T(q y)) \to \Delta (\sigma x q x)$$

Thus, when it comes to evaluating sentences such as “the present queen of France is bald”, we cannot prove that the representation of the sentence is a proposition. This is because we cannot prove that “the present queen of France” is a natural language denotable, as there is no “present queen of France”. The failure to prove the proposition-hood of a sentence means that we cannot apply the axioms of $T$ to determine the truth conditions of the sentence; the sentence is not the sort of object whose truth conditions should be considered.

This can be generalised to plurals and mass terms, by replacing this axiom with:

$$(\forall x (T(q x) \to \Delta x) \& \exists y (\Delta y & T(q y))) \to \Delta (\sigma x q x)$$

which says that a definite descriptor is denotable if the associated property is a property of denotables, and there is a denotable in its extension. The form of this axiom is justified in [Fox, 1993].

### 3.4.2 Quantified Plurals

The plural quantifier “some” in the following example:

*The minutes listed some questions raised.*

can lead to the following truth conditions, where questions-raised′ is abbreviated to q-r′:

$$\exists x (T(q-r′x) & T(listed′x(\sigma z \text{minutes}′x)))$$

Any special effects due to plural nature of the quantifier are embodied in the property. As an example, the pure collective reading of:

*Some men met.*

is obtained in the truth conditions:

$$\exists x (T\text{men}'x) & T\text{met}'x)$$

with a non-distributive reading of “met”, and when there is only one $x$ which satisfies the proposition. We may wish to avoid the apparent “over-generation” of the representation, where intermediate distribution can appear in either the translation of the verb, or via the satisfaction of the quantifier, but formally this does not appear to gain anything.

With some determiners, such as ‘all’, and ‘the’ there is the possibility that they should be represented by genuine second-order quantification over arbitrary subsets. Boolos, for example, argues that there are natural language examples which require such quantification [Boolos, 1984a; Boolos, 1984b]. As an example, the intended reading of the sentence:
If there are \{some numbers\}; all of which are natural numbers, then there is one of \{them\}; that is smaller than all the \{others\}.

expresses the well-ordering principle of natural numbers, which is not equivalent to any first-order formula [Boolos, 1984b].

Such examples of natural language statements of mathematical expressions appear to lead to a truly incomplete logic with a set-theoretic approach. In PT, there can be no such quantification over arbitrary subsets, as in effect only those sets which can be defined in terms of properties exist in the theory. If natural language semantics were to require second-order quantification in full generality, then the version of property theory presented here would be inadequate. Lønning speculates whether Boolos’ examples really should be considered to have the intended second-order representation, or whether there are additional effects at work [Lønning, 1989].

3.4.3 Bare Plurals

With bare plurals, the weak typing in PT allows the associated property to be treated just like any other first-order object in predications and relations:

\( \text{Itel sold personal computers to Apcom.} \)

can be represented as:

\( (\text{sold-to-Apcom}'(\text{personal-computers'}))\text{Itel'} \)

The actual existence of the personal computers (which were sold) would have to be derived via additional axioms.

3.4.4 Dependent Plurals

No special treatment of dependent plurals, as they occur in examples like:

\( \text{All the sales representatives have company cars.} \)
\( \text{Most customers got the computers they wanted} \)

is offered. It can be argued that “company cars” and “computers” are plural only because they depend upon a plural. Such examples might be taken to be a specific case of a distributive reading.
3.4.5 Collective and Distributive Readings

It is possible to adopt Link’s treatment of the collective-distributive distinction [Link, 1991], or perhaps Schwarzschild’s treatment [Schwarzschild, 1990; Schwarzschild, 1992]. In either case, the ambiguity should lie in the verb phrase, so:

Smith and Jones left London and met in Edinburgh.

has the truth conditions:

\[ T(D_{\text{left-london}}(s' \oplus j')) \land T(D_{\text{met-in-edinburgh}}(s' \oplus j')) \]

where:

\[ T(D_{p}(a \oplus b)) \equiv T(pa) \land T(pb) \]

With sentences such as:

Five departments own 15 mainframes.

there is some argument that the collective-collective reading is the most natural [Roberts, 1987]. The bijective reading of the example:

Four men installed four computers.

is then not part of the semantics, it is just a model which satisfies it.

3.4.6 Reciprocals

PT does not immediately give a special treatment of reciprocals, displayed in examples like:

The representatives spoke to each other.
Most of the representatives spoke to each other.

although Schwarzschild’s suggestions could be explored [Schwarzschild, 1990; Schwarzschild, 1992].
3.5 Monotonic Semantics

3.5.1 Definite, Indefinite, Quantified and Bare Plurals

The differing quantificational forces attaching to definite, indefinite, quantified and especially bare plurals can be handled with QLF by mapping determiners onto a range of possible quantifiers.

For example, bare plurals sometimes have an existential force, and sometimes a more universal force, e.g. *We ate chips for lunch, Dogs are warm-blooded.* Whether a bare plural is existential or more universal often depends on whether it occurs in subject or object position respectively (though there are numerous exceptions to this). Within the CLE, this variable interpretation for bare plurals is achieved by mapping bare plural determiners onto different quantifiers:

\[
\text{term}(q(ntpc, bear, plur), H, I^-[chip, I], \\
\quad \text{exists}, qnt(H))
\]

\[
\text{term}(q(tpc, bare, plur), H, I^-[dog, I], \\
\quad \text{forall}, qnt(H))
\]

where the tpc feature in the category favours a universal quantifier over an existential.

This treatment is at best a crass simplification. Assigning a universal quantifier to bare plurals is a weak attempt at representing a generic reading. As is well known, generics can correspond to a variety of quantifiers:

* Dogs are warm-blooded: all dogs*  
* Birds fly: most birds*  
* Humans can high jump over 2 metres: very few humans*  

One could attempt to deal with this by mapping bare plurals onto a greater range of (contextually determined) quantifiers. But this is to assume that genericity is simply a matter of the kind of quantifier associated with certain noun phrases. It is more plausible to suppose that genericity arises out of subtle interactions between the quantificational force of noun phrases, and some sort of implicit quantification over cases, perhaps introduced by some kind of habitual tense. If this is so, it may be that the bare plural can always be understood existentially:

In all cases involving (some) dogs, those dogs are warm-blooded  
In most cases involving (some) birds, those birds can fly  
In a few cases involving (some) humans, those humans can jump over 2m

The CLE makes no attempt at dealing with this kind of phenomenon. Nor is any attempt made to deal properly with generic interpretations of plural definites (e.g. in *The English drink warm beer*).
Non generic plural definites are normally treated as universal quantifiers over some contextually restricted domain. The same also holds of singular definites, except that the domain is limited to include just one entity. However, if no contextually salient restriction is available (e.g. in a book beginning with the sentence *The policemen kicked down the door*), then it is treated as a plural existential.

### 3.5.2 Dependent Plurals

In some cases where plural noun phrases are anaphorically dependent on a plural antecedent, the noun phrase can have a non-plural interpretation. So in *The husbands telephoned their wives*, the pronoun *their* can be interpreted as referring back to each individual husband, and (in a monogamous society) the plural *wives* would be understood as referring to single wives. Partially resolved, we have

\[
\text{[phone,}
\text{term(ref(def, the, plur), C, D', [husband, D], forall, _]),}
\text{term(q(\_, poss, some, _), W,}
\text{E' [and, [wife, E],}
\text{form(poss, P,}
\text{F' [and, [wife, E],}
\text{[F, E,}
\text{term(ref(pro, they, plur), T}
\text{G' [entity, G], exists, strict(C)]],}
\text{[\_, ]},
\text{exists, qnt(W)]}
\]

### 3.5.3 Collective and Distributive Readings and Scope Ambiguity

Recall that collective (or set) quantifiers are represented as \( \text{set}(\lambda n \lambda m. Q(n, m)) \). Here \( n \) correspond to the cardinality of the union of all the items satisfying the restriction, and \( m \) to the cardinality of some subset of this union satisfying the body. That is, a set quantifier acts like an existential quantifier over sets of a certain size. Because of this, certain scope ambiguities that arise with distributive quantifiers do not arise with set quantifiers. So on collective readings of sentences like *Five departments own fifteen computers* there is only one scoping, involving existential quantification over a set of five departments and a set of fifteen computers.

 Conjunctive noun phrases are analysed by building up a set containing the elements of the conjuncts. In distributive conjunctions, individual elements (strictly, singleton subsets) of the set are universally quantified over. In collective conjunctions, a universal set quantifier quantifies over the elements, which has the effect of building up the original set again. Thus in *Smith and Jones signed two contracts*, the conjunction can be resolved either collectively or distributively.

The treatment of the collective/distributive ambiguity in the CLE is only partly satisfactory.
One of the reasons for this is simply the difficulty of setting up a back-end inference system to adequately test proposed analyses. However, these are flaws in the CLE, and not necessarily in QLF or monotonic interpretation; there is reason to suppose that the problems could be solved in a QLF-style formalism.

Mixed distributive / collective quantification emerges in sentences like Smith and Jones left London and met in Edinburgh, where the subject is distributive in the first conjunct and collective in the second. This suggests that we need access both to the group term set up by the conjunction and the distribution over it, and that the predicate to which the term applies must be resolved to indicate which of the two is used. Similar arguments would apply to any plural term that can have both a collective and distributive reading. So perhaps all plural terms should be resolved as set quantifiers, with an additional quantifier over its elements for distributive readings.

Related to this is the fact that collective / distributive distinctions are lost in the restrictions of terms. If five men installed a computer has a collective distributive ambiguity, the same should hold in the five men who installed a computer got a bonus. But the current treatment of set quantifiers makes the collective distributive distinction one of vagueness rather than ambiguity in relative clauses like this: The set quantifier takes the union of all the men who satisfy the restriction through being involved in installing a computer, and does not distinguish between those who do it collectively and those who do it distributively. One moral to draw from this is that collectivity and distributivity needs to be marked both on terms and on predicates.

3.5.4 Reciprocals

No significant attempt to deal with reciprocals is made in the CLE.

4 Anaphora

4.1 Discourse Representation Theory

On a broad interpretation the term anaphor refers to linguistic objects which do not have independent reference but refer by virtue of being linked to some other object in the linguistic or non-linguistic environment. Cases in point are pronouns, possessive pronouns, demonstratives, reflexives, reciprocals and anaphoric uses of definite NPs.

The constraints on anaphora are in part syntactic-configurational (c.f. Principles B and C of the Binding Theory), partly morphological (person, number and gender agreement), partly logical (c.f. Accessibility Relation of DRT) and partly a matter of discourse pragmatics (c.f. the work of [Grosz et al., 1983] and of [Asher, 1993] and others).
4.1.1 **Bound - Referential**

Anaphors can realise a variety of referential functions:

- pronouns can be and demonstratives are used *deictically* - i.e. they refer to an individual in the speaker's environment which s/he points at or demonstrates otherwise. In DRT deictic reference is handled in terms of the *external anchor device* discussed with respect to example (57) above.

- pronouns, possessive pronouns, reflexives and reciprocals can function in the manner of variables *bound* by the quantifier in the NP they are anaphoric to.

- pronouns, possessive pronouns, reflexives, reciprocals and definite NPs can *refer* back to non-quantificational NPs like e.g. proper names (and indefinites).

The pronoun *her* in

(107) Smith used her workstation.

is referential. In the corresponding DRS this is represented in terms of an identity statement relating the discourse referent associated with Smith and the discourse referent introduced by the pronoun:

\[
\begin{array}{c|c|c|c}
 x & y & z \\
\hline
 \text{smith}(x) & \text{workstation}(y) & s(z, y) \\
 z = x \\
\end{array}
\]  

(108)

By contrast, in the next example the occurrence of the discourse referent introduced by the pronoun is bound by the quantifier in the antecedent NP:

(109) Every executive used his workstation.

The corresponding representation is

---

28 An *external anchor* represented \[(x, a)\] is a function which maps some discourse referent \(x\) to some individual \(a\) in the domain of interpretation. It constrains the (partial) variable assignments used in the definition of verification of DRSs.
In example

\((111)\) His advisor misled John.

the possessive pronoun can be interpreted as being coreferential with John\(^{39}\) while the pronoun in

\((112)\) His advisor misled every executive.

cannot be interpreted as being anaphoric to the quantified object NP. It is sometimes argued that the weak-crossover distinction between (111) and (112) supports the analysis that her in (107) is referential, but at least some people dispute the weak-crossover data.

4.1.2 Intersentential

Anaphoric reference can transcend sentence boundaries. This is always possible with referential anaphora, or when the antecedent is an indefinite or definite NP as illustrated in

\((113)\) Smith attended a meeting. She chaired it.

The corresponding DRS is

\[(114)\]

\[
\begin{array}{c}
x, y, z, u \\
\text{smith}(x) \\
\text{meeting}(y) \\
\text{attend}(x, y) \\
z = x \\
\text{chair}(z, u) \\
u = y
\end{array}
\]

Matters are more complex when the antecedent is a (or is embedded in a) universal NP, — in general, when it occurs in a downward monotonic context. Here, anaphoric reference is not

\(^{39}\)As it stands the DRS construction algorithm cannot construct a representation representing this reading.
always possible, c.f. (115), though in some cases, often referred to as modal subordination type cases (116), anaphoric reference is fine.

(115) Every executive; attended a meeting. ??She; gave a good presentation.

(116) Every meeting had a chairperson. She; was selected from one of the participating companies.

In the DRS-construction algorithm the reading indicated in (115) is excluded in terms of the unavailability of a suitable discourse referent \( z =? \) for the purposes of resolving the pronoun in subject in the second sentence:

\[
\begin{array}{c}
\text{executive}(x) \\
\forall x \quad \forall y \\
\text{meeting}(y) \\
\text{attend}(x, y) \\
\text{good presentation}(u) \\
\text{give}(z, u)
\end{array}
\]

Currently there is no fully formally worked out account for treating the modal subordination cases illustrated in (116), c.f. [Roberts, 1987]. Part of the problem is to formulate precise criteria for when exactly the DRS representing the second sentence in a mini-discourse like (116) can be accommodated into the nuclear scope DRS of the quantificational structure induced by the first sentence to give an intuitively correct representation as in:

\[
\begin{array}{c}
\text{chairperson}(y) \\
\text{have}(x, y) \\
\text{select}(V, z) \\
\text{company}(W) \\
\text{participate}(W, x) \\
V \in W \\
|V| = 1
\end{array}
\]

\[40\] The picture is different in the case of a specific reading of the indefinite NP.
\[41\] Here we only give a narrow scope and collective reading of the partitive NP one of the participating companies.
4.1.3 Plural Anaphora

Plural pronouns pose certain special problems. Sometimes they are undecided between a set and an individual denotation:

(119) Few companies sold more than five computers to customers who didn’t like them.

Antecedents for plural pronouns cannot in general be identified with a single NP but often need to be constructed (i) from a variety of NPs each of which contributes to a plural antecedent or (ii) from quantificational structures defined by some material in the (preceding) sentences. The next example provides an illustration for (ii). It involves a plural pronoun referring back to a plural quantified NP in the preceding sentence:

(120) ITEL has sent most of the reports Smith needs. They are on her desk.

The determiner *most* in first sentence gives rise to a quantificational structure (a duplex condition) in the DRS. We then abstract over the merge of the restrictor part and the nuclear scope part of the quantificational structure to construct a representation of the set of reports which Smith needs and ITEL has sent. This set is then available for anaphoric reference by the plural pronoun in the second sentence in (120):

\[
\begin{array}{c}
\begin{array}{c}
Z \\
report(z) \\
need(y, z) \\
\text{end}(x, z)
\end{array}
\end{array}
\]

\[
U = Z \\
v = y \\
desk(w) \\
on(U, w) \\
'\mathbf{is}(v, w)
\]

The following two examples illustrate the fact that there are curious restrictions on which implicit plural antecedents can be referred to by pronouns:
(122) Two of the ten machines are not in the office. They are in the lobby.

(123) Eight of the ten machines are in the office. *They are in the lobby.

The "minimal pair" (122) - (123) (the example is originally due to B. Partee) was one of the starting points for the DRT account of plural anaphora. The importance of the example becomes clearer, when one compares the impossibility of interpreting the they of (123) to refer to the two remaining machines with such cases as (120) and

(124) Smith read the reports and asked his colleagues to do so too. They were very worried.

In (120) they can refer to the set of those books ITEI has sent (and which constitute most of those Smith needs). In (124) they can refer to the set consisting of Smith and his colleagues. Neither of these two sets is denoted by a single NP in the text; they must therefore be obtained through certain "inferential" operations (those of Summation and Abstraction) from individuals and sets that are represented directly. The ability that plural pronouns have to refer to such interentially obtained sets might easily be thought of as an indication that a set is a possible antecedent for a plural pronoun provided its existence can be deduced from the context. (123) shows that in general this is not so. More specifically, there are certain logical operations - that of forming the set-theoretical difference of two given sets is one of them - which are not permitted as means of constructing plural pronoun antecedents.

This combination of facts - on the one hand the possibility of the described interpretations in (120) and (124) and on the other the impossibility of the intuitively plausible interpretation in (123) - has led to the view that plural pronoun anaphora involves a very limited "inference mechanism", which includes Summation and Abstraction but excludes set subtraction. The constitutive principles of this mechanism should be seen as belonging to a part of the language system that might be best described as "discourse semantics" - a level of semantic processing that is essentially transsentential but nevertheless controlled by specific, formally articulable constraints.

As things stand the DRS-construction algorithm would simply map (123) into a representation where the plural pronoun in the second sentence would be anaphoric to the subject NP in the first.

The following two examples illustrate the fact that plural antecedents can be constructed from a variety of (singular or plural) NPs (possibly spread out over different sentences). This is achieved in terms of a summation operation \( \oplus \). Sometimes, as is the case in (125), some of the NPs in question have to be "constructed" themselves in the first place (here in terms of an ellipsis resolution):

(125) Smith took one machine out of the office. So did Jones. They are in the lobby.

The mini-discourse in (125) is mapped into the following (simplified) representation:
Plural antecedent construction in terms of summation is non-deterministic. This is employed to model the ambiguity in

(127) John and his colleagues went to a conference. They disliked it (but he enjoyed it).

where They can either refer to John and his colleagues, or just the colleagues, but not just John. The corresponding DRSs are\textsuperscript{42}

The following two two-sentence discourses illustrate a phenomenon that has sometimes been analysed as a form of E-type anaphora.\textsuperscript{43}

(129) Each department has a dedicated line.
\[
\begin{align*}
\begin{cases}
\text{They are rented from BT.} \\
\text{They rent them from BT.}
\end{cases}
\end{align*}
\]

In the case of the first discourse Each department has a dedicated line. They are rented from BT. the plural pronoun in the second sentence refers to the set of all dedicated lines of the

\textsuperscript{42}Here we only give the collective reading for the subject NP.

\textsuperscript{43}See also the discussion with respect to examples (132) and (133) below.
The second two sentence discourse in (129) is *Each department has a dedicated line. They rent them from BT.*. Here *They* refers to the set of all departments in question and *them* has a reading where it acts as a form of dependent plural pronoun, i.e. where each department individually rents its particular line from BT. For this reading the DRS-construction algorithm yields the following representation:

\[ X = \sum_y : \begin{array}{l}
department(z) \\
line(y) \\
dedicated(y) \\
has(z, y)
\end{array} \]

\[ Y = X \]

\[ \text{rented} \quad from(Y, x) \quad \text{bt}(x) \]

\[ (130) \]

\[
x X Y
\]

\[
\forall z \quad \text{department}(z) \\
y \quad \text{line}(y) \\
\exists z \quad \text{dedicated}(y) \\
\exists y \quad \text{has}(z, y)
\]

\[ z \]

\[ X = \Sigma_y : \begin{array}{l}
\text{department}(z) \\
\text{line}(y) \\
\text{dedicated}(y) \\
\text{has}(z, y)
\end{array} \]

\[ Y = X \]

\[ \text{rented} \quad from(Y, x) \quad \text{bt}(x) \]

\[ (130) \]

44Here we only give the collective reading. The construction algorithm would also yield the distributive reading where each of the dedicated lines in question is rented from BT individually. Note that we simply disregard the subtle distinctions between *each* and *every*. Note also that the representation does not really *insist* that every department has a *different* dedicated line.
The notation \(y^{pl(v)}\) marks \(y\) as a discourse referent dependent on the constituent parts \(v\) of the plural discourse referent \(V\) which can be picked up by the dependent plural pronoun \(them\) in the nuclear scope box of the distributive condition in (131).

A further use of pronouns that has been argued to be a case of E-type pronouns is that of the so-called “pay check pronouns”, exemplified by the \(it's\) of (132):

(132) Each department has a dedicated line.
  The sales department rents it from Mercury.
  The research department rents it from BT.

In the case at hand the context suggests that there exists a map \(f\) from things of one kind \(D\) to things of another kind \(R\). In (132) the first sentence implies the existence of a map from departments to their dedicated lines. When \(f\) is salient enough, it may be available for pronominal interpretation in the sense that a subsequent pronoun is interpretable as referring to \(f(d)\) where \(d\) is some mentioned member of the domain \(D\). Thus the \(it's\) of the 2nd and the 3rd sentence of (132) can be understood as referring to \(f(d_1)\) and \(f(d_2)\), respectively, where \(d_1\) is the sales department and \(d_2\) is the research department. Currently there is no fully worked out approach to capture the reading discussed here.\(^{45}\)

\(^{45}\)The DRS construction algorithm would yield the highly improbable reading where the indefinite a dedicated line gets a specific reading (i.e. wide scope with respect to the quantified subject NP) and thus introduces an individual discourse referent which can be picked up by the pronominal \(it\) in the subsequent sentence(s).
4.1.4 E-Type

A topic of much discussion since the mid-seventies have been the so-called “E-type pronouns”. The most uncontroversial examples of such “pronouns” are plural pronouns of the sort exemplified in:

(133) GFI owns several computers. ITEL maintains them.

As [Evans, 1977] was the first to notice, a two sentence discourse such as (133) is not equivalent to the single sentence which says that GFI owns several computers which ITEL maintains, for this paraphrase is compatible with GFI owning other computers that are not maintained by ITEL, whereas (133) seems to assert that ITEL services all the computers that GFI owns. [Evans, 1977] and [Cooper, 1979] suggested that such pronouns were analyzed as if they were definite descriptions, e.g. by substituting for the pronoun a description that is obtained from the antecedent part of the sentence or discourse and then interpreting the resulting sentence.

In fact, E-type pronoun came to mean “pronoun that has to be analysed via replacement by a suitable description”. Whether the various cases that have been considered E-type in this sense, should be analyzed along these lines is still a subject of lively debate. In DRT as yet there is no fully worked out approach to deal with the phenomena illustrated by (133). If we analyse several computers as an indefinite NP we will fail to capture the maximality condition commonly associated with E-type anaphora:

If, however, we choose to analyse several computers as a genuinely quantificational NP the maximality condition can be reconstructed in terms of the plural antecedent forming set abstraction principle:
4.1.5 Donkey

The following two sentences are instances of so-called “donkey sentences”. In both (136) and (137) the indefinite NP a computer behaves more like a universal quantifier than an existential and is accessible for anaphoric reference from the nuclear scope part of the quantificational structure in (136) and the consequent of the conditional in (137):

(136) Every customer who owns a computer has a service contract for it.

(137) If a customer owns a computer he has a service contract for it.

The DRT analyses of these sentences are

and

106
The proportion problem has been discussed in section 1.1.5.1 in D8 Generalized Quantifiers. To briefly recapitulate: under a non-selective binding theory like DRT (this amounts to adopting clause (41 in D8) as the verification condition for duplex conditions) the sentence

\[(140) \quad \text{Most customers who own a computer have a service contract for it.}\]

is interpreted as quantifying over all \(\langle \text{customer}, \text{computer} \rangle\) pairs such that the first element in a pair is a customer while the second element is a computer s/he owns in such a way that (140) is true if and only if most of these pairs are pairs such that the customer has service contract for the computer. Note that this does not require that some particular customer has a service contract for all or even most of the computers s/he owns nor that most of the computer owning customers have a service contract. On this account (140) would come out true in a situation where there are, say, three customers, the first of which owns five computers each of which is covered by a service contract while the other two customers own only one computer each for which there are no service contracts. Under a selective notion of binding (i.e. adopting clause (40 in D8) as the verification condition for duplex conditions) (140) would come out false in the situation described above. The selective notion of binding, however, runs into trouble in the case of a donkey sentence like (136) which would come out true in a situation where the customer who owns five machines only a has a service contract for one of them while the other two customers who own a single machine each have them covered by service contracts. This is kind of like the proportion problem “in reverse”. It seems that in the case of donkey sentences which involve universal quantification and a discourse referent introduced by an indefinite in the restrictor part of the universal which is picked up by a pronoun in the nuclear scope part of the quantifier a non-selective notion of binding gives the intuitively right truth conditions. In the case of most a selective notion of binding seems to get us closer to what we want. However, it has been argued that the presence of the indefinite NP in the restrictor and the singular pronoun it in the scope of the quantifier in (140) militates against using the sentence in a context where one or more of the customers own more than one computer. The same point could be made with respect to

\[(141) \quad \text{Every representative who had an advisor brought him to the meeting.}\]

On the un-selective binding approach for (141) to come out true every representative would have to take all of his/her advisors to the meeting.
4.1.6 Subsectional / Functional (Discussion Only)

Often definite NPs function anaphorically in the sense that they refer to denotations introduced by other NPs in the linguistic environment. The link between anaphor and antecedent can be one of simple identity of denotation (as in the case of pronominals) or consist of a functional relationship where the definite NP refers to an element that is systematically related to the antecedent (e.g. in terms of a part-whole relationship).

(142) Lots of shareholders were at the meeting. The small investors objected to the chairman.

In this example the small investors are naturally interpreted as a subset of the shareholders while the chairman is a functional part of the mentioned meeting. Currently there is no formally worked out approach to definite NPs in DRT which covers subsectional and functional anaphoric properties of such NPs to the degree illustrated by (142).

4.1.7 Simple Reflexives

Finally we briefly turn to the intrasentential “anaphors” of the theory of Government and Binding - reflexives and reciprocals - which, roughly speaking, are subject to the syntactic constraint that they must be bound by a c-commanding antecedent “nearby”, usually in the same (minimal and complete) clause while other pronominal NPs cannot find an antecedent within their (minimal and complete) clause. A simple example involving a reflexive like

(143) The director awarded himself a pay rise.

is mapped into

\[
\begin{array}{|c|c|c|}
\hline
x & y & z \\
\hline
\text{the director}(x) & y = x & \text{award}(x, y, z) \\
& & \text{pay rise}(z) \\
\hline
\end{array}
\]

4.2 Update and Dynamic Semantics

The treatment of nominal anaphora in terms of Dynamic Semantics has been illustrated in the fragment in Section 2.2 in D8. The basic idea of dynamic semantics here is to use named registers (markers, programming variables, store names) to store values for indefinites, and to access the appropriate store for anaphoric linking. As we have seen, new store names should
in general be used to ensure that anaphoric references to previously introduced antecedents remain possible.

Narrowly connected with the phenomena of anaphora is presupposition. A theory of presupposition in natural language has to give a general account of the reasons why *John loves his wife* presupposes that John has a wife, whereas *If John is married, then he loves his wife* has no such presupposition. The account that is suggested by the dynamic approach to natural language semantics capitalizes on the fact that a similar phenomenon is observed in imperative programming, where 3 aborts with error in states where \( x \) has a value \( \geq \) the value of \( \text{MaxInt} \), while 4 never aborts.

\[
3 \ x := x + 1.
\]

\[
4 \text{ IF } x < \text{MaxInt} \text{ THEN } x := x + 1.
\]

Such an analysis of presupposition can be viewed as a rational reconstruction of theories in the tradition of Karttunen [Karttunen, 1973], Karttunen and Peters [Karttunen and Peters, 1979; Peters, 1977] and Heim [Heim, 1983]. See Beaver [Beaver, 1992; Beaver, 1993], Krahmer [Krahmer, 1994], Van Eijck [Eijck, 1994] and Zeevat [Zeevat, 1992] for more information on how presuppositions can be handled dynamically in a framework which gives a partial dynamic interpretation of basic units of information. Presuppositions of utterances fall out as the pieces of information you convey with an utterance no matter whether your utterance is true or not. In other words, the presupposition of an utterance \( U \) can be viewed as the assertion that \( U \) can be processed without error, and a presupposition projection calculus can be set up with assertion statements about the absence of error abortions.

### 4.3 Situation Semantics

#### 4.3.1 Nominal Anaphora

The Situation Semantics treatment of pronouns and of VP anaphora is based on Gawron and Peters'; in particular, we assume their analysis of the strict/sloppy ambiguity. We also assume with them that the content of pronouns is a parameter, restricted by requirements on gender. An utterance of a pronoun, \( u \), may support infons of the form \( \{\text{covary}, a, \alpha\} \) where \( \alpha \) is either another NP utterance (in the case of referential anaphora, including intersentential anaphora and bound anaphora) or a VP role (in the case of what Gawron and Peters call role-linking anaphora). This will control the resolution of pronouns. The unresolved meaning for pronouns is given by the following rule.

**LEX-PRO-NP** If \( u \) is a use of type \([\text{XP} \ \alpha]\) where \( \alpha \) is the a singular pronoun with gender \( \beta \), then
The resolved meaning of the pronoun use depends on the **covary**-fact that it supports:

1. If \( u \) is a use of of type \([\text{NP} \, \alpha]\), where \( \alpha \) is a singular pronoun and \( u \models \langle \text{covary,} \, u, \, \text{NP} \rangle \), then
   \[
   [u]_{\text{res}} = \lambda f \cup \{ \langle \text{par,} \, u_{\text{NP}} \rangle \rightarrow X \langle [u], \{ (\text{ref,} \, u) \rightarrow X \} \}
   \]
   where \( f \) is a mia for \( \{ [u], \{ (\text{ref,} \, u) \rightarrow X \} \} \).

2. If \( u \) is a use of of type \([\text{NP} \, \alpha]\), where \( \alpha \) is a singular pronoun and \( u \models \langle \text{covary,} \, \rho, \, \text{VP} \rangle \), then
   \[
   [u]_{\text{res}} = \lambda f \cup \{ \langle \rho, \, u_{\text{VP}} \rangle \rightarrow X \langle [u], \{ (\text{ref,} \, u) \rightarrow X \} \}
   \]
   where \( f \) is a mia for \( \{ [u], \{ (\text{ref,} \, u) \rightarrow X \} \} \).

3. Otherwise, \( u \) is a use of of type \([\text{NP} \, \alpha]\), where \( \alpha \) is a singular pronoun, then \( [u]_{\text{res}} = [u] \)

The effect of both of the main clauses is to change the role for the referent of the pronoun to a role which is shared with another constituent. In the first case it will be the parameter role of the antecedent noun-phrase. This means that whenever the antecedent is quantified in, the pronoun will get bound as well, provided that it is appropriately within the scope of the antecedent. The second case is more complicated. Aligning the pronoun with a VP-role does not automatically require that it get abstracted over at the point at which the VP is interpreted. We will return to this when we discuss VP interpretation.

Now let us turn to possessive pronouns. Possessive pronouns such as *his* are treated as determiners, as follows:

**LEX-POSS-PRO** If \( u \) is a use of type \([\text{Det,} \, \text{quant,} \, \alpha]\) and \( \alpha \) is a possessive pronoun with gender \( \beta \), then

---

46This is, of course, an oversimplified treatment of the relationship between grammatical and natural gender.
The resolution of possessive pronouns is defined in the same way as for other pronouns except that the rule that gets aligned with the antecedent is possref rather than ref.

Now let us see how the pronoun resolution rules interact with the rule for interpreting verb phrases with transitive verbs. First we look at the basic rule for giving unresolved interpretations to such VPs.

**PS-TVP** If $u$ is a use of type $[\text{VP}, \alpha] \rightarrow [\text{V}, \alpha, \text{NP}]$ where V is a transitive verb and $u$ has constituents $u_1$, $u_2$, respectively, then

$$[u] = \lambda f([u_1], f([u_2], f))$$

where $f$ is a mia for $[[u_1], [u_2]]$

There is one special case that we need to look at for resolution: where there is role-linking.

If there is a constituent of $u$ (not necessarily an immediate constituent) $u'$ such that $u' \models \langle \text{covary}, u', <\rho, u > \rangle$ then

$$\[u]_{\text{res}} = \lambda f''(\lambda[Z](\lambda f')(\lambda f U) \left[ \begin{array}{c} <\text{subj}, u_1 > \rightarrow X \\ <\text{obj}, u_1 > \rightarrow Y \end{array} \right] ([u_1]_{\text{res}}, f\{Y, [X]\} - [\text{subj}, u_1 > \rightarrow Z]). f''))$$

where:

- $f$ is a mia for $[[u_1]]$.
- $f'$ is a mia for $[[u_2]], \lambda[Z](\lambda f U) \left[ \begin{array}{c} <\text{subj}, u_1 > \rightarrow X \\ <\text{obj}, u_1 > \rightarrow Y \end{array} \right] ([u_1], f\{Y, [X]\})$, and
- $f''$ is a mia for $\lambda f''(\lambda f U) \left[ \begin{array}{c} <\text{subj}, u_1 > \rightarrow X \\ <\text{obj}, u_1 > \rightarrow Y \end{array} \right] ([u_1], f\{Y, [X]\}, [<\text{subj}, u_1 > \rightarrow Z]))$
Otherwise, \([u]_{res} = [u]\).

The special case involves a complicated \(\lambda\)-expression, so let us take it piece by piece with an example. The meaning of a transitive verb is given in \textbf{LEX-TV}.

\textbf{LEX-TV} If \(u\) is a use of type \([ \alpha \) where \(\alpha\) is a transitive verb and \(\alpha'\) is 

\[
\begin{array}{c}
\text{tns:} \\
\{ \text{pres} \}
\end{array}
\]

the situation theoretic relation corresponding to \(\alpha\), then

\[
[u] = \alpha'(X, Y, T)
\]

\[
s = \begin{cases} 
< \text{if [tns: pst] is the feature on } u \\
\circ \text{if [tns: pres] is the feature on } u 
\end{cases}
\]

Let us take \([u_1]\) to be such an object. The effect of the central part of the \(\lambda\)-expression:

\[
\lambda u \left[ \begin{array}{c} 
<\text{subj}, u_1 > \rightarrow X \\
<\text{obj}, u_1 > \rightarrow Y 
\end{array} \right] ([u_1]_{res} f'[Y] [X])
\]

will be to flatten the verb meaning replacing the roles for the subject and object which in the original meaning are represented Montague style with two unary abstractions. They become context roles labelled \((\text{subj}, u_1)\) and \((\text{obj}, u_1)\), respectively. The result is:

\[
\begin{array}{c}
ds \rightarrow DS, \langle \text{utt-time}, u_1 \rangle \rightarrow U, \langle \text{ev-time}, u_1 \rangle \rightarrow T, \langle \text{subj}, u_1 \rangle \rightarrow X, \langle \text{obj}, u_1 \rangle \rightarrow Y \\
\alpha(X, Y, T)
\end{array}
\]

\[
\begin{array}{c}
\text{DS} \\
\text{utt-time}(u, U) \\
\text{ev-time}(u, T) \\
T \ast U
\end{array}
\]

This result is then applied to the assignment

\([\langle \text{obj}, u_1 \rangle \rightarrow [u_2]_{res} f']\)

That is, the resolved meaning of \(u_2\) with parameters supplied for its context roles by the index assignment \(f'\) is substituted for \(Y\). The result will be
Now this whole object is applied to the same index assignment \( f' \) which \( \llbracket u_2 \rrbracket_{\text{res}} \) is applied to. This means that if \( \llbracket u_2 \rrbracket_{\text{res}} \) shares any roles with the whole object they will now be associated with the same parameter. The relevant role for role-linking in this case is \( \langle \text{subj}, u_1 \rangle \). \( f' \) is then used as the first argument in abstraction:

\[
\lambda f'(X, [u_2]_{\text{res}}, f', T)
\]

This means that we know have a ‘flat’ interpretation of the VP with the roles appropriately linked. The rest of the \( \lambda \)-expression involves returning this flat interpretation to a layered one where the subject role (represented by the parameter \( Z \) in the expression) is separated out from the context roles.

This is a good example of how the basic mechanisms of abstraction and application in the Aczel-Lunnon variant of the \( \lambda \)-calculus can be used to capture the fact that roles in natural language can vary between argument roles, context roles, and roles used for binding.

The rules \textbf{LEX-POSS-PRO} and the new \textbf{PS-TVP} yield the following meaning for the VP \([\text{loved}_1 [\text{his}_2 \text{ mother}_3]_4]_5\):
Assuming that $u_2 \models \langle \text{covary}, u_2, <\text{subj}, u_5 > \rangle$ and $u_4 \models \langle \text{scope-in-situ}, u_4 \rangle$ then the resolved meaning of $u_5$ will have the role-linking of his to the subject rule of the VP.
This makes the interesting, though possibly incorrect, prediction that the role-linking readings for intensional verbs must be *de dicto*.

**Intersentential**

(D5.52) Smith attended a meeting. She chaired it.

Let the utterance of *Smith* be \( u_1 \). Then, in order to obtain a reading where the use of *she* is anaphoric to \( u_1 \) its reference role must be \( \langle \text{ref}, u_1, . \rangle \). Since both sentences will share this role, the roles will fall together (i.e. be associated with the same parameter) when the discourse rule is applied.

**Simple Reflexives**

(D5.69) The director awarded himself a raise.

Reflexives have not been included in the current grammar although it would be straightforward to treat basic cases as instances of role linking.
4.4 Property Theory

PT can inherit treatments from Dynamic Montague Grammar (using Chierchia’s Dynamic PT), or from dependent type analysis (using Martin-Löf’s Type Theory in PT).

Both approaches will be illustrated in more detail. The first, due to Chierchia, gives a dynamic interpretation of generalised quantifiers by adding operators which allow the existential quantifier to bind outside its syntactic scope [Chierchia, 1991b]. The second approach makes use of dependent types [Martin-Löf, 1982; Martin-Löf, 1984], which can be defined in PT [Turner, 1990], and can then be used to give a ‘naturally’ dynamic behaviour [Sundholm, 1989; Ranta, 1991; Davila-Perez, 1994; Turner, 1994; Ahn and Kolb, 1990] which requires no alterations to the basic theory or its model. This second approach also treats examples where the universal quantifier appears to bind outside its syntactic scope.

4.4.1 Dynamic PT

Chierchia has considered means by which quantification can be made dynamic [Chierchia, 1991b]. He achieves this by altering the model of the theory. This has a potential advantage over Dynamic Montague Grammar [Groenendijk and Stokhof, 1990a; Groenendijk and Stokhof, 1991], in that paradoxes are not re-introduced when anaphoric reference to properties is considered.

Essentially this approach follows Karttunen in saying that indefinites sets up discourse referents which can subsequently be referred to [Karttunen, 1976]. In the representation, this means that the existential quantifier should be able to bind outside its syntactic scope. To achieve this, Chierchia adds the operators $\cup, \cap, \circ$ to the language of terms the sentence. The first two operators are used to effectively allow what would otherwise be improper $\lambda$-reduction, where a free variable in the argument becomes bound. The third operator is for linking sentences in discourse. As an example:

$$A \text{ man walked in.}$$

would be translated as:

$$\lambda p. \exists x (\text{man}'x \land \text{walk-in}'x \land \cup p)$$

Similarly, the sentence:

$$He \text{ looked tired.}$$

can be represented with:

$$\lambda p. (\text{looked-tired}'x \land \cup p)$$

The discourse:

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A man walked in. He looked tired.

would be represented with:

\[ \lambda p. \exists x (\text{man}'x \land \text{walk-in}'x \land \uparrow p) \circ \lambda p. (\text{looked-tired}'x \land \uparrow p) \]

where:

\[ A \circ B = \lambda q. A(\Gamma B(q)) \]

So the final representations of the sequence of two sentences is equivalent to:

\[ \lambda q. \exists x (\text{man}'x \land \text{walk-in}'x \land \uparrow \Gamma (\text{looked-tired}'x \land \uparrow q)) \]

We require that the existential quantifier bind the \( x \) in the representation of the second sentence. In effect, can be achieved by allowing \( \uparrow \) to cancel with \( \Gamma \). To do so in a simple minded way would lead to improper \( \lambda \)-conversion (the \( x \) would have to be renamed). To avoid this, the model of PT can be altered in a manner that mirrors the model for Groenendijk and Stokhof’s Dynamic Montague Grammar. The operator \( \Gamma \) abstracts over variable assignments in the model, and \( \uparrow \) applies them:

\[
\begin{align*}
\| \Gamma \alpha \|_\omega &= \lambda \omega. \| \alpha \|_\omega \\
\| \uparrow \alpha \|_\omega &= ||\alpha|^\omega(\omega)
\end{align*}
\]

where \( \omega \) is the function which assigns a value to each variable, and \( \lambda \) is a meta-level abstraction. This interpretation effectively allows \( \uparrow \) to cancel with \( \Gamma \), giving the expression:

\[ \lambda q. \exists x (\text{man}'x \land \text{walk-in}'x \land \text{looked-tired}'x \land \uparrow \Gamma q) \]

Chierchia points out that such a theory has an advantage over Dynamic Montague Grammar in that the model for \( \uparrow \) and \( \Gamma \) may require the felicity of self-application via loops in set membership, which is banned in Montague Semantics. These loops can arise if \( \omega \) contains assignments of values to propositional variables. On the dynamic view, propositions can be taken to be true with respect to assignments, rather than to assignments, worlds and instants. So, we may have \( \langle p, a \rangle \in \omega \), where \( p \) is a propositional variable, and \( a \) is the set of assignments where \( p \) is true. However, if \( p \) happens to be true at \( \omega \), then we have both \( \omega \in a \) and \( \langle p, a \rangle \in \omega \). This is legitimate in PT, but not in strongly typed theories. It seems that a dynamic PT has the advantage of allowing dynamic binding of variables of arbitrary type.

In common with Dynamic Montague Grammar, Chierchia’s dynamic PT takes universal quantification to be static. The sentence:

\[ \text{Every man walked in.} \]

would be represented by:

\[ \lambda p. (\Theta x (\text{man}'x \Rightarrow \text{walk-in}'x) \land \uparrow p) \]

so that the pronoun in the continuation:
He looked tired.

is not bound. This corresponds with "box splitting" in DRT. However, there are examples
in which undermine the view that universal quantification should be externally static, as will
be seen below.

As with Dynamic Predicate Logic [Groenendijk and Stokhof, 1991], and Dynamic Montague
Grammar [Groenendijk and Stokhof, 1990a], the semantics are such that an existential quanti-
tifier occurring in the antecedent of a conditional is interpreted as universal quantification,
so the sentences:

\[ \text{If a man owns a book, he reads it.} \]
\[ \text{Every man who owns a book reads it.} \]

are given the same truth conditions.

Dynamic logics have arisen out of work in computer science in the formal specification of pro-
grams and programming languages. The property theory presented here uses the \( \lambda \)-calculus
as the language of terms. The \( \lambda \)-calculus is a theory of operations. As has been shown in
4.1.2.2 in D8, it is also possible to embody Martin-Löf’s Type Theory (MLTT), with its de-
pendent type operators, in PT. MLTT can be used as a language of program specification.
Thus, there already seems to be a close connection between PT and elements of theoretical
computer science. It is possible to exploit this, and give a more direct treatment of anaphoric
reference in PT using dependent types, without making the theory require a particular em-
bellished model which gives non-standard semantics for the quantifiers. This will also allow
universal quantification to be externally dynamic. The infelicity of the example:

\[ \text{Every man walked in. He looked tired.} \]

will then arise in the typing of the representation.

4.4.2 Interpretation with Dependent Types

In MLTT, a proposition is an object which is true if we can produce a proof of it. A proposition
in this sense can be said to specify its proofs. If the class of proofs specified is demonstrably
not empty, then the proposition is true. This is an intensional view of propositions, as truth
conditionally equivalent propositions are distinct if they specify different proofs. A proposition
in MLTT can be interpreted as a classical property which holds of its ‘proofs’.

There are many subtleties to this theory, but for the purposes of this discussion, the important
perspective is that we may view proofs as a structured "\textit{context}". The representations of
sentences are then properties of contexts. A sequence of sentences is true if we can construct
a legitimate ‘context’ which satisfies those sentences.
If we use dependent types in the interpretation of quantifiers, connectives and sequences of sentences, then an important consequence is that some parts of the ‘context’ used to verify a sentence are accessible to subsequent sentences.

In more detail, we can give the semantics of NL in terms of properties (or propositions) which hold of one of: (1) structures (represented as nested pairs) that satisfy the properties (propositions); or (2) functions on such structures; or (3) proofs of basic propositions, which includes witnesses to properties.

Roughly, we can represent NL expressions of the form:

\[ \text{Some/}a \ p \, \varphi. \]
\[ t \text{ and } s. \]

using $\Sigma$. These will be properties that hold of a structure. NL expressions of the form:

\[ \text{Every } p \, \varphi. \]
\[ \text{If } t \text{ then } s. \]
\[ p \text{ who } \varphi \]

can be represented using $\Pi$, and will be properties that hold of functions from structures to structures, or proofs.

As an example, with the sentence:

\[ \text{If a man owns a book, he reads it.} \]

a compositional analysis in terms of the internal analogues of the conventional, externally static quantifiers would produce a term something like:

\[ \exists x((\text{man'}x) \land \exists y((\text{book'}y) \land (\text{owns'}yx)) \Rightarrow (\text{reads'}yx)) \]

with the following truth conditions (assuming it constitutes a proposition):

\[ \exists x(T(\text{man'}x) \land \exists y(T(\text{book'}y) \land T(\text{owns'}yx))) \rightarrow T(\text{reads'}yx) \]

where neither $x$ nor $y$ are bound as required.

If, instead, we use the dependent type constructors $\Sigma, \Pi$, then the sentence could be represented by the term:

\[ \Pi(\Sigma \text{man'}\lambda x.(\Sigma \text{book'}\lambda y.\text{owns'}yx))\lambda \varepsilon . \text{reads'}(\text{it}_0)(\text{he}_0) \]

Initially, this may appear to gain nothing. However, it must be born in mind that the effect that $\lambda \varepsilon . \text{reads'}(\text{it}_0)(\text{he}_0)$ has on the evaluation of the truth of the sentence depends upon the preceding context, as will be illustrated.
The antecedent:

\[ \Sigma \text{man} \lambda x. (\Sigma \text{book} \lambda y. \text{owns}(yx)) \]

is satisfied by a structure of the form:

\[ \langle m, \langle b, \varphi \rangle \rangle \]

where \( m, b \) are a man and a book respectively, and \( \varphi \) is a proof that \( m \) owns \( b \).

If we examine the definition of \( \Sigma \) in 4.1.2.2 in D8, it can be seen that the consequent will be satisfied by a proof \( \psi \) that:

\[ \lambda z. \text{reads}'(\text{it}_0)(\text{he}_0)\langle m, \langle b, \varphi \rangle \rangle \]

Now, the anaphora are effectively resolved if we take \( \text{it}_0, \text{he}_0 \) to be selectors that pick out appropriate parts of the context; if we set \( \text{it}_0 = \text{fst}(z) \) and \( \text{he}_0 = \text{fst}(\text{snd}(z)) \), then the consequent will be:

\[ \text{reads}'(b)(m) \]

So, the whole proposition will be satisfied by a function that takes any structures like:

\[ \langle m, \langle b, \varphi \rangle \rangle \]

which satisfy the antecedent, and produce a proof \( \psi \) that:

\[ \text{reads}'(b)(m) \]

The appropriate selectors can be established either during parsing, with Cooper Storage-like annotations on the syntactic rules, or via some subsequent processing.

This treatment can cover some examples which are not handled by Dynamic Montague Grammar, or Chierchia's Dynamic Property Theory. Both of those theories assume that universal quantification is externally static. This is to prevent infelicitous examples such as:

*Every man walked in. He whistled.*

In the dependent type analysis, this example is ruled out via a type mismatch [Ranta, 1991]:

\[ \Sigma (\Pi \text{man} \lambda x. \text{walked-in}'x)(\lambda z. \text{whistled}'\text{he}_0) \]

The term (‘context’) made available to the second sentence is not a structured object which can have the selector functions \text{fst, snd} applied to it, but rather it is a function.

As universal quantification is dynamic in this treatment, it allows for an analysis of the following two examples (elaborated by Davila [Davila-Perez, 1994] and Ranta [Ranta, 1991] respectively):

*Every driver has a licence. Peter has to renew his.*
*If every man finds a pen, some man loses it.*
Although not elaborated here, using dependent types in PT, rather than directly in MLTT, allows for a mixture of both classical and intuitionistic interpretations of propositions. In addition, classical quantification is available. In principle, this means that it is possible to express the meaning of:

\[
\text{Every man who owns a book reads it.}
\]

with:

\[
\Theta(m, b)(\{m, b\} \Sigma \text{man}(\lambda x \cdot y : \text{book}(y) \land \text{owns}(y, x)) \Rightarrow \text{reads}(b, m))
\]

where propositions are interpreted classically and do not require witnesses. This expression has the truth conditions:

\[
\forall(m, b)(\text{T(man}(m)) \land \text{T(book}(b)) \land \text{T(own}(b, m)) \Rightarrow \text{T(reads}(b, m)))
\]

However, there is no obvious means of deriving this representation compositionally.

Two additional benefits of using MLTT implemented in PT rather than vanilla MLTT are: (1) the representation of \textit{de re} and \textit{de dicto} attitudes is straightforward in PT, it is not obvious how to achieve it in MLTT\textsuperscript{47}; (2) in MLTT, false propositions are equated.\textsuperscript{48} This is not so with PT as propositions are taken to be basic.

### 4.5 Monotonic Semantics

All anaphora is treated by means on placing a contextual restriction on the range of quantification anaphoric terms. As all quantification in QLF is potentially open to this kind of contextual restriction, this tends to blur some of the traditional distinctions between anaphoric and non-anaphoric noun phrases. However, it is useful to distinguish between different types of contextual restriction.

**Deictic** Sometimes the contextual restriction amounts to the property of being identical to some entity or set of entities salient in context, but where these entities have not been referred to by earlier expressions. This covers deictic uses of pronouns, proper names where there is a particular individual in the (non-linguistic) domain who bears the name, or definite descriptions where there is a particular individual in the domain uniquely satisfying the restriction of the term.

**Linguistic Co-Reference** Instead of referring to non-linguistically salient entities, the contextual restriction can ensure quantification over the same set of entities as some previous term. This encompasses both of what have traditionally been called bound and

\textsuperscript{47}This might be achieved by using a Universe within MLTT [Martin-Löf, 1984], but this admits the primitive nature of propositions (and hence result in a form of property theory) counter to the anti-realist philosophical motivation of MLTT.

\textsuperscript{48}A proposition in MLTT specifies its proofs. If two propositions specify the same set of proofs, then they express the same proposition. A false proposition in MLTT has no proof. As there is only one empty set, all false propositions are equal.
referential anaphor, as well as E-type anaphora. The contextual restriction is generally indicated in the QLF by some sort of function acting on a preceding term’s index.

**Linguistic Dependence** Similar to linguistic co-reference is linguistic co-dependence. Here the contextual restriction is again dependent on the range of quantification of a preceding term but instead of duplicating the range, the restriction is some variant of it. Examples of this include functional anaphora (e.g., having referred to a car, one can anaphorically refer to the steering wheel), one anaphora, and sloppy identity between pronouns. The restriction is again marked by some sort of function or relation on a preceding term index.

In the case of linguistically derived contextual restrictions, the nature of the functions/relations on term indices is open to a number of alternative interpretations, as we will see below. Some of the discussion on this matter goes beyond what is currently implemented in the CLE.

### 4.5.1 Deictic and Bound Anaphora

The following abbreviated resolved QLF for the sentence *John used his workstation* indicates the difference between a deictic contextual restriction for *John* and a bound/linguistically co-referential restriction for *his*:

```
[use,
  term(proper_name(tpc), C, 
    D'[name_of,D,John],
    exists,ent(john_smith)),
  term(q(ntpc,poss_some,sing), W, 
    E [and, [workstation,E], 
      [own,E, 
        term(ref(pro,he,sing),H,G^[male,G], 
          exists,intra(C))], 
        exists,qnt(W))]
```

Here, `ent(john_smith)` is an abbreviation for the property `X^X= john_smith`, and we are assuming that the constant `john_smith` names a salient object in non-linguistic context bearing the name “John”. The proper name term acts as an existential quantifier over objects named “John” and identical to this individual. Had there been no such individual available in non-linguistic context, the proper name term would have been resolved to

```
term(1([John]), proper_name(tpc), C, 
  D'[name_of,D,John],exists,qnt(C))
```

i.e. a quantifier over objects named “John”. As such, it would act more like an indefinite than a deictic pronoun.
The pronoun *his* is co-indexed with the proper name term, *C*. To a first approximation \( \text{intra}(C) \) is an abbreviation for \( X^* X = C \). Given the way that terms and their indices are discharged in the QLF semantics, the QLF is interpretable if the proper name term is given wide scope over the pronoun, so that the index *C* in the pronoun restriction gets discharged to a variable bound by the proper name in evaluation.

Arguably, it would also have been possible to resolve *his* deictically, so that its contextual restriction was \( \text{ent}(\text{john smith}) \). Whether this is a real possibility is not clear; truth conditionally it would make no difference, but the interpretation of certain kinds of ellipsis (see section 5.5.7) suggests—weakly, and theory-externally—that it should not be permitted.

### Constraints on binding

As the example above shows, co-indexing on terms can give rise to ‘bound variable’ intra-sentential anaphora. The theoretical linguistics literature makes much of constraints on binding and co-reference in such cases. In QLF, these amount roughly to saying that terms which stand as arguments to the same predicate cannot be coindexed, unless one of the terms corresponds to a reflexive pronoun, in which case it must be coindexed. There is nothing intrinsic to QLF enforcing this kind of constraint. Indeed, the only kind of constraint emerging from the QLF semantics is that when a term is coindexed with some antecedent, the antecedent must (usually) be given wide scope in order to discharge the co-indexing (though see the discussion of donkey anaphora).

These constraints on co-indexing can be enforced as properties of the salience relation \( S \) selecting contextual restrictions for terms, and this is what is done (the constraints are expressed as ones on QLF rather than syntactic structure). Even so, the ‘constraints’ admit a number of exceptions. Picture-of reflexives provide a well-known counterexample to the constraint on reflexives, and examples like *No one likes John. Even John doesn’t like him.* indicates that at most it is co-indexing rather than co-reference that is prohibited.

Weak-crossover sentences (*His advisor misled John* cf (*His advisor misled every executive*) also violate the c-command constraint on binding, although this has been used to argue that there is a difference between bound and referential anaphors rather than a violation of the constraint. At least one of us (SGP) is skeptical of this data (e.g. *Their personnel department was cited by almost every company as being the greatest source of corporate inefficiency*), and besides QLF does not motivate a bound/referential distinction in addition to a co-indexed/deictic distinction.

#### 4.5.2 Intersentential Anaphora

While intra-sentential co-indexing readily lends itself to handling ‘bound-variable’ anaphora, this is less obviously so for inter-sentential co-indexing (unless one adopts a dynamic perspective on quantification). Nevertheless, the same co-indexing mechanism is used.

In the discourse *Smith attended a meeting. She chaired it.* let us suppose that in the first sentence both the proper name and the indefinite noun phrase act as indefinities, (existential
quantifiers over persons named Smith and meetings). Schematically

\[
\text{[attend}, \text{term}(\ldots, S, X \ [\text{name_of}, X, \text{`Smith}], \exists \text{exists}, \text{qnt}(S)),
\text{term}(\ldots, M, X \ [\text{meeting}, X], \exists \text{exists}, \text{qnt}(M))]
\]

Resolving *she* and *it* in the second sentence we get (schematically)

\[
\text{[chair}, \text{term}(\ldots, X \ [\text{female}, X], \exists \text{exists}, \text{inter}(S)),
\text{term}(\ldots, X \ [\text{entity}, X], \exists \text{exists}, \text{inter}(M))]
\]

where the two pronouns are co-indexed with their antecedents in the preceding sentence. (Note: in adding the first QLF to context, the term indices will get ground to unique constants, and it is these, rather than prolog variables, that occur in resolving the second QLF. But for expository purposes we have continued representing them as the variables S and M).

We cannot construe \text{inter}(S) as an abbreviation for \(X^*X=S\), since this would introduce an undischARGEABLE index into the second QLF. Instead, \text{inter}(i) expresses a contextual association between a term index i and some kind of function or property. The same is also true of \text{intra}(\ldots), though we rather simplified this above by focussing on the case where the property is something like \(X^*X=S\).

The CLE can associate two kinds of function / property with term indices. The first is based around the E-type treatment of anaphora of Cooper [Cooper, 1979] (and also Webber [Webber, 1983]). This associates properties with indices that (are intended to) uniquely apply to those objects quantified over by the term. In the examples above, the properties would be (a) that of being an individual named Smith who attended a meeting for the index S, and (b) the property of being a meeting attended by such an individual. These properties are used to form definite descriptions (`the person named Smith who attended a meeting’ etc). In QLF such definite descriptions would be treated as a universal quantification over the relevant property, so that a paraphrase of the second sentence would be something like: all people named Smith who attended a meeting (at time t) chaired every meeting that a person named Smith attended (at time t). As should be apparent from the paraphrase, this particular analysis is problematic if there is more than one person named Smith who attended a meeting at time t. The problem is that the E-type properties formed do not necessarily uniquely pick out the particular Smith and meeting referred to by the first sentence, and neither the first nor the second sentence entails that there is a unique Smith / meeting pair.

Webber attempts to resolve this difficulty by including in the properties the fact that the Smith and the meeting were ‘invoked’ in the preceding sentence, though the semantics of this invocation are rather unclear. A possible alternative available within the CLE is to associate term indices with skolem constants and functions.

This association is brought about when a resolved QLF is converted to TRL (recall that this conversion essentially applies the semantic evaluation rules for QLF) and the TRL is skolemised.\footnote{TRL is skolemisable because generalised quantifiers are converted to existentials with a higher-order} When discharging a term and its index, the term and index is replaced by
a variable bound by the appropriate quantifier. But in addition to this, an extra formula is introduced associating the variable with the original index. When the TRL expression is skolemised, this has the effect of automatically associating the index with the relevant variable, skolem constant or skolem function.

After skolemising the TRL of the first sentence in the discourse above, the indices $S$ and $M$ become associated with two skolem constants. The pronouns are resolved to existential quantifiers over objects restricted to be identical to whatever is denoted by the constants. This ensures that the same (arbitrary) Smith and meeting are referred to in both sentences. Indeed, after converting the second sentence to skolemised TRL a process of de-skolemisation takes place, which merges the two sentences into a single formula with wide scope existentials over Smith and the meeting.

When indices are associated with skolem functions as opposed to constants, the evaluation of QLFs (in terms of conversion to TRL) within the CLE is not, at present, robustly implemented. Arguments of the appropriate kind must be supplied to the function. Information about what constitutes the right kind of argument is supplied by the association of the arguments (represented as TRL variables) with term indices. At present, these arguments are filled in during conversion to TRL by the E-type properties associated with the argument indices, but it is not clear that this is the correct way to proceed. In other words, a skolem association with indices is only properly implemented for skolem functions, and further work needs to be done to see if this can be generalised.

4.5.3 Plural Anaphora

Plural entities can be referred to by plural anaphors. Not any old plural entity, though. It generally has to be one directly introduced by some preceding noun-phrase (to allow coin-dexing). Thus *Eight of the ten machines are not in the office. They are in the lobby* fails because although the existence of two machines not in the office is asserted, these machines are not referred to by any NP.

We also need to invoke two kinds of number agreement: syntactic and semantic. Plural pronouns may refer back to syntactically singular NPs if those NPs occur in a context that makes them semantically plural (e.g. within the scope of a plural quantifier). Hence *Each department has a dedicated line. They rent them from BT, where them refers back to a dedicated line.* In the current implementation, the second sentence receives a final E-type interpretation along the lines of: for every line possessed by a department, every department that possesses the line rents it from BT.

cardinality restriction.
4.5.4 E-Type

In *GFI owns several computers. ITEL maintains them*, the term for *several computers* will introduce a contextual association between the term index and some property describing those computers. The plural pronoun *them* picks up on this contextual association and employs a universal quantifier. Consequently the sentence implies that ITEL maintains all of those computers.

4.5.5 Donkey

Using an assignment to terms and indices in the semantics of QLF, we could duplicate a dynamic treatment of donkey anaphora (by making the assignment behave dynamically). Which would suggest some connection between term indices and DRT’s discourse referents. At one stage, this was how donkey anaphora was treated in the CLE, but subsequently the treatment reverted to an E-type analysis. The E-type analysis has the virtue of permitting both a universal and existential reading for donkey sentences, depending on whether the pronoun is resolved to a universal or existential quantifier, i.e. *every customer who owns a computer has a service contract for it*: (a) a contract for all computers they own, or (b) a contract for at least one computer they own.

A possible alternative might be to make use of the contextual association between indices and skolem functions. Thus in *every customer who owns a computer has a service contract for it, it* picks up a skolem function which takes the variable ranging over customers as its argument (using the same mechanism as in modal subordination). But as pointed out before, contextual associations of term indices with anything other than skolem constants has not been worked out or implemented. What is more, on a standard treatment of skolemisation, the embedded existential would in fact be skolemised to an implicit universal variable rather than a skolem function.

4.5.6 Subsectional/Functional

Resolving anaphora by means of placing contextual restrictions lends itself to subsectional and functional anaphora. In *Lots of shareholders were at the meeting. The small investors objected to the chairperson*, the NP *the small investors* is co-indexed with *lots of shareholders*. The NP universally quantifies over small investors that were at the meeting, through conjoining the explicit restriction of the *term* with the contextual restriction.

Functional anaphora is somewhat different in that the quantification must be over objects functionally related to the chosen antecedent, but not necessarily comprising a subset of the set of antecedent objects. The CLE has not implemented functional anaphora.
5 Ellipsis

5.1 Discourse Representation Theory

5.1.1 Gapping

\[(145)\] Smith went to Paris by car and Jones by train.

The strategy to deal with gapping within DRT which we will sketch here assumes that the parser will recognize the syntactic incompleteness of the gapped clause, then try to find a matching source clause. (This search is quite straightforward since the possible syntactic configurations of a gapped clause and its source are extremely restricted - either source and elliptical clause are first and second conjunct of a coordination construction, or the elliptical clause occurs in the comparative clause of a comparative construction of which the main clause is the source.) The notion of matching needs to be carefully defined. Here we simplify somewhat. Still the definition is complicated and it will help to illustrate it at the hand of the given example. Here Smith went to Paris by car is the source clause and Jones by train the gapped clause. The latter is shown to match the former by the following correspondence between the parse tree for the source and a "quasi-parse tree" for the gapped clause:

\[(146)\]

\[\begin{align*}
\text{TS} & \quad \text{TG} \\
S \quad \quad & \quad S \\
NP \quad & \quad NP \\
Smith & \quad Jones \\
VP \quad & \quad VP \\
went & \quad by \\
to Paris & \quad by train \\
\end{align*}\]

The diagram establishes matching in the following sense. On the left we have a parse tree $T_S$ for the source clause. Call the major constituents of this tree (or for that matter of any other parse tree) those tree nodes which are either (i) the node of the main verb, or (ii) the node of an argument of the verb; or (iii) the node of an adjunct to the verb or to its VP; or (iv) the node of any auxiliary verb$^{50}$ Thus the major constituents of the parse tree of the source clause in (1) are: the $V$ node; the subject $NP$ node and the two $PP$ nodes. On the right we have a "quasi-parse tree" $T_G$; the map $f$ establishes a 1-1 structure-preserving correspondence.

---

$^{50}$ This last possibility does not occur in the present example!
between a subtree $T'_1$ of $T_G$ and that subtree $T'_S$ of $T_S$ whose leaves are the major constituents of $T_S$. $f$ matches $T_G$ with $T_S$ in virtue of the fact the following conditions are fulfilled: (i) for each node $n$ of $T'_G$ the syntactic category of $n$ is identical with that of $f(n)$; (ii) the node of $T_G$ of category $V$ is empty (i.e., its successor in $T_G$ is labelled $\epsilon$); moreover, where $T_S$ contains nodes for auxiliary verbs, the corresponding nodes of $T_G$ are empty as well; (iii) at least two of the nodes of $T_G$ are the roots of subtrees of $T_G$ that are parse trees of non-empty expressions. (In the example there are exactly two of these, the subject NP Jones and the prepositional adjunct by train.)

Once the source clause has been found and a matching correspondence constructed, the interpretation of the elliptical clause - in other words, its DRS construction - can proceed as follows. We first construct a “pseudo-parse tree” for the elided clause by attaching to each empty node $n$ of $T_G$ the subtree of $T_S$ whose root is $f(n)$. We can then use this pseudo-parse tree to construct a DRS for the gapped clause. The result of processing both the source clause and the gapped clause of (145) - and thus the DRS for (145) as a whole - is given in (146). (We finesse a problem which is orthogonal to the one with which we are concerned here by provisionally representing the adjuncts by car and by train as predications of the relevant motion events).

<table>
<thead>
<tr>
<th>$e$</th>
<th>$s$</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$e &lt; n$</td>
<td>smith($s$)</td>
<td>paris($p$)</td>
</tr>
<tr>
<td>$e : go\ to(s, p)$</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>$e'$</th>
<th>$j'$</th>
<th>$p'$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$e' &lt; n$</td>
<td>jones($j$)</td>
<td>paris($p'$)</td>
</tr>
<tr>
<td>$e' : go\ to(j, p')$</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(147) N.B. In this discussion we have had to assume that syntactic analyses are of certain forms. However, most of the details of the assumed syntactic theory have no influence on the analysis proposed here. All that is required is that the syntactic structures have nodes corresponding to what we have been calling “major constituents”.

In general DRS construction for the elliptical clause is subject to certain parallelism constraints: The parallelism that must be construable between the elliptical clause and the source clause in order for the elliptical clause to be accepted as grammatical is symptomatic of a deeper semantic parallelism, which is operative also where one and the same syntactic configuration is compatible with two or more distinct semantic construals. Thus

(148) Bill’s assistant reminded him of his father and his secretary of his next appointment.

with the intended interpretation that Bill can’t help thinking of his father when he sees his assistant, and that Bill’s secretary told him that his next visitor was waiting, feels at best like a joke; it isn’t really possible to interpret the second, “reconstructed” instance of remind in its agentive sense after having interpreted its first occurrence as psych verb. And

(149) The first manager told his assistant that he had been promoted and the second manager his secretary.
cannot be understood as saying that the assistant was told about his own promotion, whereas
the secretary was informed about the promotion of the second manager: you cannot interpret
the pronoun he the first time around as referring to the indirect object and the second time
as referring to the subject. (However, the matter is complicated by cases where an elliptical
constituent can be interpreted as referentially identical with its counterpart in the source
clause. Thus

(150) The manager told Bill that he was fired and Bill his wife.

can be understood in such a way that both tellings concerned Bill’s being fired; i.e. both
times the constituent that he was fired is interpreted as referring to the same proposition.

5.1.2 VP Ellipsis

(151) ITEL sent CRC a report and APCOM did too.

There are two major differences between VP deletion and gapping. The first concerns the
parallelism between elliptical clause and source clause. In the case of VP ellipsis this is
a simpler matter than it is in the case of gapping. Cases of VP ellipsis are, as the name
indicates, clauses whose verb phrases are “elliptical”. There are three types of cases: (i) the
main verb is “dummy” do, (“dummy” in the sense that it occurs without any complements
or adjuncts); (ii) the main verb is “dummy” be; (iii) the VP consists of a (simple or complex)
verb which takes to-infinitival, together with a to-complement from which all but the to
itself is missing (As in: Bill didn’t write the paper though he wanted to).51 Here we confine
ourselves to the first case. The parallelism between elliptical clause and source clause, then,
comes to no more than this: that the source clause must have a VP that is “compatible” with
the (elliptical) VP of the elliptical clause - this means that if the main verb of the elliptical
clause is be, then that of the source clause must be be too, and if the main verb of the elliptical
VP is do, then the main verb of the source clause may not be be.

The second difference concerns the configurational relationship between source clause and
elliptical clause. In the case of VP ellipsis this relation is much less constrained than it is
in the case of gapping. In fact, there do not appear to be any hard constraints at all, only
pragmatic constraints that prevent the two clauses from being “too far apart” (we have no
good idea of what that means precisely).

Although this way of proceeding is less compelling in the case of VP-ellipsis than it is for
gapping, we can deal with the interpretation of VP deletion along the same lines as we have
just been using there: we form the pair consisting of the parse tree of the source clause and
that of the elliptical clause, correlating the VP node of the elliptical clause with the node
of the VP identified as its source. We then insert the source NP in lieu of the dummy verb
in the elliptical VP (or as complement of to, if the elliptical VP is of the last of the three

51Question: Is this actually the correct, exhaustive case description?
types mentioned above) and proceed with the construction of the semantic representation.
(As in the case of gapping, the reconstructed VP and that of the source clause have to be
interpreted in parallel, in the sense that whenever there are two or more interpretational
options, the same option is chosen each time.)

In the case of our example (151) this comes to the following. At the first stage we have the
connected pair of parse trees shown in (152):

(152)

After insertion of the subtree dominated by the VP node of the tree on the left under the VP
node on the right and DRS construction we obtain:

(153)

<table>
<thead>
<tr>
<th>e x y z</th>
<th>e' u y' z'</th>
</tr>
</thead>
<tbody>
<tr>
<td>e &lt; n</td>
<td>e' &lt; n</td>
</tr>
<tr>
<td>itel(x)</td>
<td>itel(x)</td>
</tr>
<tr>
<td>cre(z)</td>
<td>cre(z')</td>
</tr>
<tr>
<td>report(y)</td>
<td>report(y')</td>
</tr>
<tr>
<td>e : send to(x, y, z)</td>
<td>e' : send to(u, y', z')</td>
</tr>
</tbody>
</table>

5.1.3 One Anaphora

1. One anaphora seems to occupy a position that is half-way between the classical cases of
referential anaphora (in particular: pronoun anaphora) on the one side and the paradigmatic
cases discussed elsewhere in this section on the other side. The kind of anaphoric one with
which we are concerned here is exemplified in the D5 sentences (74/75)

(154) Smith owns a white BMW and Jones a red one.
(155) Smith owns a white BMW. Jones a red one.

This is, by the way, not the only use of the word *one* which might be considered anaphoric. A very different type of at least superficially anaphoric use is illustrated by the second one in a sentence like *If one doesn’t watch out in Amsterdam, one is sure to be pickpocketed.*. Here too the *one* in question cannot be properly interpreted without registering the referential connection that exists between the second and the first occurrence of *one*, but the interpretation principles are very different from those involved in the type of case represented in (154).

As said, it is only that use which concerns us now. Tokens of *one* that are used in this way might be described as “second order anaphors”. For what they do is to pick up (or: stand in for) some property. To characterize *one* as a “property anaphor” would be misleading, however, as it might well suggest that *one* can latch on to any contextually salient property whatever. This is not so. In fact, it isn’t even the case that one can pick up any property that is salient through having been explicitly and recently introduced into the antecedent discourse. For instance, properties introduced by verb phrases are not accessible to *one*.

The properties which are accessible are those introduced by simple or complex common noun phrases. It is in view of this - that it is only properties that are introduced by expressions of a particular grammatical type which *one* can pick up as denotata - that *one* appears to have much in common with the paradigms of ellipsis, such as gapping or VP-deletion: in either case the meaning of the clause containing the ellipsis can be explicited as resulting from a largely syntactic reconstruction followed by an interpretation process which is by and large the same as that for non-elliptical clauses.

2. We said that the anaphoric antecedents of *one* can be “simple or complex common noun phrase”. The disjunction is important. In sentence (154) - we will from now on concentrate on this example, setting aside the closely similar (155) - the property picked up by *one* is clearly that expressed by the common noun BMW. But suppose we change (154) into (156)

(156) Smith owns a white BMW. Bill has one, too.

Here, *one* can be interpreted as “a BMW”, but also as “a white BMW”. In the second interpretation the property picked up by *one* is that expressed by the complex common noun phrase *white BMW*.

3. To say that *one* is anaphoric to some simple or complex common noun phrase, or that it takes the property expressed by that phrase as its denotatum, fails to do justice to an aspect of its semantics which we have so far ignored, but which is transparent in the paraphrases “a BMW” and “a white BMW” which we used in the last paragraph. For as those paraphrases show, the role of *one* is that of an indefinite NP; to the DRS it should contribute a new individual discourse referent *x*, representing the kind of entity that falls under the sortal property expressed by the common noun phrase to which *one* is anaphoric. Thus the anaphoric aspect of *one* concerns the constraining condition on *x* - it concerns the *P* in *P(x)* - rather than *x* itself.
To deal with the anaphoric aspect of \textit{one}, then, there are in principle two avenues open to us. The first is to take the constraining condition $P(x)$ as consisting of two discourse referents, an individual discourse referent $x$ and a property discourse referent $P$. $x$ is subject to the novelty condition - i.e. it should not be identified with a discourse referent that is already present in the context - and $P$ is to be interpreted anaphorically, as the property defined by a common noun phrase that is part of the context already. The second alternative is to copy the antecedent common noun phrase directly over into the constraining condition. Thus for the second clause of (154) we get something like in (157) if we adopt the first strategy and something like (158) if we follow the second.

\begin{center}
\begin{tabular}{|l|}
\hline
\textit{j y b z P} \\
\hline
\textit{john(j)} \\
\textit{bmw(y)} \\
\textit{white(y)} \\
\textit{bill(b)} \\
$P(z)$ \\
\textit{red(z)} \\
\hline
$P = \lambda z', \text{bmw}(z')$ \\
\hline
\end{tabular}
\end{center}

\begin{center}
\begin{tabular}{|l|}
\hline
\textit{j y b z} \\
\hline
\textit{john(j)} \\
\textit{bmw(y)} \\
\textit{white(y)} \\
\textit{bill(b)} \\
\hline
\textit{bmw(z)} \\
\textit{red(z)} \\
\hline
\end{tabular}
\end{center}

At present we do not know how to choose between these two options. (Perhaps there are no principled reasons for going one way or the other on this.) We will for now adopt the second one.

4. Exactly what common noun phrases are available as \textit{one}-antecedents is not a trivial question. In (156) we saw that both \textit{BMW} and \textit{white BMW} are possible antecedents. It is also possible for \textit{one} to pick up a complex common noun phrase consisting of a noun together with an attached relative clause, as in

\begin{center}
(159) John has a BMW that goes more than 150mph. Bill has one too.
\end{center}

This last possibility does not always seem to be available, however. For instance, in

\begin{center}
(160) John has a car which he uses to go to work. Bill has one too.
\end{center}
it does not seem possible to interpret one as “a car which he uses to go to work” (irrespective of whether we take he to refer to Bill or to John). Precisely what is responsible for this difference between (159) and (160) is not clear to us.

When the common noun phrase all or part of which serves as antecedent for a given occurrence of one, is even more complex than the examples so far considered, judgements as to what is possible and what is not become very delicate. For example, in

(161) John owns a white BMW that can go more than 150 mph. Bill owns one too.

it seems that both BMW and white BMW that can go more than 150 mph are clearly possible. But what about white BMW or BMW that can go 150 mph? Though we do not feel that these possibilities can be definitely excluded, they appear to us as less natural than the first two alternatives. But again, what principles may lie behind these intuitions, we do not yet understand.

5.1.4 Sluicing

The deep question that is posed by sluicing\(^{52}\) is: Why is this construction possible at all? Why is it possible to say:

(164) Somebody won the contract. But we don’t know who.

but not:

(165) Somebody won the contract and Sarah knows Fred.

(with the sense that Sarah knows that Fred won the contract) or

(166) Somebody won the contract, but I do not for the life of me think Fred.

If one sets this question aside and simply accepts that sluicing is a separate species of ellipsis, the problem of dealing with it reduces to: (i) defining the environments in which sluicing

\(^{52}\) Warning: This section is off the cuff and even more impressionistic than many of the others. It is meant as no more than a provocation of discussion.

\(^{53}\) Compare also:

(162) Somebody has won the contract; in fact, Fred. (?)

(163) Somebody has won the contract, but certainly not Fred.
is possible; and (ii) describing how sluicing constructions receive their intuitively correct interpretations.

As far as (i) is concerned: it appears that sluicing is possible whenever the elliptical clause and its source clause are the second and first member, respectively, of a coordination; moreover the elliptical clause itself has the form of a matrix clause which takes embedded questions, followed by a wh-word - who(m), which or what; this wh-word acts as the complementizer of a missing embedded question. Finally, the source clause must contain an NP which can be identified as the “antecedent” of the wh-word. To interpret the sluicing construction - here we switch to (ii) - it is necessary to see the variable for the wh-word as occupying the site of its “antecedent” in the source clause. Thus the we don’t know who of (164) is to be interpreted as involving the embedded question which we get when substituting the variable introduced by who for the one corresponding to its “antecedent” somebody in somebody has won the contract. Thus the embedded question is something like

\[(167) \quad \text{wh } x \ (x \text{ has won the contract})\]

There appears to be a further constraint, which pertains to the antecedent of the wh-word. Apparently this can only be an indefinite NP. For compare (168), which seems to us a quite acceptable example of sluicing, with the (we think) quite unacceptable (169).

\[(168) \quad \text{Someone has won the contract, but Sarah does not know who.}\]

\[(169) \quad \text{Fred has won the contract. But Sarah does not know who.}\]

Note that from a pragmatic point of view (169) makes perfectly good sense; I may know that Fred won the contract and also that Sarah doesn’t know this. But nevertheless I cannot very well express this in the manner of (169). In fact, it appears that only indefinite antecedents are good in sluicing constructions. Quantified NPs, such as most applicants as in

\[(170) \quad \text{Most applicants were awarded a fellowship. But I don’t know who.}\]

do not seem to do much better than definite NPs.

(N.B. Perhaps (168) is not an optimal example of sluicing either. We have an impression that the most natural sluicing examples are those where, as in (164), the matrix clause of the elided question is in the first person. We will come back to this below.)

Whence this limitation to indefinite antecedents? We suspect that the answer is connected with the weathered intuition (which keeps rearing its head in papers on syntax) that “wh-words are indefinites”. There is a tendency in such papers to not explain what is meant by this (at least not in terms which we find accessible). But we take it that the intuition amounts to something like this: Both indefinite NPs and wh-elements act as introducers of
“free” variables. The notion that “indefinites are free variables” has come to be associated with File Change Semantics and DRT, though not infrequently the slogan is thrown about in ways which make it doubtful whether there exists a clear idea of what it is that is being claimed. But the writings which gave rise to the idea - this is true especially of Heim’s “The Semantics of Definite and Indefinite Noun Phrases” - make perfectly clear what the sense of the slogan is: while all NPs introduce variables, some, in fact the majority, themselves impose certain binding conditions on their variables. This is patent for genuinely quantifying NPs such as every computer, but it is also true of the various different types of definite NPs, which, in one way or another, demand of their referents that they be “anchorable” in the given context. Indefinites, in contrast, do not carry such a binding constraint; their variables have to hunt for a binder elsewhere. The question which File Change Semantics and DRT raised for the first time, but for which we still do not have a complete answer (not even one that holds just for the one language English), is precisely how and where they find their binders. Part of that question is: What are the possible binders? and in particular: Are those binders always semantic - i.e. part of the logical form of the sentence or discourse containing the indefinite; or can they also be of a pragmatic nature, such as for instance an assertion operator?

As long as these questions have not been satisfactorily cleared it won’t presumably be possible either to say the last word about the similarities and differences between indefinites and wh-words, let alone about sluicing. But let this not keep us from speculating.

That wh-words are “free variable introducers” in the sense just alluded to is not immediately obvious. For instance, doesn’t the wh-word of a direct question carry with it the instruction that its variable be (λ-) bound, so that the logical form of the question can be interpreted as denoting a set of individuals (or, if that is preferred, a corresponding set of propositions)? While objections of this kind should not be taken too lightly, we believe that it may nevertheless be possible to make a good case for the “free variable” hypothesis. Indeed, there appears to be evidence suggesting that direct questions involve a question operator which should be regarded as distinct from the wh-word which may coincide with it in surface structure. (Drawing this distinction is one strategy for explaining why, in a language like English or German, one wh-word has to move to the beginning of the sentence.) Also there is the fact that, in English and other languages, wh-words serve a number of distinct purposes all of which can be seen as involving their variables being bound by some independent agency.

So let us assume that wh-words are indefinites in the intimated sense. How does this help us to explain why the sluicing construction demands, or strongly prefers, that the antecedent of the wh-word be indefinite? Recall our earlier remark that the paradigmatic examples of the sluicing construction are those where the antecedent is indefinite and the matrix clause of the elided question is in the first person. In fact, there is a closely related further variant of the sluicing construction, an example of which is given in

\[(171)\quad \text{Somebody has won the contract. But who?}\]

The story we hypothesize about (171) is this. The indefinite of the first sentence is bound by an assertion operator, the force of which is that the semantic form of the sentence (given by
its DRS) is in fact instantiated. The attached question *But who?* now is to be interpreted as follows. *who* somehow picks up the variable (or discourse referent) of its antecedent - precisely how it does this is a story that has to be worked out - and in so doing copies the semantic form to which this variable belongs (This is the ellipsis part of the story, which also needs further underpinning; however, as we will see again in the following sections on ellipsis phenomena, the deeper syntactic nature of ellipsis constructions is still but poorly understood generally; so one cannot expect too much here for the special case of sluicing.) At the same time the question operator associated with *who* - note that (171) is a direct question, so its wh-word is associated with such an operator! - then binds its variable, making the copied semantic form into its scope. Crucial to this operation is that the semantic form does not itself bind the variable to which *who* latches on. For then we would have a case of double binding (in grammar, double binding is always a double bind). Therefore it is essential that the variable in question be introduced by a “free variable introducer” and that the operator which does its binding the first time round is part of the use which the first utterance of (171) makes of the semantic form, and not of the semantic form itself.

In order to tell a similar story about (164) we must see the entire phrase *we don’t know who* as expressing an operator which binds the variable associated with *who* - again, precisely how this works needs further investigation.

We conclude this exploration with a final conjecture about the preference for matrix clauses that are first person. The reason, we suspect, why (168) isn’t quite as felicitous as, eg., (164) is that the former sentence carries some suggestion that the speaker does know who won the contract. Inasmuch as the suggestion is there, it suggests that there is a sense in which the speaker uses the subject phrase *somebody* as a specific indefinite: the discourse referent representing the one who won the contract in the speaker’s mind is anchored to some particular individual. Thus, insofar as it is the representation in the speaker’s mind that we take his words to express, the variable in question seems already bound as part of the relevant semantic representation; which runs afoul of the binding that is to be performed by the operator of the following direct or indirect question.

### 5.1.5 Syntactic Constraints on Ellipsis

In the next couple of paragraphs we will address in a very preliminary way the problems raised in section 5.2 of D5.

1. (ad 5.2.1) It would be nice to have an illuminating linguistic explanation of why it is that the configurational relationship between source clause and elliptical clause is so much more restricted in the case of, say, gapping and sluicing than it is in that of VP-ellipsis and “pseudo-gapping”. What is it?

2. (ad 5.2.2) As the “identity” problems mentioned in D5 indicate, there is a problem with the syntactic reconstruction which our sample treatments of gapping and VP-ellipsis above have blythely ignored. In terms of the analysis given there, the point is that after reconstruction the resulting tree does not in general satisfy all the well-formedness constraints imposed by
the grammar. In particular, there may be violations of agreement (person, gender, number). For the most part this does not affect the DRS construction that uses the reconstructed tree as input. But one has to be careful. For instance, when a reconstructed constituent contains a pronoun, the desired interpretation of this pronoun may go against the usual constraints imposed by its morphology - that a first person pronoun can only refer to the speaker, that plural pronouns must take antecedents that are (in the relevant sense) plural, and so on. Therefore special provisions are needed which allow these morphological constraints to be overruled by considerations of parallelism (as between the interpretation of the reconstructed pronoun and its origin). Relaxation is also needed in connection with binding theory constraints, which limit the possible interpretation of pronominals and of the so-called “anaphors” (reflexives and reciprocals).

3. Besides this need to relax certain constraints at the level of DRS construction there also exists the need to relax the matching constraints we stated above. In particular, there is, as example (86) of 5.2.2.2 illustrates, the possibility of differences in word order between source clause and elliptical clause.

On none of the problems reviewed in these last three paragraphs we have much to contribute. To deal with these problems we would want to rely on work that has been done and is being done in Saarbrücken. Moreover, as far as the “vehicle change” problems mentioned under 2. are concerned, here it is possible to make use of a substantial and growing body of work within syntax.

One aspect of the “to copy or not to copy” problem about deleted NPs has been given special attention within DRT. This is the problem of what is to be done with indefinites. As Klein rightly observes, (See e.g. [Klein, 1987]), there are many cases where something like copying of indefinite NPs is needed. For example, the natural reading of

(172) Jones bought a new lap-top and Carter (did) too.

is one according to which Jones and Carter bought distinct lap-tops. In order to obtain this reading we either have to copy the indefinite a new lap-top, so that subsequent processing of the copied phrase will introduce a separate discourse referent for it, which is distinct from the discourse referent that gets introduced for its original occurrence inside the source clause; or else we have to copy, as Klein proposed, the DRS that has already been constructed for the relevant part of the source clause.

There are also cases, however, where source clause and elliptical clause are understood as being about the same individual, which is introduced by an indefinite that belongs to the source clause. (173), for instance,

(173) Fred invited a friend of his to the inauguration of the new building, and so did Alan.

is ambiguous between a reading in which Fred invited a friend of Fred’s and Alan invited a

\[\text{54 C.f. in particular the recent book by Fiengo and May [May and Fiengo, 1994].}\]
friend of Alan's and the reading according to which there was a certain friend of Fred's who was invited to the event both by him and by Alan. The second of these readings appears to be available only when - and to the extent that - the NP can be interpreted as a specific indefinite. This suggests that the second reading is a natural consequence of what we may want to say about specific indefinites anyway: that specific indefinites carry, like proper names and many other definite NPs, the presupposition that they refer to an entity that is already familiar - and that, therefore, the discourse referent for the NP can be identified with the one which represents this entity in the context. For even if the specific indefinite is processed twice over - introducing a new discourse referent each time - the net effect will be that both these discourse referents get identified with the one which represents the contextually salient entity, so that source clause and elliptical clause are both about that entity.

But there is a snag. As we have put the matter, it is not clear why (173) could not get an interpretation according to which Alan invited the same person as Fred, but where the reconstructed occurrence of the NP a friend of his is interpreted as implying that this person is a friend of Alan's (and not only of Fred's); for there is nothing that we have said which entails that anchoring the discourse referent for this NP prevents the reconstructed pronoun from being given a "sloppy" interpretation, so that it refers to Alan. We are convinced, however, that (173) just does not have this reading, (even though it is, in view of what interpretations are possible, quite difficult to establish this unequivocally).

The fact that this reading is not possible is one indication that specific indefinites and other definite NPs which require contextual anchoring are not subject to the mechanisms of reconstruction and/or parallel interpretation which, we believe, are a crucial ingredient in the interpretation of ellipsis and which, in particular, are responsible for the possibility of assigning pronouns sloppy readings. Thus, by interpreting the indefinite of (173) specifically one takes it thereby out of the relevant "parallelism domain". To give substance to this metaphor it will of course be necessary to make the notion of "parallelism domain" operational.

This is something that is still to be done. However, to see how things would work according to an account along these lines, we have, in the representations of the different possible interpretations of (173) below, indicated (by means of dotted lines) the parallelism domain relevant for this particular example. The first of these, (174), gives the non-specific sloppy reading.
The specific reading is given by (175)

(175) indicates how the “discourse connectedness” of the specific indefinite takes the phrase - and with it both the discourse referent $y$ and the conditions it introduces - outside the parallelism domain, leaving within that domain only the occurrence of $y$ in the argument slot of the verb invite. This prevents the indefinite from being interpreted anew as part of the elliptical clause, so that no second discourse referent will be introduced for it. By the same token it blocks a “sloppy” interpretation of the pronoun his. For “sloppy interpretation” is a matter of reinterpretation. But here the pronoun is interpreted only once. (We are aware that there is a fair amount that has to be taken on faith here, since the diagrams (174) and (175) do not show the relevant details of the construction algorithm. We will address these details elsewhere.)
Are (174) and (175) all the interpretations that can be assigned to (174)? According to the construction algorithm that has been used to construct these, there is still a third possibility, which consists in taking the indefinite as non-specific, as in (174), but assigning the pronoun his a strict interpretation, so that the sentence talks about invitations to two friends of Fred’s. It seems to us that this reading does in fact exist. The only combination that is not allowed is that of taking the NP as specific and assigning a second, sloppy interpretation to the pronoun.

(ad. 5.3.3.4)

(176) Five years ago, Anna was taller than Sarah.

D5 presents this sentence as showing that Comparative Ellipsis is more flexible than Gapping or Stripping in that it “does not necessarily require copying of tense and adjuncts”. The sentence is presumed to show this because it allows both for the reading that five years ago Anna was taller than Sarah is now and the reading that five years ago Anna was the taller one of the two of them.

Since (176) does seem to allow for these two interpretations, there is clearly a sense in which it “does not necessarily require copying of tense and adjuncts”; for if these were copied, only the second of the two readings would have been possible. We are not sure, however, that this is the best way of glossing the apparent ambiguity of the sentence. For it isn’t clear to us that (176) must be construed as a case of ellipsis in the first place. But if it is not, then the question of copying or not copying tense and/or temporal adverb simply does not arise.

We suspect that (176) might well have a syntactic analysis according to which the complement of the particle than is an NP (or possibly DP), and not a truncated clause. This, we believe, is almost certainly the right analysis for sentences like

(177) Five years ago, Anna was (already) taller than 1 m. 50.

Neither the syntax nor the semantics of this sentence suggests that it should be seen as elliptical (for something like than 1m. 50, or whatever). Nor, for that matter, does there seem to be any possibility of embedding 1m. 50 into a complete clause so that the resulting sentence is more than marginally grammatical.

Admittedly the parallel between (177) and (176) is not perfect, for the comparative phrase taller than does not seem to do exactly the same job in (176) as it does in (177). In (176) it overtly relates a person and a height, in (176) it relates two persons. But the difference does not seem to be a very fundamental one. For in either sentence the comparison reduces to one between two heights; that the subject of the comparison (here Anna) enters into it by way of her height is a general property of comparisons involving taller - this is what has been called the “dimensional aspect” of the meaning of tall. Even after this has been noted, it remains true that (176) and (177) represent two distinct cases, one in which the second term of the comparative relation is a term that denotes a height directly and one where it denotes an entity that we can assume to have a definite height. But the difference between them would
seem to be comparatively minor; while it is clearly a matter of grammar that both uses are permitted, the use we find in (176) is arguably related to the one exemplified in (177) by simple metonomy.

If we are right in believing that (176) has a non-elliptic analysis, then the ambiguity of (176) is not a matter of constraints on ellipsis but is to be explained differently. The explanation should now presumably be along the same lines as an account of the ambiguity of sentences like

(178) When I met Bill a couple of years ago, his car was brand new.

(178) can be interpreted either as saying that the car that Bill has now was brand new at the time of the earlier meeting, or that at the time of that meeting the car Bill was driving then was brand new. As first extensively discussed in En(198?), common noun phrases have the property that the time at which they are supposed to be true of the objects they describe need not be identical with that of the eventuality described by the clause in which the common noun phrase occurs. This is true in particular for those cases where the common noun is the lexical head of a definite description, as it is in (178), where, as we have just seen, his car can, but need not be interpreted as denoting the object which satisfies the predicate “car which Bill has” at the time of the meeting event described by the sentence.

The same story could be plausibly told, it appears to us, about the comparative phrase Sarah of (176). For, according to what we said about the semantic contribution which the phrase makes, it acts essentially as the description “Sarah’s height” and this latter phrase allows for descriptive evaluation at different times just as his car does.

Further investigations will have to show whether the syntactic analysis of (176) on which this story rests is tenable. But assuming that it is, there still remains a further question, viz whether this is its only syntactic analysis. Perhaps (176) also has an analysis according to which Sarah is the subject of an elliptical clause. We suspect that there are no good grounds on which such an analysis could be excluded, since it is clearly required for many other comparative sentences, like e.g.

(179) Fred drove faster than Bill.

In view of the apparent structural similarity between (176) and (179), it would require a special argument to show that an elliptical analysis is inadmissible in the case of (176). The unlikelihood of such an argument appears reinforced when we compare (176) and (177) with sentences like

(180) Anna is taller than Sarah is.

(181) Fred drove faster than Bill drove.
(180) is an unmistakable instance of ellipsis and its interpretation coincides with that of

(182) Anna is taller than Sarah.

just as the interpretation of (181) coincides with that of (179). All this suggests strongly that
the difference between (180) and (182) is, like that between (182) and (179), a simple case of
the alternation between VP deletion and stripping.

To sum up: we assume that sentences like (176) are syntactically ambiguous, between an
analysis which treats the complement of than as a phrase and one which treats it as an
elliptical clause. On the first analysis the observed ambiguity is of the same making as that
of a sentence like (178). When (176) is analyzed as involving ellipsis, then, we conjecture, it
is an authentic case of stripping. This would entail that the sentence is not ambiguous, but
only has the second of the two readings we described at the outset (that according to which
Anna’s height five years ago exceeded Sarah’s height five years ago).55

5.1.6 Interaction of Ellipsis and Quantification.

The “reconstruction + parallel processing of source clause and reconstructed elliptical clause”,
which DRT has been proposing (and to which we have alluded repeatedly in these comments),
deals unproblematically with examples like (90) and (91):

(184) Every accountant contributed to a report on a project, and every executive did too.

(185) Every accountant contributed to a report on a project. Every executive did too.

More problematic are the notorious instances of “antecedent-contained deletion”, as in

(186) Smith consulted everyone that Jones did.

When we construct a DRS for (186) in the manner of [Kamp and Reyle, 1993], things come
out the way they should, provided we appeal, at the crucial point, to a new principle. To
see where the problem lies, consider (187), which results from processing the subject and the
direct object of (186). (We have assumed here that everyone can be analyzed as every person.

55Question: Can a sentence like

(183) In yesterday’s Indianapolis Grand Prix Schumacher drove faster/better/better even than Fittipaldi.

be interpreted as something like S. drove faster, etc. than F. usually did/ever did; and can it be used
feliciously even in a case when Fittipaldi did not participate in the given race (and where he has in fact retired
from Formula 1 racing altogether or may even be dead? N.B. I do not really get these possibilities, but I may
be biased by the present proposal: H. K.

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Moreover, for reasons of presentation we ignore problems of tense here; thus we work within the framework of [Kamp and Reyle, 1993], Ch. 1 - 4, not that of Ch 5.:

![Diagram](image)

(187)

The problems emerge when we try to carry out the next construction step. This step ought to be the one which decomposes the complex condition on the left into a condition which only concerns the head noun and a condition that concerns the relative clause. The operations that are needed to obtain this second condition presuppose that the relative clause contains a gap which corresponds to the relative pronoun; when this presupposition is satisfied, the effect of the operations is to insert the discourse referent in parentheses - here $x$ - into the gap and at the same time to remove the relative pronoun.

But are these presuppositions fulfilled here? This is difficult to say, since, as it stands, the relative clause in question is elliptical. Should we then first reconstruct this clause? Let us see, whether this is going to help.

One problem we are facing here is that in the case of (187) reconstruction cannot be carried out at the level of syntax. For the reconstruction source, i.e. the main VP of (186), has already been processed. In general we must, in order to be able to cope with situations of this kind, keep, as we construct the DRS, a record of the syntactic structure from which the construction starts as well as how the parts of the emerging DRS correlate with the different syntactic constituents of this structure. Doing this will result in something like a sign in the sense of HPSG, in which syntactic and semantic structure are correlated both at global and at the local level. The construction of such correlated structures requires a certain amount of bookkeeping which most current versions of DRT (including that of [Kamp and Reyle, 1993]) have not bothered to go into. But it can be done. (As it now is in the syntax-semantics interface which is being developed within the project VERBMOBIL.)

Let us assume that it has been done and that, in particular, it tells us that the material in (187) that corresponds to the main VP of (186) is the “VP part” of the condition of the right hand side sub-DRS. (Recall that DRS conditions inherit part of the syntactic structure that serves the construction algorithm as input. In particular, the condition in question will be as in (188), where the “VP part” has been delineated by a dotted line:

Reconstruction, with the help of this constituent, of the VP deletion in the left hand side sub-DRS, should involve inserting the subject of the deleted clause in the subject slot of the condition. This is a general constraint on the reconstruction of VP deletions at DRS level, which reflects the intuition that what is constructed in such cases is a predicate of the subject and which holds also for cases of VP deletion which do not involve antecedent containment. We regard this constraint as uncontroversial and assume that VP-deletion reconstruction
obey it.

Carrying out this reconstruction we obtain (189)

At this point the real difficulty comes into view: the presupposition of the construction rule that should be applied now, viz. that what follows the noun person in the last condition on the left has a gap corresponding to the relative pronoun, is not fulfilled. So the rule cannot be applied and that is where the milk train stops.

What can be done? One solution, first suggested by [Lappin, 1993], is that antecedent-contained deletion is really a species of the kind of ellipsis which in the literature goes by the unfortunate name of ”pseudo-gapping”, a construction which we find e.g. in the sentence

(190) Smith wrote to the president after Jones did to the secretary.

It needs little to see that pseudo-gapping is closely related to VP deletion - an indication is that one finds it only in the comparatively few languages (of which English is one) which permit VP deletion. In fact, it might be said that pseudo-gapping stands to VP-deletion as gapping stands to stripping.

In unmistakable instances of pseudo-gapping such as (190) the elliptical clause contains besides the subject and the dummy verb one or more further constituents, which like in gapping constructions must be “major constituents” (roughly: either arguments or adjuncts of the deleted verb). This is a condition which, on the face of it, is not satisfied by cases of antecedent-contained VP deletion. But this may be just a matter of appearance; for it might be that the additional constituent whose presence distinguishes pseudo-gapping from VP-deletion is present, but as an empty element. If this were so, then the syntactic structure of the relative
clause of (186) would have the form:

(191)

Furthermore, reconstruction would now, as in all other cases of pseudo-gapping, involve re-
constructing just the missing verb (as well as perhaps, depending on the relationship between
the elliptical clause and its source, some further constituents, but for our example this is irre-
levant). This means that if the relative clause of (186) has the form given in (191), then
reconstruction in (187) will yield the DRS ((192)

where, just as in (191), $t_1$ is the gap of the relative clause. Application of the construction
rule for complex common noun phrases will now do what it should and give us (193)

\[\Diamond\]

From a formal perspective this solution may seem attractive enough. But unfortunately it
runs into empirical problems. For pseudo-gapping is a fairly marked construction in Eng-
lish, which is subject to stringent (albeit not yet fully understood) constraints. Antecedent-
contained deletion, on the other hand, is not subject to many of these constraints, which
would be puzzling if it were a piece of the same currency.

If for such reasons the pseudo-gapping solution is rejected, only one solution that we know of
remains. This is the one proposed by [May and Fiengo, 1994], who see it as evidence for the

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need of LF as a separate level of representation. According to this solution, reconstruction of the elliptical clause takes place in the syntax, but after quantifier raising has been applied to the phrase *everyone that Jones did*. The quantifier raising leaves behind an NP trace in the position of the direct object of the main clause, which is then copied into the relative clause during reconstruction. The syntactic structures (194) and (195) show the crucial stages:

(194)

(195)
DRS construction off the syntactic structure (195) will now follow the lead of the coindexation, entering the discourse referent introduced for the index 1 at all places where this index occurs (we omit the obvious details). This leads to the DRS (196)

\[
\begin{array}{c}
\text{Smith consulted } x \\
\forall x \\
\text{Jones consulted } x \\
\text{person}(x) \\
s \end{array}
\]

which yields the correct representation after processing of the two proper names.

It is worth reflecting briefly on the difference between the Fiengo-May solution and the procedure with which we started out, which, we recall, ran into problems over the conversion of the condition \(\text{person that Jones consulted } x (x)\). In that condition there is, so to speak, one occurrence of \(x\) too many. The Fiengo-May solution avoids this problem because it does the reconstruction before the bound variable of the quantifier every gets introduced. This way, what gets reconstructed is the trace, which acts as the gap of the reconstructed relative clause. It should also be noted in this connection that this trace originates as the place holder for the raised direct object of the sentence; through reconstruction it acquires a new function, that of the trace of the relative pronoun \(that\).

What does the trick here is that LF gives us a representation of a “VP with a gap”, something which we lose when we embark on DRS-construction too soon.

### 5.1.7 Interaction of Ellipsis and Anaphora

The problems illustrated by the examples in this section - those concerning so-called “strict” and “sloppy” interpretations of reconstructed pronouns - have already been touched upon in passing.

A large proportion of the discussions one finds of this topic in the literature concerns examples such as

(197) Smith represents his company and Jones (does, ) too.

(198) Smith represents his company. Jones (does,) too.

Such examples, which involve VP-deletion or stripping, are comparatively simple, insofar as the pronoun options that they present only concern one issue: Should the reconstructed pronoun be interpreted as referring to the new or to the old subject? \(e.g.,\) should ((197),(198)) be
The problem is comparatively simple in the cases before us because here there is only one major constituent, viz. the subject, with regard to which elliptical clause and source clause differ. With gapping and pseudo-gapping, where there are two or more such constituents, we find a corresponding increase in possibilities, as can be seen in

(199) Fred said to Carl that he had been wrong and Bill to Alan.

(199) is multiply ambiguous. First there is the referential ambiguity of the first conjunct, which can be interpreted as claiming that Fred said to Carl that Fred had been wrong or that Fred said to Carl that Carl had been wrong. Suppose that the first of these possibilities is chosen. Then the interpretation of the second, elliptical clause still allows for two interpretations, the strict one, according to which the reconstructed pronoun refers to Fred, and the sloppy interpretation, according to which it refers to Bill. Note that, given our assumption about the interpretation of the first conjunct, these are the only two possibilities for the second conjunct; neither the interpretation which interprets the reconstructed he as Carl nor the one which interprets it as Alan are available. Similarly, when the first conjunct is interpreted according to the second option, the only two possibilities for the he of the second conjunct are Carl and Alan.

It is not hard to see the principle underlying this pattern of possibilities. It has two parts:

- with (199), as with all cases of gapping and pseudo-gapping, there exists a structural parallelism between the constituents of the elliptical clause and certain constituents of the source clause; in the present case, Bill corresponds to Fred and Alan to Carl. This parallelism drives first the reconstruction of the elliptical clause and then the coordination of the interpretations of reconstructed clause and source clause.

- reconstructed pronouns allow for only two interpretations, a “strict” and a “sloppy” interpretation; strict interpretation means that the reconstructed pronoun is construed as anaphoric to the same antecedent as the non-reconstructed occurrence, sloppy interpretation that it is anaphoric to that constituent of the elliptical clause which is parallel to the anaphoric antecedent of the non-reconstructed occurrence.

It can be verified that all cases of gapping and pseudo-gapping follow these principles. Moreover, it is easily seen that the anaphoric possibilities we find with stripping and VP deletion are in accordance with these principles too, but under the simplified conditions that there is always just one pair of parallel constituents. This means that a solution to the strict-sloppy problem which works for pseudo-gapping and gapping will work for stripping and VP-deletion as well.

To explain the algorithm which has been proposed within DRT to deal with this problem

\[^{56}\]In suitable contexts the pronoun he could also be interpreted as referring to some third, earlier mentioned individual, but let us ignore that possibility here!
in all details would carry too far. So let us just present the highlights of the analysis as it applies to one particular case, viz. to (199).

The first task is for the parser to recognize the second conjunct of (199) as a case of gapping, to identify its constituents, to find a possible source clause (taking into consideration the special constraints on the connection between source clause and elliptical clause that are imposed by the type of ellipsis in question; e.g. with gapping the two clauses must be coordinated or else related as main clause and comparative clause of a comparative construction, etc.), and to find appropriate parallel syntactic analyses of source clause and elliptical clause, together with a correspondence between these analyses which makes the parallelism explicit. In the case of (199) this leads to a syntactic analysis of the following kind:

(200)

On the strength of this analysis it is then possible to reconstruct the elliptical clause by replacing the -nodes of the right hand side S-tree by copies of their images under f.

We now come to the actual construction of the DRS. In cases involving ellipsis DRS construction proceeds in tandem for the two correlated S-trees. The constructions for the two trees must be parallel in the sense that where there is a choice between two construction rules, or between two ways of applying the same rule, the same choice must be made on the right hand side that is also made on the left hand side. (For instance, when an indefinite NP from the first conjunct is given a specific interpretation and this NP has been copied over to the right hand tree, it must also get the same specific interpretation there, etc.). Note that because the two syntactic trees are largely isomorphic (i.e. they have isomorphic subtrees each of which covers most of the nodes of its host tree), the two DRS constructions will for the most part involve the same rules or rule options.

Given these stipulations most of the construction process for (200) is uneventful. We present the two DRSs at the point where the construction procedure has got to the two occurrences
of he.\textsuperscript{57}

\begin{verbatim}
<table>
<thead>
<tr>
<th>f c p b a q</th>
</tr>
</thead>
<tbody>
<tr>
<td>fred(f)</td>
</tr>
<tr>
<td>carl(c)</td>
</tr>
<tr>
<td>bill(b)</td>
</tr>
<tr>
<td>alan(a)</td>
</tr>
<tr>
<td>told(f, c, p)</td>
</tr>
</tbody>
</table>

\[(201)\]
\[
p = [\_ [NP he] [VP had been wrong]]
\]
\[
told(b, a, q)
\]
\[
q = [\_ [NP he] [VP had been wrong]]
\]
\end{verbatim}

In (201) the correspondences established by \( f \) between the two halves of (200) have been transferred to constituents of the two DRSs. Again, it should be clear that there is no fundamental obstacle to setting up the construction algorithm in such a way that it does this.

For the first \( he \) of (201) we consider, as we said we would, only the two possibilities of its referring to Fred and to Carl, respectively. Let us choose the second option. This turns (201) into (202)

\textsuperscript{57}We have represented the indirect discourse locution \( \ldots \) told \( \ldots \) that \( \ldots \) as a relation “told” between the sayer, the addressee and a proposition, the meaning of which is given by a DRS for the complement clause.
For the second he there are now just two options: (i) the strict interpretation. Assuming y is the discourse referent introduced by the second he, this interpretation will be given by the equation $y = c$; (ii) the sloppy interpretation, in which the second he is interpreted as anaphoric to that constituent of the elliptical clause which corresponds to the antecedent of the first he - i.e. to the image of that antecedent under $f^{-1}$. This leads to the equation $y = a$. For good measure the second interpretation is displayed in (203)
We noted that in the right context the first occurrence of *he* might refer to an individual not mentioned in the source clause but earlier in the discourse. Thus in

(204) That afternoon John’s chances to be elected to the board received a serious setback. Fred said to Carl that he had been wrong and Bill to Alan.

Here it is plausible to interpret the *he* of the source clause as referring to John (though interpreting it as referring to Fred makes good sense too; perhaps Fred had been supporting John, thinking he was the right man for the job, but has just come to change his opinion). Note, however, that when the first *he* is so interpreted, then there is only one option for the reconstructed *he*: it too must refer to John. Note also that this is what the theory predicts: Since John is not a constituent of the source clause, it cannot be the counterpart of any constituent of the elliptical clause. So the precondition for the sloppy reading is not fulfilled, and only the strict reading remains.

For a third example showing the theory at work, consider

(205) Fred hired a candidate who was prepared to say that he was the best programmer in town and so did Bill.

The first conjunct of (205) has two interpretations, both of which are quite natural (the first portrays Fred as credulous, the second as vain.) If we choose the first interpretation, then we can interpret the second conjunct either as saying that Bill hired someone who claimed that Fred was the best programmer or as claiming that he, Bill, was the best one. If the first conjunct is interpreted as being about a candidate who was prepared to call himself the best programmer in town, then this same interpretation is available also for the second conjunct. All this the theory predicts. It also predicts that on this second interpretation of the first conjunct there is also a second interpretation for the second clause. According to this interpretation the candidate hired by Bill said that it was the candidate hired by Fred who was the best programmer in town. This does not appear to be a reading that springs to mind. Even so, we believe that the sentence can be legitimately given this reading.

At last we return to the examples of D5. Consider the instance of “Cascaded Ellipsis” given there, viz.

(206) John realizes that his company will not win the contract, but Fred doesn’t, even though Mary does.

This sentence has a reading according to which John realizes that John’s company will not win the contract, Fred does not realize that Fred’s company will not win the contract, but Mary does realize that Fred’s company will not win the contract. This reading assigns the second *his* a sloppy and the third *his* a strict interpretation.

Such interpretations have been used in the literature to argue against all analyses which
attempt to account for the strict-sloppy distinction as originating in a structural ambiguity of the source clause: whether the reconstructed pronoun is to be interpreted the strict or the sloppy way is a matter of how the original token of the pronoun is embedded in its (i.e. the source) clause. Clearly this flies in the face of the reading which we just spelled out for (206); for the position of the pronoun *his* in the first clause would on the one hand have to licence its sloppy interpretation as part of the second conjunct and on the other the strict interpretation it receives in the third clause. Obviously you cannot have it both ways. (For discussion see in particular [Sem, 1994].)

The DRT account of ellipsis is not of this kind and so is not directly ruled out by this argument. Of course this is no guarantee that things will come out right. But they do come out right, provided we assume - but this is entirely consistent with the strategy pursued so far - that in a “cascade” each next elliptical clause may choose any of the preceding clauses in the cascade for its source, with a strong bias for the immediately preceding clause. Moreover, once a source has been chosen, the interpretation of reconstructed pronouns in the reconstructed clause in question are subject to the very principles which we have been using. For (206) this means that interpretation can proceed as follows. (i) the second clause, for which of course only the first clause qualifies as source clause, is given the reading with the sloppy interpretation for *his*. (ii) the second clause is chosen as source clause for the third clause, (iii) when *his* is to be interpreted as part of assigning a reading to the third clause there is the choice between a sloppy reading, according to which Mary realizes that her company will not win the contract (this reading may be inhibited somewhat by the “vehicle change” it involves) and a strict reading, which gives the interpretation we described at the outset.

What other interpretations are possible for (206)? First, one that is not possible. This is the reading according to which Fred did not realize that John’s company will not win the contract and Mary realizes that Fred’s company will not win the contract. The reason why this reading is out should be clear: To interpret the second clause the way the present reading has it, we have to interpret its *his* as referring to John and thus as having an antecedent lying outside the clause itself. If we then use the second clause as source clause for the third clause, the only option is the strict reading; in other words, *his* must once more be taken to refer to John. It is clear, moreover, that taking the first clause as source clause for the third clause would not get us the impossible reading either.

What about the following seemingly close variant of the reading of the last paragraph: Fred doesn’t realize the fate of John’s company, but Mary realizes the fate of her own company? This reading seems quite marginal to us. Whether our theory licences it depends on how seriously we take the possibility that the third clause may use the first clause, rather than the second, as its source. If it can, then it should be possible in principle for the third *his* to get a sloppy interpretation - which it can now receive because the antecedent of the first *his* is within the first clause. If however, the first clause is ruled out as source clause for the third, then the present reading is of course no more possible than the one of the last paragraph.

D5 contains two more examples which should be mentioned here. The first is

(207) Smith believed that he represented his company, and so did Jones.
When reconstruction involves, as in (207), more than one pronoun, then there is the possibility of giving some a strict and some others a sloppy interpretation. (207) exemplifies this, for it has the reading according to which Jones believed that he, Jones, represented Smith’s company. But at the same time it shows that not everything goes; for it lacks the reading according to which Jones believed that Smith was representing Jones’s company. It was thought for some time that the prohibition against this last reading was a matter of syntactic configuration: when one of the pronouns commands the other, then giving the commanding pronoun a strict reading prevents assigning a sloppy reading to the commanded one. However, it seems now clear that other factors, having to do with argument structure and the thematic roles of the arguments of verbs, play a part that is at least as important. (See in particular [Engdal, 1990]). The final story about such sentences is still to be told. As things are, there is no reason to believe DRT will have much to contribute to it.

The final example.

(208) Bill suggested to Frank’s boss that they should go to the meeting together, and Carl to Alan’s wife.

has played a fairly prominent role in DRT-based discussions about ellipsis, especially about the place of the theory of ellipsis within a comprehensive description of English. The example has many of the features we have discussed in connection with (199). But in addition it presents an aspect which (199) does not have and which is crucial to the methodological point it was meant to score. This is that the interpretation of the reconstructed plural pronoun they is on the one hand subject to the same parallelism constraints which we stated in our discussion of (199) and on the other hand requires, here as in many other places, reliance on the principle of “Summation” to provide it with the wanted antecedents. And, as has been argued at length within the DRT-literature, Summation is a prime example of what may be called “principles of discourse semantics” - principles which are unequivocally part of the grammar insofar as they capture aspects of the meaning and use of certain expressions, rather than being principles of general logic; but whose place within the over-all theory is nevertheless at the level of discourse interpretation, because they must often be applied to elements of the discourse representation which stem from distinct sentences. These observations suggest that the interpretation of sentences like (208) happen at a direct interface between syntax and discourse semantics and that the conception of a theory of grammar as involving a level of “syntax-friendly” semantics to mediate between the syntax proper and a level of discourse interpretation that is heavily infected with pragmatics, cannot be easily upheld.

5.2 Update and Dynamic Semantics

In the dynamic semantic perspective, it has been proposed to interpret the distinction between strict and sloppy readings of VP anaphora, as in 5, as the distinction between procedure calling with static or dynamic variable binding (see Gardent [Gardent, 1991] and Van Eijck and Francez [Eijck and Francez, to appear]).
5 John loves his wife. Bill does too.

A reasonable representation for the source clause of this example is:

\[ y = j; tz : \text{wife-of} (y, z); \text{love} (j, z). \]

Here \( y \) is the marker for representing his. Now we assume that the VPE is interpreted by means of a call to a procedure \( P \) which is extracted from the source clause. Then the full representation of source clause, definition of the relevant VPE procedure, and target clause would look something like this:

\[
y = j; tz : \text{wife-of} (y, z); \text{love} (j, z);
\text{PROC} P(x) : tz : \text{wife-of} (y, z); \text{love} (x, z)\text{END};
\text{NEW} y : \eta y; y = b; P(b)\text{END}.
\]

The procedure definition just says that the name \( P \), with a parameter, can be used to anaphorically refer to the verb phrase of the source clause. Note that the procedure body contains an occurrence of \( y \), a variable which is global to the procedure. In the representation of the target clause, a local variable with the same name \( y \) gets declared, \( y \) is set equal to the representation of the subject of the target clause, and the procedure is called with a parameter referring to the subject of the target clause.

The difference between static and dynamic binding of variables, in this case the variable \( y \), depends on whether the variable name is interpreted to refer to its location at the time of procedure definition (this is called static binding) or at the time of procedure calling (this is called dynamic binding). In this case: does \( y \) refer to the location at the time of procedure definition, which contains the value \( j \), or to the new location which was created by the \texttt{NEW} local variable declaration, which contains the value \( b \).

To work out the formal details of this, a distinction is necessary between allocations and memory states. Let \( A \) be a set of addresses of storage cells. Then \( (A \cup \{*\})^V \) is the set of all allocations for \( V \). If \( l \) is an allocation and \( l(v) = * \) then we say that \( v \) has not been allocated by \( l \), or that \( v \) has not been initialized by \( l \), or that \( v \) is an undeclared variable under \( l \). Otherwise the allocation of \( v \) is an address in \( A \). Let \( M = (U, I) \) be a first order model of the right signature to interpret the relation symbols of a particular DPL language. (we assume that \( U \neq \emptyset \)). \( U^A \) is the set of all memory states for \( M \). For a systematic study of the distinction between allocation and storage in dynamic semantics of natural language we refer the reader to [Vermeulen, 1994; Vermeulen, December 1991].

If \( s \) is a state and \( l \) is an allocation, then \( s \circ l \) is the partial assignment of individuals in \( U \) to variables in \( V \) which is defined as follows:

\[
s \circ l(v) = \begin{cases} s(l(v)) & \text{if } l(v) \neq * \\ \uparrow & \text{otherwise.} \end{cases}
\]

Because the composition of an allocation and a state is a partial assignment, one has to modify the original DPL semantics to cater for the possibility that a relation is called without an
Ellipsis is the general name of the phenomenon where part of the syntax and/or semantics of a natural language sentence or text (the elliptic clause) has to be reconstructed on the basis of similarity with another part of the sentence or text (the antecedent). If defined like this, VP anaphora is a kind of ellipsis. It seems plausible that the ‘procedural approach’ to VP anaphora can be extended to cases of ellipsis. A sketch of a discourse approach to ellipsis which includes VP anaphora and gapping is given in Prüst [Prüst, 1991].

5.3 Situation Semantics

The treatment of VP ellipsis builds on the treatment of anaphora. The actual ellipsis mechanism has not yet been incorporated into this grammar.

5.4 Property Theory

It appears that no special treatment of ellipsis, exemplified by:

\[\text{Smith went to Paris by car, and Jones by train.}\]
\[\text{ITEL sent CRC a report, and APCOM did too.}\]

has been explored in PT, although it must be noted that Dynamic PT allows propositions to be anaphoric without re-introducing the paradoxes, as in Dynamic Montague Grammar with conventional set-theoretic models.

5.5 Monotonic Semantics

The treatment of ellipsis in QLF bears many parallels to that of [Dahyrmple et al., 1991] (henceforth DSP) in that it gives broadly similar results. However, it employs a simple system of substitutions on QLF rather than higher-order unification, and the order in which scope and ellipsis resolutions are carried out is not significant. (The treatment is even more similar to that of Kamp, as outlined in [Gawron and Peters, 1990]).

5.5.1 Simple VP Ellipsis

A simple, uninteresting example to fix the basic ideas:
We can represent the first sentence, heavily abbreviated and ignoring tense, as a resolved QLFL

$$[J]: [\text{sleep},$$

$$\quad \text{term(proper\_name(tpc),J),}$$

$$\quad X^\ast [\text{name},X,'John'],$$

$$\quad \text{exists,ent(j\_smith)})]$$

We can represent the ellipsis, again abbreviated, as

form(vp\_ellipsis(...), E,

$$\quad P'P, \text{term(proper\_name(_),M),}$$

$$\quad X^\ast [\text{name},X,'Mary'],$$

$$\quad _,_)]$$

To resolve the elliptical form, we need to find some contextually salient property to which the form restriction can be applied. In this case, the property is furnished by the preceding sentence, and we can represent the results of the application\(^{58}\) as

$$[J]: [\text{sleep},$$

$$\quad \text{term(proper\_name(tpc),J),}$$

$$\quad X^\ast [\text{name},X,'John'],$$

$$\quad \text{exists,ent(j\_smith)})]$$

:/{ \text{term(proper\_name(_),M,X^\ast [\text{name},X,'Mary'],_,_) /}$$

$$\quad \text{term(proper\_name(tpc),J,X^\ast [\text{name},X,'John'],\text{exists,ent(j\_smith)}),}$$

$$\quad \text{M/J}]}$$

That is, replace occurrences of the index \(J\) by \(M\), and occurrences of \(\text{term(...J...)}\) by \(\text{term(...M...)}\).

When resolving the ellipsis we do not actually make the substitutions listed. However, doing so would give

$$[M]: [\text{sleep},$$

$$\quad \text{term(proper\_name(_),M),}$$

$$\quad X^\ast [\text{name},X,'Mary'],$$

$$\quad _,_)]$$

A couple of points. First, the substitutions are not applied in the conventional order; i.e. first replace \(J\) by \(M\) throughout the expression and then replace \(\text{term(...J...)}\) by \(\text{term(...M...)}\).

\(^{58}\)The property is a vacuous one-place abstraction over this expression
The first substitution would ensure that there was no term(...) for the second substitution to replace. The order in which substitutions apply instead depends on the order in which the expressions occur when making a top down pass through antecedent expression, such as one would do when applying semantic evaluation rules to it.

Second, the term indices are also replaced in scope nodes, ensuring the (quantificational) term for Mary gets scoped in the same way in the ellipsis as the term for John did in the antecedent. The scope parallelism this engenders is not significant for names (though easier to illustrate), but is useful when it comes to more obviously quantificational terms.

5.5.2 Unscoped Antecedents

To obtain scope parallelism, the antecedent does not have to be fully scoped beforehand. An unscoped version would have an uninstantiated meta-variable in place of the scope node, [J]:, and scoping simply instantiates the meta-variable. Since the ellipsis substitutions actually apply to the antecedent QLF, any meta-variable instantiations on the antecedent will automatically show up on the ellipsis resolution, since these share meta-variables.

The idea behind the substitutions is that whatever the meaning of the antecedent turns out to be, you reinterpret it according to the substitutions. At the time of deciding what the reinterpretable substitutions should be, you may not yet have fully determined what the meaning of the antecedent is. If you were to apply the substitutions as soon as you had decided on what they are and leave it at that, subsequent resolutions of the antecedent meaning would be missed by the ellipsis interpretation.59

5.5.3 Strict and Sloppy Identity

The notion of strict and sloppy identity is usually confined to pronominal items occurring in antecedents and (implicitly) in ellipses.60 A standard example is

\[ \text{John loves his mother, and Bill does too.} \]

On the strict reading, Bill and John both love John’s mother. The implicit pronoun has been strictly identified with the pronoun in the antecedent to pick out the same referent, John. On the sloppy reading Bill loves Bill’s mother. The implicit pronoun has been sloppily identified with its antecedent to refer to something matching a similar description, i.e. the subject or agent of the loving relation, Bill.

The sentence

59If the antecedent were fully resolved, i.e. contained no meta-variables, it would be safe to apply the substitutions on a once only basis.
60Also to pronouns of laziness.
John read a book he owned, and so did Bill.

has three readings: John and Bill read the same book; John and Bill both read a book belonging to John, though not necessarily the same one; John reads one of John's books and Bill reads one of Bill's books.

Intuitively, the first reading arises from strictly identifying the elliptical book with the antecedent book. The second arises from strictly identifying the pronouns, while sloppily identifying the books. The third from sloppily identifying both the books and the pronouns. In the literature, the first reading would not be viewed as a case of strict identity. But this view emerges naturally from our treatment of substitutions, and is arguably a more natural characterisation of the phenomena.

Following DSP [Dalrymple et al., 1991], we need to distinguish between primary and secondary terms in ellipsis antecedents. Primary terms, like John in the example above, are those that correspond terms appearing explicitly in the ellipsis. Secondary terms are those that do not have an explicit parallel in the ellipsis.61

For primary terms, we have no choice about the ellipsis substitution. We replace both the term and its index by the corresponding term and index from the ellipsis. But for all secondary terms we have a choice between a strict or a sloppy substitution.

A sloppy substitution involves substituting a new term index for the old one. This has the effect of reindexing the version of the term occurring in the ellipsis, so that it refers to the same kind of thing as the antecedent term but is not otherwise linked to it.

A strict substitution substitutes the term by its index. In this way, the version of the term occurring in the ellipsis is directly linked to antecedent term.

To illustrate, an abbreviated QLF for the antecedent *John read a book he owned* is

```
_S:[read,
   term(...,J,...,ent(j_smith))
   term(...,B,
   X^[and,[book,X]
   [own, term(...,H,...,intra(J)),
   X]],
   ...
  ]
```

Here, we have left the scope node as an uninstantiated meta-variable _S_. The pronominal term H occurs in the restriction of the book term B. The pronoun has been resolved to be that co-indexed with the subject, J.

The ellipsis can be represented as

61 How to decide which terms are primary and secondary is touched on below.
The three readings are illustrated below (listing substitutions and the results of their application)

**Strict book**

Substitutions:
{ term((...W...)/term((...J...), W/J, B/term((...B...), ...}

Result
_S_:[read, term((...W,...,ent(w_jones)) term((...B1, X^[and,[book,X]
[own, E, X]], ...
]

(a) Since all reference to the term H is removed by the strict substitution on the term in which it occurs, it makes no difference whether the pronoun is given a strict or a sloppy substitution.
(b) Strict substitution for the book leaves behind an occurrence of the index B in the ellipsis. For the QLF to be interpretable, it is necessary to give the antecedent book term wide scope over the ellipsis in order to discharge the index.

**Sloppy book, strict pronoun**

Substitutions:
{ term((...W...)/term((...J...), W/J, B1/B, H/term((...H...})

Result
_S_:[read, term((...W,...,ent(w_jones))
    term((...B1, X^[and,[book,X]
        [own, H, X]], ...
    ]

As above, the antecedent pronoun is constrained to be given wide scope over the ellipsis, on pain of the index H being undischargable. (Pronouns, like proper names, are treated as contextually restricted quantifiers, where the contextual restriction may limit the domain of quantification to one individual.)
Sloppy book, sloppy pronoun

Substitutions:
\[ \{ \text{term(...W...)/term(...J...), W/J,} \]
\[ \text{B1/B,} \]
\[ \text{H1/H} \} \]

Result
\[ _S: [\text{read,} \]
\[ \text{term(...W,...,ent(w_jones))} \]
\[ \text{term(...B1,} \]
\[ \text{X' [and, [book, X] } \]
\[ \text{[own, term(...H,...,intra(W)), } \]
\[ \text{X]], ...} \]
\[ ] \]

The index substitution from the primary term reindexes the contextual restriction of the pronoun. It becomes coindexed with \( W \) instead of \( J \).

5.5.4 Co-indexing and Co-reference

A sentence like *John claimed he had verified his proposal, and so did Bill* lacks a reading where Bill claims that John verified Bill’s proposal. This reading is absent on a substitutional analysis if we represent the antecedent as follows

\[ [\text{claim,} \]
\[ \text{term(...J...),} \]
\[ [\text{verify,} \]
\[ \text{term(...HE...,intra(J))} \]
\[ \text{term(...P,} \]
\[ \text{X' [and, [proposal, X] } \]
\[ \text{[of, X, term(...HIS,...,intra(HE))]],} \]
\[ ...]] \]

That is, the antecedent of *his* is \( he \), and the antecedent of *he* is *John*. This pattern of co-indexing ensures that any strict substitution for *he* will have the effect of a strict substitution on the co-indexed *his*. That is, *he* cannot be strictly interpreted in the antecedent to refer to John, but *his* be sloppily interpreted to refer to Bill. Other readings obtainable are

- Bill claims Bill verifies Bill’s proposal (sloppy he, his, and proposal)
- Bill claims Bill verifies John’s proposal (sloppy he, strict his or paper)
- Bill claims John verifies John’s proposal (strict he)
(We assume that there is at most one proposal per person; without this assumption, the strict/sloppy distinction on papers can multiply the number of readings). The substitutions that might be thought to give the missing reading involve interpreting \textit{he} strictly to refer to John, but \textit{his} sloppily, supposedly to refer to Bill:

\[\begin{align*}
\text{[claim,} & \quad \text{term(\ldots J\ldots),} \\
\text{[verify,} & \quad \text{term(\ldots HE\ldots, intra(J))} \\
& \quad \text{term(\ldots P,} \\
& \quad \quad X^\wedge \text{[and, [proposal, X]} \\
& \quad \quad \quad \text{[of, X, term(\ldots, HIS, \ldots, intra(HE))]}], \\
& \quad \quad \text{\ldots]]} \\
& \quad \text{\ldots]/term(\ldots \ldots), B/J} \\
& \quad \text{HE/term(\ldots HE\ldots), \% strict} \\
& \quad \text{P1/P, \% sloppy} \\
& \quad \text{HIS1/HIS \% sloppy} \\
\end{align*}\]

But applying these substitutions gives

\[\begin{align*}
\text{[and,} & \quad \text{[claim,} \quad \text{term(\ldots J\ldots),} \\
& \quad \quad \text{[verify,} \quad \text{term(\ldots HE\ldots, intra(J))} \\
& \quad \quad \quad \text{term(\ldots P,} \\
& \quad \quad \quad \quad X^\wedge \text{[and, [proposal, X]} \\
& \quad \quad \quad \quad \quad \text{[of, X, term(\ldots, HIS, \ldots, intra(HE))]}], \\
& \quad \quad \quad \quad \text{\ldots]]} \\
& \quad \quad \text{\ldots]/term(\ldots \ldots), B/J} \\
& \quad \text{HE/term(\ldots HE\ldots), \% strict} \\
& \quad \text{P1/P, \% sloppy} \\
& \quad \text{HIS1/HIS \% sloppy} \\
\end{align*}\]

That is, it is still John’s proposal that Bill verifies.

However, if the antecedent had been resolved so that both \textit{he} and \textit{his} are independently co-indexed with \textit{John}, but not with each other, we would have

\[\begin{align*}
\text{[claim,} & \quad \text{term(\ldots J\ldots),} \\
& \quad \quad \text{[verify,} \quad \text{term(\ldots HE\ldots, intra(J))} \\
& \quad \quad \quad \text{term(\ldots P,} \\
& \quad \quad \quad \quad X^\wedge \text{[and, [proposal, X]} \\
& \quad \quad \quad \quad \quad \text{[of, X, term(\ldots, HIS, \ldots, intra(HE))]}], \\
& \quad \quad \quad \quad \text{\ldots]]} \\
\end{align*}\]
which after applying the substitutions gives

\[
\begin{align*}
\text{[and,} & \text{[offer,term(...,HIS,...,intra(J))]}, \\
\text{[verify,} & \text{[term(...,B,...,intra(J))]} \\
\text{[term(...,P,} & \text{X \text{[and,}[\text{[offer,term(...,HIS,...,intra(B))]}]}, \\
\text{...]}} & \text{[claim,} \\
\text{[term(...,B...),} & \text{[verify,} \text{HE} \\
\text{[term(...,P,} & \text{X \text{[and,}[\text{[offer,term(...,HIS,...,intra(B))]}]}, \\
\text{...]]} & \text{]}
\end{align*}
\]

That is, the missing reading.

It is worth noting that DSP have to impose an additional restriction on permitted solutions to ellipsis equations to prevent the missing reading: if a position corresponding to a more deeply embedded pronoun is abstracted over, co-referential but less embedded pronouns must also be abstracted over. (This restriction also blocks the impossible sixth reading in the previous example).

In our terms, this restriction corresponds to saying that the more deeply embedded pronouns must be co-indexed with the less deeply embedded ones, and not merely co-referential. Phrased thus, the restriction outlaws certain types of ellipsis antecedent, but not certain kinds of term substitutions.

Both restrictions — DSP’s and ours — are open to question. The DSP restriction is hard to express properly, since it refers to depths of embedding of pronouns in logical forms, where the logical forms do not indicate what is and is not a pronoun. The parallel restriction in QLF is easier to express, since QLF distinguishes between pronominal and non-pronominal terms; and to the extent that QLF represents the syntactic structure of a sentence, the appeal to depth of embedding does not look so much like an illicit appeal to the syntax (rather than
meaning) of logical forms. Put another way, QLF can distinguish between alternative semantic compositions that might in some cases lead to identical meanings.

The problem lies in motivating our restriction on independent grounds. To block the unwanted reading, we are committed to rejecting resolutions of he verified his proposal where he and his have the same antecedent. Instead, his must have he as its antecedent (or perhaps vice versa). Taken in isolation, there is no truth conditional difference between the two resolutions. Differences only emerge in elliptical contexts.

5.5.5 Comparisons

DSP's account of the first reading of the example above is significantly different from their account of the last two readings. The first reading involves scoping the book quantifier before ellipsis resolution. The other two readings only scope the quantifier after resolution, and differ in giving the pronoun a strict or a sloppy interpretation. In our account the choice of strict or sloppy substitutions for secondary terms can constrain permissible quantifier scopings. But the making of these choices does not have to be interleaved in a precise order with the scoping of quantifiers.

The use of terms and indices has parallels to proposals due to Kehler and Kamp [Kehler, 1993a; Gawron and Peters, 1990]. Kehler adopts an analysis where (referential) arguments to verbs are represented as related to a Davidsonian event via a thematic role functions, e.g. agent(e)=john. Pronouns typically refer to these functions, e.g. he=agent(e). In VP ellipsis, strict identity corresponds to copying the entire role assignment from the antecedent. Sloppy identity corresponds to copying the function, but applying it to the event of the ellided clause.

For Kamp, strict identity involves copying the discourse referent of the antecedent and identifying it with that of the ellided pronoun. Sloppy identity copies the conditions on the antecedent discourse referent, and applies them to the discourse referent of the ellided pronoun.

Neither Kamp nor Kehler extend their copying/substitution mechanism to anything besides pronouns, as we have done. In Kehler's case, it is hard to see how his role assignment functions can be extended to deal with non-referential terms in the desired manner. DRT's use of discourse referents to indicate scope suggests that Kamp's treatment may be more readily extended in this manner; lists of discourse referents at the top of DRS boxes are highly reminiscent of the index lists in scope nodes. It is an open question whether the treatment we have presented in terms of QLF can be reformulated in DRT.

\textsuperscript{62}The converse also holds. Giving an antecedent term wide scope over the ellipsis renders the choice of a strict or a sloppy substitution for it in the ellipsis immaterial. During semantic evaluation of the QLF, discharging the antecedent through scoping will substitute out all occurrence of the term and its index before ellipsis substitutions are applied. Note though that this order dependence applies at the level of evaluating QLFs, not constructing and resolving them.
5.5.6 Other Phenomena

Space permits only cursory comments on other phenomena pertinent to interactions between scope and ellipsis.

**Type Raising:** DSP invoke unification going beyond second-order matching for dealing with certain cases where constants are matched with quantifiers, e.g. the reading of *every student revised his paper and then Bill did* where Bill revises his own paper. This holds no added complications for our approach. This may be a result of treating all terms as quantificational.

**Antecedent Contained Deletion:** A sloppy substitution for *every person that Bill did* in the sentence *John greeted every person that Bill did* results in re-introducing the ellipsis in its own resolution. This leads to an uninterpretable cyclic QLF in much the same way that DSP obtain a violation of the occurs check on sound unification.

**Cascaded Ellipsis:** The number of readings obtained for *John revised his paper before the teacher did, and then Bill did* was used as a benchmark by DSP. The approach here gets the four readings identified by them as most plausible. With slight modification, it gets a fifth reading of marginally plausibility. The modification is to allow (strict) substitutions on terms not explicitly appearing in the ellipsis antecedent — i.e. the implicit *his paper* in the second ellipsis when resolving the third ellipsis.

We do not get a sixth, implausible reading, provided that in the first clause *his* is resolved as being coindexed with the term for *John*; i.e. that *John* and *his* do not both independently refer to the same individual. Kehler blocks this reading in a similar manner. DSP block the reading by a more artificial restriction on the depth of embedding of expressions in logical forms; they lack the means for distinguishing between coindexed and merely co-referential expressions.

**Multiple VP Ellipsis** Multiple VP ellipsis [Gardent, 1993] poses problems at the level of determining which VP is the antecedent of which ellipsis. But at the level of incorporating elliptical material once the antecedents have been determined, it appears to offer no special problems.

**Other Forms of Ellipsis:** Other forms of ellipsis, besides VP-ellipsis can be handled substitutionally. For example, NP-ellipsis (e.g. *Who slept? John*) is straightforwardly accommodated. PP-ellipsis (e.g. *Who left on Tuesday? And on Wednesday?*) requires substitutions for *form* constructions in QLF (not described here) representing prepositional phrases.

5.5.7 Parallelism

Selecting ellipsis antecedents and parallel elements within them is an open problem [Prüst, 1991; Prüst et al., 1994; Kehler, 1993b; Grover et al., 1994; Hardt, 1992]. Our approach to
parallelism is perhaps heavy-handed, but in the absence of a clear solutions, possibly more flexible. The QLFs shown above omitted largely committed category information present in terms and forms.

Tense in VP-ellipsis illustrates how categories can be put to work. In

\[
I \textit{ enjoyed it. And so will you}
\]

the ellipsis is contained within a form expression whose category corresponds to

\[
\text{vp_ellipsis[tense=inf,modal=will,perfect=_ ,progressive=_ ,pol=pos,...]}
\]

This states the syntactic tense, aspect and polarity marked on the ellipsis. It also constrains resolution to look for verb phrase/sentence sources, which come wrapped in forms with categories like

\[
\text{vp[tense=past,modal=no,perfect=no,progressive=no,pol=pos,...]}
\]

It also says that the term in the antecedent whose category identifies it as being the subject should be treated as parallel to the explicit term in the ellipsis.

As this example illustrates, tense and aspect on ellipsis and antecedent do not have to agree. When this is so, the source is used as the basis to form the actual antecedent used. This takes the restriction of the form and constructs a new category for it by taking the features of the source category, unless overridden by those on the ellipsis—a kind of (monotonic) priority union [Grover et al., 1994] except using skeptical as opposed to credulous default unification [Carpenter, 1993]. When a new category is constructed for the antecedent, any tense resolution also need to be undone, since the original ones may no longer be appropriate for the revised category. In other words, ellipsis antecedents are sometimes constructed from antecedent QLFs, without being strictly identical to them.

In constructing antecedents, it is quite possible that recourse to higher-order unification will sometimes be needed. In some cases, inference may also be required:

\[
\text{We spent six weeks living in France, eating French food and speaking French, as we did in Austria the year before.}
\]

(Austrians speak German).
6 Adjectives

6.1 Discourse Representation Theory

Many of the “classical” semantic problems about adjectives - such as their vagueness and the intensionality of the positive uses of scalar adjectives - have traditionally been thought to belong to the domain of model theory (e.g.: What structure must models have in which adjectives can be given partial extensions in a conceptually plausible way?) We still believe that by and large this is the proper locus for such questions. If this is so - if these are problems that concern the model-theoretic evaluation of DRSs and DRS conditions rather than their form and construction - then nothing that is specific to DRT can be expected to be much help in resolving them.

This is not to deny that there are countless questions about individual adjectives about which DRT ought to have something to say, as they do affect the construction and form of DR-theoretic representations. Two important subgroups of adjectives which present such problems are (i) adjectives with a deictic, anaphoric or indexical aspect to their meaning, such as former, next, local, respective; and (ii) adjectives with an intentional meaning or meaning component, such as intentional, mistaken, inadvertent, erroneous, fake, alleged. Note well: our speaking of two subgroups is not to be construed as a plea that either of them could be dealt with by a global, whole-sale solution. Rather, each adjective may be expected to present its own problems, which, though in important respects similar to what we find with other members of the group, will nonetheless be different enough to require individual attention. Thus, these are problems which have to be dealt with at the lexical level, as part of the lexical entries for the particular items in question. On certain individual items of either group work is now under way, as part of a general effort to come to a linguistically motivated and computationally operational lexicon that can serve as basis for the construction and inferential exploitation of DRSs.63

There is, however, one general issue concerning adjectives that impinges also on the form, and not just on the evaluation, of discourse representations. This is the question whether, or when, the semantic form of an adjective should be taken to contain an implicit argument for the degree to which the referential argument of the adjective (i.e. that of which the adjective is understood to predicate something) satisfies that predicate. It is now quite generally accepted that at least some adjectives should be assumed to have such a form; for only in this way does it appear possible to account for a host of phenomena, having to do with comparatives, the possibility of making the degree explicit (He is six feet tall, He is 5 inches taller than she is.) and so forth. For DRT adopting this assumption means that the representations of sentences containing such adjectives should make their implicit degree arguments visible in some way, and that the lexical entries for those adjectives should make the implicit arguments available to them. This raises a number of questions about the status and use of the representatives (so-called “implicit discourse referents”) of the degree arguments in DRSs for sentences and

63Naturally, though, this work is focussed on the relevant phenomena - deixis in the one case, intensionality in the other - addressing without restricting attention to just one particular word class. Thus, one concentrates on deictic aspects of verbs, adverbs, nouns and adjectives all at once.
texts.

To see more clearly what these questions are, it is best to turn to a particular set of phenomena. An especially rich field of applications that bring these and other problems to light is that of comparative constructions.\(^{64}\)

There is one further issue connected with the question of degree arguments, which we like to raise here, although we have no solution for it. When does an adjective have such an argument? It is with a purpose that we have put the question in this particular form, and not, say, as “Which adjectives have such arguments?” For we suspect that a solution of the problem will not take the form of specifying the class of adjectives which have such an argument, and have it once and for all, while the remaining adjectives do not - where this really and truly means: never. Let us note in this connection that the most frequently used argument in favour of degree arguments is that the adjective admits comparatives and measure phrases without strain. By the same token, adjectives which lack this property, such as *four-legged*, *binary* or *amphibian*, are argued to lack a degree argument. If these are the criteria, however, for distinguishing between adjectives with and those without a degree argument, we face a serious classification problem. For what are we going to say about adjectives like *purple* or *clever*? These two do not admit measure phrases; and while *clever* is used in comparatives quite freely, *purple* doesn’t even like comparatives very much. Are we to say that such adjectives also have a degree argument, but unlike the scalar adjectives, they have buried it so deeply, or have so many strings attached to it, that it is extremely difficult for the grammar to exploit it? Or should we say that, though they do not always have such an argument, we can, up to a point, coerce them into a semantic form which includes a degree argument? As we intimated by the way we put the question at the beginning of this paragraph, we think this second possibility is a serious option. However, at this point we dare not be more positive than that.

If the second possibility turned out to be the right one, we would be faced with an important conclusion about semantic form in general, viz that semantic form is not in all cases an absolute matter, but that for some expressions form is a function of the context in which they appear. This conclusion is also suggested by certain other considerations (such as, for instance, those concerning the stage level - individual level distinction), but it is nevertheless one with serious methodological implications. We do not know of anyone who has tackled either the particular question about degree arguments or the more general issue of variable semantic form in general. If this is indeed so, then it is high time for someone to try.

### 6.2 Update and Dynamic Semantics

The perspective does not force a specific treatment here, but is compatible with a standard analysis (in the style of Montague, say). The interpretation of adjectives is linked to the issue...
of vague predication and vague updates, where an update perspective is potentially useful.

6.3 Situation Semantics

Although our current grammar does not handle adjectives, it would be fairly simple to extend it to do so. The treatment of adjectives in EKN is illustrated in (209).

(209) a. ITEL has a poor record.

This treats adjectives as predicate modifiers, here cashed out as relations between individuals and types.

6.4 Property Theory

PT allows for property modification without resulting in an non-semidecidable logic since properties are taken to be first order objects. It is possible that many adjectives should be treated as property modification and further, that verb phrases may often implicitly require property modification [Landman, 1989; Fox, 1994] (and others). For example:

\[ \text{ADCOM is bankrupt.} \]

may really mean that “ADCOM is a bankrupt company” (as opposed to “morally bankrupt”). The sentence:

\[ \text{The ITEL-XZ is fast.} \]
may mean “The ITXL-ZX is a fast ITXL computer”, or “fast computer”, rather than just “fast” or “fast car”. In this case, the modified property gives the appropriate comparison class.

Measure phrases, such as “two years” in:

\[ \text{The ITXL is 2 years old.} \]

are mentioned by Fox, who criticises the extensional nature of Bunt’s treatment [Bunt, 1985; Fox, 1992].

6.5 Monotonic Semantics

No distinction at QLF is currently made between the categories of intersective and scalar adjectives. A simple sentence like *John is tall* gets a QLF like:

\[
\text{form(verb(pres,no,no,no,y),A,} \\
\text{ B^[be, A,} \\
\text{ term(proper_name(tpc),J,C^[name,C,John],} \\
\text{ -_.),} \\
\text{ D^[tall,D]])],} \\
\text{_.)}
\]

The ‘be’ predication and its attendant event index A are there to bear the tense. A simplified equivalent LF might be just

\[
[tall, John]
\]

In principle, it would be possible to revise the semantics for adjectives like *tall* to include a form resolving to a contextually given comparison class.

Measure adjective phrases like *three feet tall* are translated thus:

\[
D^[degree,E^[tall,E],D,F^[foot,F],3]
\]

‘Degree’ is a predicate related to that used for comparatives (q.v.). A paraphrase of the intended interpretation of this LF is:

‘the degree of tallness of John when measured in feet is 3’
7 Comparatives

7.1 Discourse Representation Theory

Here we have to refrain from a presentation of what little we would have to say on the subject apart from pointing out that [Lerner and Pinkal, 1992] have developed an extensive treatment of comparative phenomena, for which there also exists a DRT version.

7.2 Update and Dynamic Semantics

Dynamic and update semantics is compatible with any reasonable theory of comparatives.

7.3 Situation Semantics

The current grammar does not deal with comparatives. Various existing treatments could be imported into EKN.

7.4 Property Theory

There is no special treatment of comparatives, as in:

\[ \text{ITEL} \text{ won more orders than APCOM.} \]
\[ \text{The PC-6082 is faster than 500 MIPS.} \]

However, some of the comments made in the previous section (§6.4) also be relevant here.

7.5 Monotonic Semantics

The analysis of comparatives follows that described in Pulman 1991. Two basic types of comparative are assumed: one type is fully compositional and is exemplified by:

(Adjectival) John is taller than Bill is. John is taller than Bill is wide.
(Nominal) John owns more dogs than Bill owns. John owns more dogs than Bill owns cats.
- and their adverbial analogues. The comparative complement contains either a phrasal or a specifier gap which is treated syntactically and semantically as a kind of wh-movement, using gap-threading.

These comparatives include those called 'Clausal Complement (Comparative Deletion)' in FraCaS D2: 7.2.

The second type of comparative is regarded as containing varying degrees of ellipsis:

John is taller than Bill. John is taller.

John owns more dogs than Bill does. John owns more dogs than Bill. John owns more dogs. John owns more.

These include all the remaining types of example discussed in D2: 'Phrasal Comparatives (Comparative Ellipsis)', Zero Complement, Differential, and Attributive, (with the exception of Measure Phrases, which are not treated correctly in the current implementation.)

Because of the relative frequency of the 'Adj-er than NP' variant, this is treated by rule rather than by ellipsis, although the ambiguity of examples like 'Paris is nearer to London than Rome' demonstrate that they are really elliptical. Nominal equivalents use the ellipsis mechanism described elsewhere to produce alternative readings, depending on how the ellipsis is resolved.

The interpretation of comparatives is in terms of a higher order predicate, 'more' (or 'less', or 'as'), with 3 arguments.

\[ \text{[more, <quant>, <more-quantity>, <than-quantity>] } \]

The 'quant' argument is a generalised quantifier relation. Typically it will default to 'greater than zero' \((X^\lambda Y^[gt,Y,2])\), but can also express the degree by which the more-quantity exceeds the than-quantity:

John owns 2/at least 3 more dogs than Bill

\[ \text{[more, X^\lambda Y^[gt,Y,2], X^\lambda Y^[geq,Y,3] } \]

This quantifier relation is built up in exactly the way that the corresponding determiner would be built up, hence the apparently vacuous outermost lambda variable. (This type of comparative is called a 'Differential Comparative' in D2: 7.5).

The remaining two arguments differ according to whether we have an adjectival or a nominal comparative. For adjectival comparatives they are predicates true of the (maximal) degree to which a property applies to an individual:

\[ A^\lambda [degree, Adj, X, A] \]
‘the maximal degree to which X is Adj is A’

For example, a (heavily abbreviated) QLF for John is taller than Bill is

\[
[\text{be, EventIdx},
  \text{term}(\ldots \text{John} \ldots),
  D^\circ [\text{more,} H^{\text{E}} [\text{gt, E, 0}],
    F^\circ [\text{degree,} G^{\text{tall, G}},
    D, F],
    H^\circ [\text{degree,} G^{\text{tall, G}},
    \text{term}(\ldots \text{Bill} \ldots), H]
  ]
]
\]

A more readable, almost equivalent form, might be:

\[
[\text{more,}
  E^\circ F^\circ [\text{gt, F, 0}],
  G^\circ [\text{degree, tall}_\text{Lofty, John}, G],
  I^\circ [\text{degree, tall}_\text{Lofty, Bill}, I]]
\]

Given the interpretation of ‘degree’ assumed above, ‘more’ can be defined here as:

\[
Q^\circ X^\circ Y^\circ [\exists A, [\text{and,} [X, A],
  [\exists B, [\text{and,} [Y, B],
    [Q, \text{dummy}, A-B]]]]]
\]

‘dummy’ is there to absorb the first argument of the quantifier relation, which then checks to see that the value A is greater than B by the required amount.

However, there are various possible alternative ways of interpreting this logical form. The predicate ‘degree’ could be defined so as to be a predicate that is true of any number in a range up to the maximum for an individual with respect to the relevant property. Then ‘more’ could be defined as

\[
Q^\circ X^\circ Y^\circ [\exists A, [\text{and,} [X, A],
  [\forall B, [\text{and,} [Y, B],
    [Q, \text{dummy}, A-B]]]]]
\]

In the case of nominal comparatives, the final two arguments will be predicates. The QLF of John owns more dogs than Bill own is, simplified:

\[
[\text{own, EventIdx}
\]

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Here the ‘more’ relationship is part of a generalised quantifier relation. If we define ‘more’ in this context as

\[ Q^X Y [Q, \text{dummy}, |X| - |Y|] \]

then a paraphrase of this interpretation would be:

‘the property of being more (by greater than zero) than the size of the set of dogs owned by Bill holds of the set of dogs owned by John’

It is clumsy to have two definitions for ‘more’. A possible way to combine them would be to assume that a degree is a unit (not necessarily a standard one) appropriate for the property in question, satisfying the requirement that if X is Adj-er than Y, then there are more of these Adj degrees for A than for Y. So if John is taller than Bill, there will be more units of John-tallness than of Bill-tallness. In the case where the unit is specified, as in: ‘John is 3 inches taller than Bill’, then the units will be inches. Then the definition of ‘more’ for nominals could be used directly for the adjectival cases too.

8 Temporal Reference

8.1 Discourse Representation Theory

The DRT approach to temporal and aspectual phenomena is inspired by and extends the analyses proposed by Davidson [Davidson, 1967], Reichenbach [Reichenbach, 1947] and Vendler [Vendler, 1967]. We will say more about aspectual phenomena in section 9.1 below. States, events and times are assumed to be basic ingredients of the temporal ontology in DRT. A model-theoretic semantics for the representations involving temporal information is presented in section 1.1.5.3 in D8.
8.1.1 Standard Use of Tenses

The fragment includes examples of the most common forms of the tenses, such as the simple present, the present progressive, the simple past, the present perfect, the past perfect and the future. Examples (210) and (212) involve the present tense with stative VPs (in the case of (212) formed with the help of the aspectual operator \( PROG \) (progressive) from an event denoting accomplishment verb.)\(^{65}\)

(210) ITEL has a factory in Birmingham.

\[
\begin{array}{|c|c|c|c|c|}
\hline
n & t & s & x & y & z \\
\hline
n = t & s \cap t & itel(x) & factory(y) & birmingham(z) & s : have(x, y) & in(y, z) \\
\hline
\end{array}
\]

(211)

(212) Smith is writing the report.

\[
\begin{array}{|c|c|c|c|}
\hline
n & t & s & x & y \\
\hline
n = t & s \cap t & smith(x) & the report(y) & s : PROG(write)(x, y) \\
\hline
\end{array}
\]

(213)

In case the simple present tense is used with a non-stative VP as in

(214) Smith smokes.

the only available interpretation is usually an iterative or a habitual one. Currently there is no fully worked out approach to cover sentences of the form (214) in DRT (c.f. the discussion of the \( HAB(t, \lambda e.K) \) predicate relating to (78) and (79) above). The simple present can also be used to refer to future events. For instance, (215) can be used to say that some particular meeting will start at 9.30 (of course the sentence also admits of an iterative reading, meaning that a meeting which occurs regularly always starts at 9.30.) This futurite use of the English simple present is often referred to as the “time table use”. Currently there is no fully worked out approach to cover sentences of the form (215) in DRT.

\(^{65}\) Here and in the following \( n \) is a discourse referent representing the time of the utterance.
The meeting starts at 9:30.

8.1.2 Temporal Adverbials

Temporal adverbials serve to locate described eventualities. They are of particular interest in DRT since often they exhibit a much greater degree of context dependence than pronominal anaphora (reference to material objects). Temporal adverbials can be classified roughly along the following lines: locating adverbials which fix (sometimes depending on context) the temporal location of described eventualities (e.g. calendar names or indexicals like on April fifth, 1994, on Sunday); locating adverbials which partially describe the temporal location (e.g. prepositional phrases or subordinate clauses like after the take-over or before Smith resigned); locating adverbials which act in the manner of quantification over bound variables (e.g. Smith always takes the Underground) and temporal measure adverbials (e.g. Smith installed the computer in an hour).

Indexicals  Indexicals function in a manner similar to definite NPs in that depending on the context they uniquely determine a location time for the described eventuality. Without additional context, the tense of the verb determines whether Sunday is understood as last Sunday or next Sunday. The DRS-construction algorithm yields:

(216) The conference started on Sunday.

\[
\begin{array}{c}
n \cdot t \cdot t' \in x \\
\quad \quad t < n \\
\quad \quad e \subseteq t \\
\quad \quad \text{the conference}(x) \\
\quad \quad \text{Sunday}(t') \\
\quad \quad t = t' \\
\quad \quad e : \text{start}(x) \\
\quad \quad t'' \\
\quad \quad t'' < t < n \\
\quad \quad \forall t' \\
\quad \quad \neg \text{Sunday}(t'') \\
\end{array}
\]

\[^{66}\text{The construction algorithm is subject to a presuppositional constraint that an utterance of an indexical like on Sunday as in (216) or (218) if uttered on a Sunday cannot employ the utterance time as origin of the computation of the temporal relations in the representations:}\]

\[
\begin{array}{c}
\neg \quad n \cdot t \\
\quad \quad n \subseteq t \\
\quad \quad \text{Sunday}(t) \\
\end{array}
\]

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The conference will start on Sunday.

\[
\begin{array}{c}
\begin{array}{c}
\begin{array}{c}
t, t' \in x \\
\text{the conference}(x) \\
sunday(t') \\
\end{array} \\
\begin{array}{c}
n < t \\
e \subseteq t \\
\end{array}
\end{array}
\end{array}
\]

‘Before’, ‘After’ (Temporal Subordinate Clauses) In general the eventuality described in the temporal subordinate clause is used to locate the eventuality of the main clause. A comprehensive treatment of temporal subordinate clauses is complicated by the fact that (i) (in contrast to the corresponding simple temporal PPs) each subordinate clause has a finite tense and (ii) there are subtle interactions between tenses in main and subordinate clauses. (227) provides an example of some of these complications. It contains a main clause in future tense with a subordinate clause in present tense denoting a future eventuality. (220) – (225) are (somewhat) more straightforward examples which can be handled by the DRS-construction algorithm:

Smith was present after Jones left the meeting.

\[
\begin{array}{c}
\begin{array}{c}
t \subseteq n \\
s \cap t \\
\text{the meeting}(z) \\
\text{smith}(x) \\
\text{present}(x) \\
t' < t \\
t'' < n \\
e \subseteq t'' \\
jones(y) \\
\text{loc}(e) = t' \\
e \subseteq \text{leave}(y, z)
\end{array}
\end{array}
\]

Jones left the meeting before Smith was present.
Note that (220) and (222) are not synonymous: in (220) for all we know Smith may have been present before Jones left the meeting. This is explicitly ruled out in (222). The next example

(224) Smith left when Jones arrived.

is already more complicated. The problem is that the precise contribution of the subordinating conjunction when depends on both world knowledge and the possible rhetorical relations between the subordinate clause and the main clause. If the event of Jones’ arrival is interpreted as the cause for Smith’s leaving the event in the main clause is naturally interpreted as following the event in the subordinated clause.67

In contrast to (220) and (222) above the subordinate clause introduced by since in

(225) Jones has been here since Smith left.

does not provide the location time for the eventuality (i.e. the state expressed by the perfect VP) described in the main clause but for the event which “results” in this state. The DRS-construction algorithm yields:

67Temporal overlap is another possible interpretation.
Subordinate clauses introduced by *until* provide upper bounds on the temporal location of the eventuality described in the main clause. In the case at hand

\[(227) \quad \text{Smith will be here until Jones arrives.}\]

the state described in the main clause is terminated by the event described in the subordinate clause. The verb in the subordinate clause is in present tense but refers to a future event. Such cases will not be handled correctly by the DRS-construction algorithm as it stands. Ignoring this complication, i.e. assuming that the verb in the subordinate clause is in future tense the construction algorithm derives:

\[
\begin{array}{l}
\begin{array}{l}
\text{n t t' t'' s s' e e' x y} \\
\quad i < n \\
\quad s \cap t \\
\quad e = \text{beg}(s') \\
\quad e' \cap s \\
\quad t' \subseteq s' \\
\quad t'' = \text{beg}(t') \\
\quad t = \text{end}(t') \\
\quad \text{jones}(x) \\
\quad s' : \text{be here}(x) \\
\quad e \subseteq t'' \\
\quad t'' < n \\
\quad e' \subseteq t''' \\
\quad t''' = \text{loc}(e') \\
\quad \text{smith}(y) \\
\quad e' : \text{leave}(y)
\end{array}
\end{array}
\]

\[(228) \quad \text{In’, ‘For’ and ‘On’ Temporal Adverbials} \quad \text{In contrast to locating adverbials, temporal measure adverbials like for a month or in an hour specify the duration of the described eventuality but do not locate it in time. The temporal measure adverbials in (229) and (231) are sensitive to aspectual properties of the sentences with which they combine. Adverbials of}\]

\[
\begin{array}{l}
\begin{array}{l}
\text{n t t' t'' s e x y} \\
\quad n < t \\
\quad s \cap t \\
\quad \text{smith}(x) \\
\quad s : \text{be here}(x) \\
\quad \text{end}(s) = t' \\
\quad n < t'' \\
\quad e \subseteq t'' \\
\quad \text{jones}(y) \\
\quad e : \text{arrive}(y) \\
\quad t' = \text{loc}(e)
\end{array}
\end{array}
\]

\[(229) \quad \text{‘In’, ‘For’ and ‘On’ Temporal Adverbials} \quad \text{In contrast to locating adverbials, temporal measure adverbials like for a month or in an hour specify the duration of the described eventuality but do not locate it in time. The temporal measure adverbials in (229) and (231) are sensitive to aspectual properties of the sentences with which they combine. Adverbials of}\]
the form in-NP only combine with accomplishment and achievement sentences, i.e. sentences
denoting eventualities with a determinate culmination point, while adverbials of the form
for-NP only combine with stative or activity sentences, i.e. those sentences whose described
eventuality does not contain a culmination point. In the analysis it is assumed that the
temporal measure adverbials do not fix the *exact* duration of the described eventuality but
provide upper and lower bounds: in the case of (229) this results in a representation where
ITEL worked at least a month on the project but possibly for longer while in (231) (on
the durative interpretation) it will take ITEL at most a month to write the report. The
construction algorithm yields

(229) Last year ITEL worked on the project for a month.

\[
\begin{array}{|c|}
\hline
n t t' s x y m t \\
last year(t') \\
\hline
n < t \\
t \subseteq t' \\
s \subseteq t \\
\hline
one month(m t) \\
itel(x) \\
the project(y) \\
dur(s) \geq m t \\
s : work on(x, y) \\
\hline
\end{array}
\]

(230)

The next example

(231) ITEL will write the report in a month.

is ambiguous between a durative reading and a locating reading of the temporal PP *in a
month*. Here we only consider the durative reading:

\[
\begin{array}{|c|}
\hline
n t t' s e x y \\
n < t \\
e \subseteq t \\
\hline
one month(m t) \\
itel(x) \\
the report(y) \\
dur(e) \leq m t \\
e : write(x, y) \\
\hline
\end{array}
\]

(232)

Depending on whether the described eventuality is a state or an event a locating temporal
adverbial like *on Sunday* expresses an overlap (235) or inclusion (233) relation, respectively.
This is borne out by the construction algorithm
(233) Smith drew up the contract on Sunday.

(235) Smith was in Paris on Sunday.

Quantificational Adverbials Quantificational adverbials (sometimes referred to as frequency adverbials) locate described eventualities in terms of quantification over discourse referents that play the role of location times. Like generalized quantifiers they introduce tripartite structures (duplex conditions) into the representations. Quantificational adverbials can take a variety of forms. They can be genuine adverbs (always, often, rarely etc.), noun phrases (every month) and prepositional phrases (before every meeting). Here we briefly consider an instance of a NP functioning as a quantificational adverbial. Adverbs of quantification and some of the problems e.g. with regard to how to determine the corresponding representations (separation and restriction problem) will be discussed in section 8.1.4 below.

(237) ITEL sent a progress report every month.
Below we give one of the readings obtained by the DRT-construction algorithm. It is probably the most "natural" reading and assigns narrow scope to the indefinite NP:

\[
\begin{array}{c|c}
 n & t \ x \\
\hline
 t < n \\
 itel(x) \\
\end{array}
\]

(238)

\[
\begin{array}{c|c|c}
 t' & month(t') & e \\
 t' \subset t & e : send(x, y) & report(y) \\
\hline
\end{array}
\]

8.1.3 Anaphoric Dimension

The DRT account of temporal perspective phenomena is inspired by and extends Reichenbach's two-dimensional theory of tense. According to Reichenbach all tenses can be analysed in terms of pairs of relations the first of which expresses a relation between utterance time and reference time and the second of which expresses a relation between reference time and described eventuality. Extended "flash-back" examples of the form exemplified in (243) motivate a distinction between a temporal reference point and a temporal perspective point instead of the simple reference point assumed in the Reichenbachian approaches. The temporal reference point is a device which is employed to account for narrative progression phenomena. The temporal perspective point essentially acts as a reference point from which a particular eventuality is seen e.g. as lying in the past or future.

Temporal reference typically involves a high degree of anaphoric dependency. This is already illustrated in our first example (which is a simple variation of an example due to B. Partee):

(239) Smith did not travel by air.

Clearly this sentence does not mean that there does not exist some event in the past such that Smith travels by air but rather that on some particular occasion or other Smith did not travel by air. If this occasion is supplied by the context, as e.g. in

(240) Smith went to Amsterdam on Monday. ... He did not travel by air.

in order to derive the desired representation the DRS-construction algorithm would have to identify that in terms of the rhetorical structure of the text in (240) the last sentence constitutes an elaboration of the first sentence and that thus the eventuality described in the final sentence provides a further characterisation of the eventuality introduced in the initial sentence. The formal reflex of this on the level of DRS construction would be an identification of the chosen reference point \( R_{rel} = \epsilon_{initial} \) with the eventuality \( \epsilon_{final} \) described by the final sentence. In the absence of a fully worked out theory of rhetorical relations the DRS-construction algorithm is based on the simplifying assumption that sequences of past tense event sentences
of the sort exemplified in (240) are related in terms of a principle of “narrative continuation” where each newly introduced event simply follows the event introduced last. The following discourse provides an instance of this type of inter-sentential temporal anaphora:

(241) Smith left the house at a quarter past five. She took a taxi to the station and caught the first train to Luxembourg.

The DRS-construction algorithm maps it into the following representation:

For the purposes of illustration we left conditions of the form $T_{tp} := e$ in the representation and put boxes around them. Strictly speaking, such conditions are only transient conditions employed as a temporal reference point tracking device which are removed as soon as they have done their work.

---

68 States are assumed to overlap with events described in the preceding sentence.
Extended flash-back examples of the form illustrated in (243) provide the motivation for the use of a device for temporal perspective tracking. Temporal perspective points serve to relate described eventualities like in the simple narrative progression in (241) above. Temporal perspective points identify points in time with respect to which described eventualities are seen as lying in the past or future. In the case of example (241) each sentence is seen as past from the point of view of the utterance time $n$. This is reflected in the conditions $t < n, t_3 < n, t_4 < n$ which were established in terms of transient conditions $T_{pp} := n$ (removed from the resulting representation) involving temporal perspective points. (241) does not involve a shift in the temporal perspective point so as far as this example is concerned the temporal perspective device is strictly speaking not required in the construction of the resulting representation. The situation is different with respect to example (243) ITEL signed the contract in 1989. They had approached CRC for additional funding. CRC had approved it. ITEL had lots of money to spend on the project. They hired two new researchers and a financial administrator. The financial administrator was incompetent. But ITEL finished the project on time and under budget. They fired the financial administrator.

Here we have a more complex example of narrative progression involving an embedded past perfect narrative (sentences 2 and 3) and a state description in sentence 4 which does not advance the narrative. It is not clear whether or not the state description in sentence 6 advances the narrative. The last sentence (8) can be taken to elaborate on sentence 7, and describes an event preceding it (though it can also be understood in a purely narrative sense as describing a subsequent event). The important point with respect to the temporal perspective point here is that sentences 2 and 3 form a sub-narrative progression (extended flash-back) within the narrative progression of the entire discourse which is seen as lying in past from the point of view of the past event introduced by the first sentence in the discourse. Shifting temporal reference points help establishing the the sub-narrative progression in sentences 2 and 3 while the temporal perspective point device ensures that this embedded narrative progression is evaluated in the past of the past event introduced by the first sentence. Here is a considerably simplified DRS representing one of the readings established by the DRS-construction algorithm:

---

69 The discourse is multiply ambiguous with respect to both pronominal and temporal anaphoric reference as well as with respect to the interpretation of the proper names and plural NPs.
We left the conditions representing the temporal perspective and temporal reference points in the representation and put them into boxes to ensure better readability.
8.1.4 Adverbs of Quantification

(245) In 1990 ITEL always delivered reports late.

(246) Mostly a customer who owns a computer has a service contract for it.

(247) Most customers who own a computer have a service contract for it.

Adverbs of Quantification locate described eventualities in the manner of quantified bound variables. Syntactically they can take a variety of forms: adverbs (always, often, rarely, regularly, mostly, never), NP’s (every morning, most Thursdays) or PP’s (after every meal). Adverbs like (often, rarely, regularly) do not have precise truth conditions. (245) doesn’t mean that at any time in 1990 ITEL was late with its reports. Separation problem. (246) requires unselective binding reading while (247) requires selective reading.

8.1.5 Temporal Interpretation of NPs

As discussed extensively in [Enç, 1981] a common noun need not be evaluated at the time of the event or state described by the clause of which it is part. A simple example of this is

(248) The wife of the president worked for APCOM in 1975.

in which the common noun phrase wife of the president is naturally evaluated at the time of speech and not at 1975, the time of the state of affairs of her working for APCOM.

(249) Every ITEL president has been a student at the Harvard Business School.

and

(250) Every executive was a student at the Harvard Business School.

are slightly more complicated illustrations of the same phenomenon: in (249) the time of evaluation of executive and that of student at the Harvard Business School are distinct; when the sentence is interpreted as quantifying over times - i.e. as concerning not only those who are executives right now, but those which were, are or will be executives within some extended period embracing the time of speech - this distinction concerns the times at which each individual executive was executive and student, respectively. Currently there is no worked out approach to the temporal interpretation of NPs in DRT.
8.2 Update and Dynamic Semantics

Temporal anaphora are handled similarly to nominal anaphora. In example 7, there is not only an intended anaphoric link between the indefinite subject of the first sentence and the pronominal subject of the second, but also between the tenses of the verbs in the two sentences.

7 A man entered. He smiled.

The events described in the example are naturally understood as occurring one after the other, with the event of entering preceding that of smiling. In terms of Reichenbach’s analysis [Reichenbach, 1947], the event time $E$ shifts during the discourse. Here is a plausible ‘dynamic’ representation:

\[
\begin{align*}
\eta_1; \eta e_1; \text{man } u_1; \text{enter } (e_1, u_1); t(e_1) < n; \\
\eta e_2; \text{smile } (e_2; u_1); t(e_1) < t(e_2); t(e_2) < n.
\end{align*}
\]

In this representation we assume that the verbs have a Davidsonian event argument [Davidson, 1967], and that $t(e)$ denotes the temporal interval during which $e$ takes place. The constant $n$ (‘now’) is supposed to refer to the speech interval. For further information on the treatment of tense and aspect in dynamic semantics we refer to Muskens [Muskens, 1994] and to Van Eijck and Kamp [Eijck and Kamp, 1994].

8.3 Situation Semantics

We give the following meaning for temporal at.

**LEX-TEMP-AT** If $u$ is a use of type $[p[+\text{temp}] \ at]$, then

\[
[u] = \begin{cases}
\text{P} & \text{if } t = \text{Time} \\
\text{DS} & \text{if } \text{ev-time}(u, T) \\
\text{T} = \text{Time}
\end{cases}
\]

We introduce names for times by the following rule.

**LEX-TEMP-PropName** If $u$ is a use of type $[\text{NP}[+\text{temp}] \ \alpha]$ where $\alpha$ is a time (9:30, Sunday, ...), then
We introduce further temporal prepositions.

**LEX-TEMP-ON** If \( u \) is a use of type \([p[+\ temp\] on]\), then

\[
[u] = \begin{array}{c}
\begin{array}{c}
\text{ds} \rightarrow DS, <\text{res}, u> \rightarrow R, <\text{time}, u> \rightarrow T \\
\end{array} \\
\begin{array}{c}
\begin{array}{c}
R \\
\text{named}(T, \alpha) \\
\end{array} \\
\begin{array}{c}
\begin{array}{c}
\text{res}(u, R) \\
\text{time}(u, T) \\
\end{array} \\
\end{array} \\
\end{array}
\end{array}
\]

**LEX-TEMP-FOR** If \( u \) is a use of type \([p[+\ temp\] for]\), then

\[
[u] = \begin{array}{c}
\begin{array}{c}
\begin{array}{c}
\text{ds} \rightarrow DS, <\text{ev-time}, u> \rightarrow T \\
\text{Time} \\
\end{array} \\
\begin{array}{c}
\begin{array}{c}
P \\
\begin{array}{c}
\text{ev-time}(u, T) \\
\end{array} \\
\end{array} \\
\end{array} \\
\end{array}
\end{array}
\]

\( T \subseteq \text{Time} \)

**LEX-TCOMP** If \( u \) is a use of type \([\text{TCOMP} \ \alpha]\), then

\[
[u] = \begin{array}{c}
\begin{array}{c}
\begin{array}{c}
\text{ds} \rightarrow DS, <\text{ev-time}, u> \rightarrow T \\
\text{Time} \\
\end{array} \\
\begin{array}{c}
\begin{array}{c}
P \\
\text{ev-time}(u, T) \\
\end{array} \\
\end{array} \\
\end{array}
\end{array}
\]

\( T = \text{Time} \)
\[ u = \begin{array}{l}
\text{Prop} \\
\text{\[ u \text{ = } p \text{ if } \alpha \text{ is 'before'} \]}
\text{\[ u \text{ = } T_2 * T_1 \text{ if } \alpha \text{ is 'after'} \]}
\text{\[ u \text{ = } \text{null-time} \]}
\text{\[ u \text{ = } \text{ev-time} \]}
\text{\[ u \text{ = } \text{ref-time} \]}
\end{array} \]

Where \( * = \begin{cases} < & \text{if } \alpha \text{ is 'before'} \\ > & \text{if } \alpha \text{ is 'after'} \\ \text{if } \alpha \text{ is 'when'} \text{ (much simplified)} \\ \text{} \text{ if } \alpha \text{ is 'since'} \\ \text{} \text{ if } \alpha \text{ is 'until'} \end{cases} \)

Where \( t_1 < t_2 \text{ iff } \text{last}(t_1) < \text{first}(t_1) \)
\( \text{and } \exists t' \text{ s.t. } t_1 < t' < t_2 \)
\( t_1 \not< t_2 \text{ iff } \text{last}(t_1) = \text{first}(t_2) \)

\textbf{PS-TEMP-PP} If \( u \) is a use of type \([\text{TimeAdv} \ P \[ + \text{temp} \ \alpha \ \text{ext} \] \ NP \[ + \text{temp} \ \alpha \ \text{ext} \] \) with constituents \( u_1, u_2 \), respectively, then
\[ [u] = \lambda f[[u_1]] \cup [[u_2]] \]

where \( f \) is a mia for \([[[u_1], [u_2]] \]

\textbf{PS-VP-TEMPADV-PAST} If \( u \) is a use of type \([\text{VP} \[ \text{tns: pst} \] \ NP \[ \text{tns: pst} \] \text{TimeAdv} \] \) with constituents \( u_1, u_2 \) respectively, then
\[ [u] = \lambda f \cup [[\text{ev-time}, u] \rightarrow T][[[u_1]], g.f.[[u_2]], g.f] \]

where \( \text{dom}(g) = \{ r | r \in \text{roles}([u_1]) \land \exists u(r = \langle \text{ev-time}, u >) \} \)
\( \text{and for all } r \in \text{dom}(g), g(r) = T; f \) is a mia for \([[[u_2]], g.f.[[u_1]], g.f] \)

\textbf{PS-VP-TEMPADV-PRES} If \( u \) is a use of type \([\text{VP} \[ \text{tns: pres} \] \ NP \[ \text{tns: pres} \] \text{TimeAdv} \] \) with constituents \( u_1, u_2 \) respectively, then
\[ [u] = \lambda f \cup [[\text{null-time}, u] \rightarrow U] \]

where \( \text{dom}(g) = \{ r | r \in \text{roles}([u_2]) \cup \text{roles}([u_1]) \land \exists u(r = \langle \text{ev-time}, u >) \} \)
\( \text{and for all } r \in \text{dom}(g), g(r) = T; f \) is a mia for \([[[u_2]], g.f.[[u_1]], g.f] \)

\textbf{PS-QUANT-TEMP-ADV} If \( u \) is a use of type \([\text{TimeAdv} \ NP \] \) with constituent \( u_1 \), then
\[ [u] = \lambda f \cup [\text{<unit-time}, u] \rightarrow \{ P \mid P \subseteq [[u], f] \} \]

\( f \) is a mia for \([[[u]]]\)

**PS-TEMP-S** If \( u \) is a use of type \([\text{TimeAdv} \ TCOMP S]\) with constituents \( u_1, u_2 \), respectively, then

\[ [u] = \lambda f (\exists \lambda g ([[u_1], g.f.[[u_2], g.f.])) \text{ or } \lambda f (\exists g ([[u_1], g.f.[[u_2], g.f.]]) \]

where \( \text{dom}(g) = \{ r \mid r = \langle \text{ref-time}, u_1 \rangle \lor (\exists u \text{ constituent-of}(u, u_2) \land r = \langle \text{ev-time}, u \rangle) \} \)

\( \forall r, r' \in \text{dom}(g), g(r) = g(r') \)

\( \forall r \in \text{dom}(g), g(r) \) is a parameter not in \([[[u_1]]] \) or \([[[u_2]]]\)

\( f \) is a mia for \([[[u_1]], [[[u_2]]]]\)

### 8.4 Property Theory

There is, as yet, no special treatment of tense and temporal reference in PT.

### 8.5 Monotonic Semantics

The treatment of tense and temporal reference is one of the weaker parts of the CLE, though this reflects channelling of development effort rather than known flaws in QLF.

#### 8.5.1 Standard Uses of Tenses

Prior to reference resolution, information about the tense etc of a verb phrase / sentence is carried on the category of a verbal form (we have been omitting this in example QLFs where tense is not an issue). For example *TEL will bid for two months*

\[
\text{[dcl,}
\text{form(verb(no,no,no,will1,y),}
\text{A,}
\text{B}^\text{[B, form(prep(for),P,}
\text{C}^\text{[C,A,}
\text{term(q(ntpc,E^D^[ eq,D,2],plur),_},
\text{E^-[month,E],[_,_]),}
\text{_,}
\text{[bid,A,}
\text{term(...TEL...)]},
\text{_)}}
\]

The category, \text{verb(no,no,no,will1,y)} indicates that the sentence is non-finite, is not in the perfect or progressive, has \text{will} as a modal auxiliary, and is active voice. Two features missing
from the category, but which ought really to be present are (a) the mood of the sentence, which is currently represented by mood operators like dcl, whq, and (b) the polarity of the sentence.

The restriction of the form, $B^0[B, \text{Modifiers}..., \text{VP}]$ is some property of the modifiers of the main verb phrase and the main VP itself.

The representation of tense is deliberately aimed at remaining neutral. Depending on how the verb form is resolved, one could adopt an operator based-treatment, and event-based treatment, explicit quantification over times, etc. For reasons that are historical as much as anything else, resolution in the CLE imposes an event-based treatment.

This involves replacing the form index ($A$) by an event term, where the restriction of the term contains information temporally constraining the occurrence of the event. The temporal modifier acts as a Davidsonian restriction on the event term. The resolved form is equivalent to:

$\begin{array}{l}
\text{[and,}
\text{[bid,}
\text{\quad term(event,A,}
\text{\quad X^-[and,[event,X],}
\text{\quad [precedes,}
\text{\quad \quad term(now,N,Y^-[current_time,Y],}
\text{\quad \quad exists,ent(20/8/94)]}
\text{\quad X]],}
\text{\quad exists,qnt(A)),}
\text{\quad term(...TEL...)]}
\text{\quad form(prep(for),P,}
\text{\quad C^-}
\text{\quad [C,A,}
\text{\quad \quad term(q(atpc,N^-D^-[eq,D,2],plur),_,}
\text{\quad \quad E [month,E],_,_])],}
\text{\quad for_duration)}
\end{array}$

Here, the underspecified $for$ adverbial has been resolved to a temporal sense, stating that the event $A$ has a duration of two months.

Other combinations of temporal auxiliaries result in temporal constraints on events following the patterns set out by [Harper and Charniak, 1986]: the past tense locates events before the present time, the present either locates them at the present time or places no temporal constraints (generic reading), the perfect locates the event prior to the time introduced by the past or present tense or modal, and the progressive locates the event as including the time selected by the tense or perfect. These are deliberately simplified resolutions: they do not constitute a serious treatment of such things as the imperfective paradox with the progressive, the current relevance of the perfect, generic/habitual uses of the present, and so on. But for many applications, this level of over-simplification is quite workable.
The replacement of the form index by an event term goes beyond what the QLF formalism allows if forms are to be interpreted by applying the restriction to some contextually salient predicate. This indicates that forms are better treated as being interpreted through applying contextually salient re-interpretations (substitutions) to the restriction.

8.5.2 Temporal Adverbials

As the example above illustrates, most temporal adverbials are resolved to Davidsonian event modifiers. No distinction is drawn between events, states or processes. In those cases where aspectual properties make a difference to the apparent interpretation of a modifier (e.g. on means overlap of time periods for states, containment for events), the conversion from QLF to TRL carries out some simple tests for aspectual properties to pick the correct relation. This is not done at the level of QLF on the grounds that a single meaning for the modifier (containment of the event or similar subevent in the case of on) accounts for both interpretations.

Indexical adverbs, such as on Sunday, are handled by the mechanism for imposing contextual restrictions on noun phrases. At present, the influence of the tense of the sentence is not very well reflected in selecting the preferred resolution (i.e. John left on Sunday — last Sunday; John leaves on Sunday — next Sunday).

Quantificational adverbs, every month etc, are treated as containing ordinary quantificational terms, which are given wide scope over the event term. The scope of e.g. quantificational and durative adverbials can be significant — John visited his mother every week for a year, John visited his mother every week for an hour.

Temporal connectives (before, after, when etc) impose a temporal ordering between the events of the main and subordinate clauses, given an event-based resolution. However, the subordinate argument to the connective is a formula rather than an event term:

Everyone left after Bill arrived

[dcl,
 form(verb(past,no,no,no,y),A,
  B^[B, form(prep(after)),_,
    C^[C,A,form(verb(past,no,no,no,y),D,
      E^[E,[arrive,D,term[..Bill..]],_,_]]
    _,_])
  ,_],
[leave,A,term(q(tpc,every,sing),_,_],
 G^[personal,G]_,_,_])],
_,_]}

This means that resolution of the connective must pick up the event term in the resolved subordinate clause. That is, the temporal clause needs to be resolved to something along the lines of
Moreover, given that event terms are resolved to have the minimum scope possible, the main clause event has wide scope over the subordinate event. This looks as though it means there is one arrival event for each leaving event. Although there is nothing to prevent it always being the same arriving event, this is not reflected in the resolved logical form. (In fact, the CLE picks out the subordinate event in conversion to TRL rather than resolution, so the above does not quite reflect what actually happens in the CLE).

### 8.5.3 Temporal Anaphora

The CLE implements nothing of temporal anaphora, beyond the treatment of indexical adverbs. However, given the general treatment of anaphora by means of contextual restriction on terms, there seems in principle no reason why temporal anaphora should not be dealt with by temporal restrictions on event terms (famous last words...)

### 8.5.4 Adverbs of Quantification

The CLE treatment of adverbs of quantification is too over-simplistic to even bear describing here. But in principle, QLF offers the tools required to deal with contextual determined quantification over cases or event.

### 8.5.5 Temporal Interpretation of NPs

Once again, the CLE does not implement anything to do with the temporal interpretation of NPs. The mechanism of contextual restriction on terms does not lend itself in a direct way to a possible treatment of this phenomenon. However, if noun phrase term restrictions were modified to include a temporal term indicating the time of the restrictions application, contextual restriction on the temporal sub-terms could perhaps be employed.

### 9 Verbs

This section discusses aspectual classes (in D2: section 9.1), de-dicto/de-re readings (section 9.2), copula light verbs (section 9.3) and modal verbs (section 9.4).
9.1 Discourse Representation Theory

9.1.1 Aspectual Classes of Verbs

The analysis of temporal phenomena in DRT draws on the work by Davidson, Reichenbach and Vendler. It is based on (i) the assumption that tensed sentences can be analysed as descriptions of eventualities where eventualities is a cover term for events and states; (ii) the observation that the semantic contribution of simple tenses and their anaphoric properties can be captured in terms of a relational account of tense in terms of the time of utterance, a reference point and a temporal perspective point and a location time of the described eventualities; (iii) the observation that depending on the type of verb involved and depending on the presence or absence of certain aspectual “operators” (like perfective or progressive) the basic event-state dichotomy admits of more fine-grained distinctions.

The DRT account of aspectual phenomena is based on the Vendler [Vendler, 1967] classification which distinguishes between accomplishment, achievement, stative and activity verbs. The differences between these verbs correspond to different inference and acceptability patterns which can best be illustrated with respect to a simple schema involving a time axis and 3 marked regions on this time axis.

```
<table>
<thead>
<tr>
<th>preparatory phase</th>
<th>culmination point</th>
<th>result state</th>
</tr>
</thead>
</table>
```

(251) I ---- II ---- III

The schema distinguishes between a preparatory phase and a resulting state separated by a culmination point. The verb classes postulated by Vendler differ with respect to whether (i) the verb itself provides an intrinsic culmination point, (ii) in case the verb provides a culmination point a tense like the simple past includes both preparatory phase and culmination point and (iii) the schema in (251) as selected by the verb class is degenerate or not.

Given the schema in (251), the progressive and the perfective are treated as “aspectual operators” the semantic effects of which can be approximated as follows:

The eventualities described by progressive forms of a verb (where it applies) denotes that part of the schema in (251) up to but not including the culmination point.

The eventualities described by perfective forms of a verb (where it applies) denotes that part of the schema in (251) starting from but not including the culmination point.\(^70\)

Sentences involving accomplishment verbs in the simple past \(^70\)In the case of stative verbs it is assumed that the perfective introduces a culmination or better “termination” point into the degenerate schema (256).
(252) ITEL wrote the report.

denote part I and part II in the schema in (251). Progressive forms of accomplishment verbs denote part I only and perfective forms refer to part III. By contrast the simple past of an achievement verb like in

(253) Smith noticed a loophole in the contract with ITEL.

only refers to the culmination point in (251). Stative (254) and activity (255) verbs lack intrinsic culmination points.

(254) ITEL employed Smith.

(255) Smith talked to Jones.

Because of the lack of culmination point in the case of stative verbs the schema in (251) “degenerates” to:

(256) state

In contrast to stative verbs activity verbs admit of and often even require the progressive. In the DRT analysis it is assumed that activity verbs are not capable of introducing a new eventuality but rather “redescribe” some eventuality introduced independently. Hence they do not by themselves select any of the areas demarcated in (251).

Below we give a few simple examples illustrating the treatment of the progressive and perfective operators in DRT. The first example involves the perfective applied to an achievement verb:

(257) ITEL has submitted a proposal.

According to what we have said above the denotation of this sentence involves a result state s which obtains after the event e (corresponding to the culmination point of the achievement verb) of ITEL submitting a proposal. In the representation this is marked $e \supset s$. The construction algorithm yields:
The “result” state described by a perfective is always based on some event that actually occurred. This is fundamentally different in the case of progressives. The sentence

\[ (259) \quad \text{ITAL is writing a proposal.} \]

does not support the inference that at some future time the proposal will actually be completed. The analysis of progressives currently offered by DRT does not give an account of how the state described by a progressive form of a verb and the event described by its non-progressive form are related. The construction algorithm yields:

\[ (260) \quad \begin{align*}
x & \in Y \\
y & \in N \\
t & \in E \\
s & \in S \\
\text{itel}(x) & \\
\text{propos}(y) & \\
s & : \text{PROG}(\text{write})(x, y)
\end{align*} \]

With stative verbs the perfective can be ambiguous with respect to whether it denotes a result state obtained through the termination of the state described by the non-perfective verb and between a reading where the state described by the non-perfective verb still obtains at the time of the utterance. A case in point is

\[ (261) \quad \text{ITAL has employed Smith for ten years.} \]

For the first reading the construction algorithm obtains the following representation which involves a state \( s \) starting at the end of an event \( e \) which marks the end of a state \( s' \) of ITAL employing Smith:

\[ \text{Inferences of this sort would involve a treatment of counterfactuals of the sort: if everything was going according to plan …..} \]

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For the second reading the construction algorithm obtains

Here the event \( e \) marks the beginning of a state \( s' \) of ITEL employing Smith and \( s' \) is constrained not to be terminated by another event \( e' \) before \( n \) which is the time of the utterance.

### 9.1.2 \( \text{De Re} \text{- De Dicto} \)

A discussion of the \( \text{DRT} \) approach to the \( \text{de re} \text{- de dicto} \) distinction can be found in the contribution to section \( 10 \) below.

### 9.1.3 \( \text{Copula and Light Verbs} \)

The problem posed by light verbs is important and intriguing and has, it seems, been pretty much neglected. Our impression, however, is that the real problems that copulas and light verbs present primarily concern aspects of the syntax-semantics interface which are orthogonal to the principal concerns and assets of \( \text{DRT} \). (The problems seem to have to a large extent
to do with the details of theta marking, and, as a semantic reflection thereof, the passing and identification of arguments. Here the details of the underlying syntax do seem to matter more than is customary for the problems that DRT has been concerned with. Much of the work to be done by a treatment of these kinds of verbs will have to focus on the correct formulation of their lexical entries.)

9.1.4 Modals

As we remarked in our comments on attitudes and the de re - de dicto distinction, there was for many years (and in certain quarters there still is) a tendency to account for the attitudes along lines originally designed for the modalities. We noted that this strategy must necessarily fall foul of the logical omniscience problem and that this is sufficient reason to reject this strategy and to use it, if at all, only in quite special circumstances, where the omniscience problem does not interfere with the particular issue that is being investigated.

Once it has been accepted that the attitudes require something different, it is difficult not to ask the same question about the modalities themselves. This is not to say that no modalities exist for which the classical modal treatment (which identifies propositions with sets of possible worlds and modalities as functions between such sets) is appropriate. We see as conclusive the arguments of Kripke and other philosophers to show that metaphysical modality must be sharply distinguished from epistemic modality and that the classical treatment is right at least for the metaphysical ones. But it is nevertheless true, we believe, that metaphysical modalities occur comparatively rarely in ordinary discourse, or at least that the modal words, such as may, might, could, should, must, ought, etc. more often refer to modalities that are not of the metaphysical sort than to modalities which are. Indeed, quite a large proportion of the occurrences of these words seem to have at least an epistemic component, and as soon as that element is present, the omniscience problem becomes a potential danger.

Indeed, we suspect that all such cases demand analyses similar to those we have sketched here for the attitudes. Precisely what these analyses should be like is of course another matter, about which we have but little to say. But there is at least a negative observation we can make here: As compared with the typical attitudinal verbs such as want or believe, the epistemic modals present the problem that it is in general not very clear precisely whose knowledge is at stake. For instance, when someone says

(264) George might have been here.

his utterance can in the normal course of events be taken as reflecting what he himself knows or believes. But that does not necessarily mean that it is part of the semantics of this sentence that it makes a claim about the speaker’s knowledge or beliefs - any more than it is part of the semantics of

(265) George owns a dog.
that the speaker knows or believes that George has a dog. It seems to us, rather, that the meaning of an utterance such as (264) is more like: “It is consistent with general knowledge that ...” So, if (264) is about attitudes at all, it is not about those of some particular person or persons (at some given time), but rather about a kind of “collective conscience”. And if that is so, then it won’t be possible to base the analysis in any direct way on the existence of individual psychological states, along the lines we have proposed to follow in the case of attitude reports.

Substantial progress on the general semantics of the modalities was achieved through the work of, especially, Kratzer [Kratzer, 1977], who showed, how the combination of two notions, modal base and ordering source, capture much of what the different modalities have in common on the one hand and what differentiates them on the other. Admittedly, Kratzer’s analysis (and the same holds for the kindred proposals of Veltman [Veltman, 1985],[Veltman, 1986],[Veltman, 1991]) is given within the framework of possible worlds theory, and so is vulnerable to the paradoxes of omniscience. But it is possible to recast her proposals in a more representational setting, in which that problem can be kept under control; and it is here, in the recasting and subsequent control that, we believe, DRT can be of some help.

The help it can give pertains in the first place to the development of a representational version of the modal base. (Whether a similar benefit can be expected with respect to the ordering source is a matter which is yet to be explored.) Up to a point this is a triviality: replace a set of propositions by a suitable set of representations of those propositions, e.g. by a DRS. (This will work only for finite sets, but in practice those are the only cases in which we are interested.) Where DRT becomes more tangibly useful is in the updating of modal bases with new information. From a representational perspective many modal sentences, viz all those which involve an element of conditionalization, require updating twice over, first of the modal base with an explicitly or implicitly given antecedent and then of the result of this with the modal consequent. In this respect such modal sentences are like conditionals - or perhaps we should say: like other conditionals, for as the work of Lewis [Lewis, 1973], Veltman, Kratzer and others has made plain, modals are naturally viewed as members of the varied family of conditional constructions. And so the general DR-theoretical perspective on conditionals, according to which the antecedent describes a type of situation and the consequent is used to update and thereby enrich this description, also applies here.

Updating of the modal base also enters into the analysis of modal sentences in another way. It is possible to strengthen a modal base by providing new verbal information, information which must be taken into account as part of the modal base for the interpretation of a modal statement that follows. There is one form that this may take which has been much discussed in recent years under the label of “modal subordination”. (See especially [Roberts, 1987].) Modal subordination can arise in situations where a conditional is followed by another conditional or modal and where the antecedent and consequent of the first conditional are taken as part of the modal base for the conditional or modal that follows. Here the result of the updates that are performed as part of the interpretation of the first conditional is used to serve again, this time as starting point for the interpretation of the next bit of the discourse. As shown in a recent paper by Steven Barker (forthcoming, L&P), the interpretational options that “modal subordination” offers are more varied than had previously been realized. So this is an as yet underexplored chapter in the semantics of modals and conditionals. But it is an
important one; and it is one where we may expect DRT to play a significant part.

Modal subordination brings out the dynamic aspects of the semantics of modals. Indeed, it seems plain enough that modal statements can be, and most often are, informative - they present the recipient with new information no less than do other statements. In the light of this more or less self-evident observation it is interesting to have a brief look at the treatment that modals get in what may be considered the dynamic theory par excellence, the update semantics of Veltman.

Veltman proposes that statements of the forms “It might be the case that A” and “It must be the case that A” are not informative in the usual sense - they are not “updates”, which narrow down the set of possibilities to those in which they themselves are true. Rather they are “tests”, statements which comment on the current information state, instead of making a new contribution to it; they are, one might say, “meta-statements”, which do not contain information about the subject matter of the discourse, but comment on the state of the available information about it. Thus they are informative - act as updates - only in the marginal sense of turning the current information state into the inconsistent information state if what they say about it is false.

On the one hand Veltman’s view seems attractive; on the other it is hard to believe that it can be right. For surely modal statements, including those with might or must, often do seem to be informative. Is this because those that do appear to be informative, aren’t cases of epistemic modality after all? We do not think so.

Of course, there need not be any real contradiction between this impression and the essence of Veltman’s proposal. For even if the modal statement is to be construed as a comment on the speaker’s own epistemic state, it may carry new and useful information for the recipient, who will typically be only partly informed about the speaker’s information state, and may in this way learn something new about it.

If this were all there is to it, all one could expect Veltman to do by way of reply would be a shrug. For that we can learn from what others tell us not only about what it is they are speaking about, but also about what opinions they hold, is a complete triviality. We do not think, however, that this is all there is to it. This suspicion is connected with our earlier remark that epistemic modals should not in general be construed as statements which the speaker makes about his own state of mind, but that they aim at something more, at commenting on the information which is, or ought to be, shared, or in the public domain. Indeed, it is for this reason, we surmise, that there is a point to challenge such statements (as people in fact often do.) If they were exclusively about the private mental life of the speaker, a challenge would rarely have much point and even more seldomly a basis. (For wouldn’t the other almost by necessity know better?)

Thus it appears to us that Veltman’s account oversimplifies the analysis of epistemic modals in that it ignores the normative pretensions epistemic modal statements typically carry.

But criticizing is easy. How to arrive at an analysis that does better is quite another matter.
9.2 Update and Dynamic Semantics

Dynamic and update semantics is compatible with any sane semantic treatment of these.

9.3 Situation Semantics

9.3.1 Aspectual Classes

The distinctions between verbs of different aspectual classes would be treated along the lines of Moens as indicated in the treatment below of the progressive and present perfect. See Cooper [Cooper, 1993b] where Montague’s □ in PTQ is treated.

9.3.2 Modals

Our current grammar does not handle modals.

9.3.3 Gawron and Peters’ treatment of Verb Phrases and Tense

The content of a VP like hired Jones, according to Gawron and Peters, is a relation abstracting over individuals and times. Their treatment of verbs and verb phrases is exemplified by the following two rules ([Gawron and Peters, 1990], p. 172 and p. 167):

\[(266) \quad V \rightarrow hired\]
\[c[V] \rightarrow \text{DO,RT}\]
\[\text{iff}\]
\[C \Rightarrow \langle \text{BEING-UTTERED, V, l} \rangle\]
\[(\text{DO } = [x_{\text{subj}}, y_{\text{obj}}, z_{\text{tns}} | \langle \text{HIRING, hirer: } x, \]
\[\text{hired: } y,\]
\[\text{loc: } z \langle \text{PRECEDES, z, l} \rangle \text{ ]})\]

\[(267) \quad VP \rightarrow V \quad NP\]
\[\llbracket = l | (\text{OBJ}) = l\]
\[c[VP] \rightarrow \text{DO, RT}\]
\[\text{iff}\]
\[C \geq C_V \land C_{NP}\]
\[(\text{DO } = [x_{\text{subj}}, z_{\text{tns}} | \text{Cl}(\text{VP}, \langle DO^V, \text{subj: } x,\]
\[\text{obj: } DO^{NP},\]
\[\text{tns: } y \rangle \text{ ]})\]

These two rules can be reformulated in EKN notation as follows:
LEX-TVERB-TENSED-GP If \( u \) is a use of \([\nu[+\text{tns}] \text{ hired}]\),

\[
\begin{array}{c}
\text{hiring} \left( \begin{array}{l}
\text{hirer} \rightarrow X \\
\text{hired} \rightarrow Y \\
\text{loc} \rightarrow Z
\end{array} \right)
\end{array}
\]

\[\mathcal{Z}: \text{Z,T} \]

\[\text{precedes}\]

PS-TVP-GP If \( u \) is a use of \([\nu \text{ V NP}]\),

\[
\mathcal{u} = \lambda f \left( \text{Closure} \left( \begin{array}{l}
\text{subj} \rightarrow X, \text{tns} \rightarrow Z
\end{array} \right) \right) \]

where \( u_1 \) is the use of \( V \), \( u_2 \) is the use of \( \text{NP} \), and \( f \) is a mia for \( \{u_1, u_2\} \).

Ignoring minor issues such as the renaming of indices, the important differences between the lexical meaning in LEX-TVERB-TENSED-GP and the one we assigned to the verb hired above are: (i) whereas Gawron and Peters propose that the content of a verb is a relation, we propose that that content is a type; and (ii) Gawron and Peters make the temporal location an argument of the relation that serves as content of the VP, whereas in our rule it has to be fixed by context.

In Gawron and Peters’ grammar, the situation an utterance is about is only part of the meaning of a whole discourse, not of its subconstituents (such as VPs). This predicts that each utterance can only be about a single situation, which is incorrect; for example, a VP may consist of two conjoined VPs that are about distinct situations, as in Many junk-bond investors had anticipated a downturn and increased the amount of cash they have in their accounts relative to junk bonds. For this reason, we propose that the content of a verb and of a VP is a type, rather than relation; in other words, that the situation described by a predicate is part of the lexical meaning of that predicate, as shown by our rule for hired above.

As for the temporal location parameter, we propose that, just like the parameters that express the content of pronouns, it might either be interpreted deictically, as in I didn’t turn off the stove, in which case it is bound at the top level; or else existentially, as in If Smith hired Jones, this company will go bankrupt, in which case the temporal location parameter is unselectively bound by an operator. And just as in the case of pronouns, we propose that we get two readings because the discourse situation affects the meaning assigned to lexical items (verbs, in this case). In case the discourse situation supports a deictic reading, a meaning like the one produced by the version of the rule LEX-TVERB-TENSED discussed above is obtained. Otherwise, a meaning similar to that proposed by Gawron and Peters is obtained. We illustrate this below.
9.3.4 Transitive Verbs

We distinguish between lexical entries for tensed verbs and lexical entries for untensed verbs. The rule for tensed verbs is a repeat of LEX-TV on Page 112.

**LEX-TV** If \( u \) is a use of type \([V_{\text{tens}}: \{\text{pres, pst}\}] \alpha]\) where \( \alpha \) is a transitive verb and \( \alpha' \) is the situation theoretic relation corresponding to \( \alpha \), then

\[
[u] = \begin{cases} 
\alpha'(X, Y, T) & \text{if tens: pst is the feature on } u \\
\alpha'(X, Y, T) & \text{if tens: pres is the feature on } u 
\end{cases}
\]

\[
* = \begin{cases} 
\text{if tens: pst is the feature on } u \\
\text{if tens: pres is the feature on } u 
\end{cases}
\]

**LEX-TV-UNTENSED** If \( u \) is a use of type \([V_{\text{untens}}: \alpha]\) where \( \alpha \) is a transitive verb and \( \alpha' \) is the situation theoretic relation corresponding to \( \alpha \), then

\[
[u] = \begin{cases} 
\alpha'(X, Y, T) & \text{if untens: pst is the feature on } u \\
\alpha'(X, Y, T) & \text{if untens: pres is the feature on } u 
\end{cases}
\]

The rule specifying the meaning of transitive verb phrases, **PS-TVP**, was presented in the section on pronouns.

**Constraints on Intensional verbs** We give here one example of a constraint which relates *seek* and *find*. Intuitively it says that if \( a \) seeks \( q \) in situation \( s \) at time \( t \) (where \( q \) is a quantifier such as
then any seek alternative for $a$ and $s$ at $t$ is one where $q$ is found by $a$ at $t'$ where $t' \geq t$.

$s \models \langle \langle \text{seek}', a, q, t \rangle \rangle \rightarrow$

$\forall s', s'$ is a seek-alternative for $a$ and $s$ at $t$ iff $\exists t' \geq t$ and

$s' \models q.$

\[
\begin{array}{c}
X \\
\text{find'}(a, X, t')
\end{array}
\]

**Constraints on Extensional verbs**  Our sample constraint for extensional verbs corresponds to Montague’s meaning postulate for extensional verbs. If $a$ finds $q$ in $s$ then $q$ is such that it is found in $s$ itself. Extensional verbs don’t involve looking at alternative situations.

$s \models \langle \langle \text{find}', a, q, t \rangle \rangle \rightarrow$

$s \models q.$

\[
\begin{array}{c}
X \\
\text{find'}(a, X, t)
\end{array}
\]

Alternatively we could state this in the following way to make it parallel to intensional verbs:

$\forall s', s'$ is a find-alternative for $a$ and $s$ at $t$ iff $s = s'$ and

$s \models q.$

\[
\begin{array}{c}
X \\
S \\
\text{find'}(a, X, t)
\end{array}
\]

**9.3.5 Intransitive Verbs**

The meaning of intransitive verbs is specified by the following rules:
LEX-IV-TENSED If $u$ is a use of type $[V[\text{tns: } \{ \text{pres} \}] \alpha]$ where $\alpha$ is an intransitive verb and $\alpha'$ is the situation theoretic relation corresponding to $\alpha$, then

$$[u] = \alpha'(X, T)$$

$$X \vdash \alpha'(X, T)$$

$$T * U$$

$$\ast = \begin{cases} < \text{if [tns: pst] is the feature on } u > & \text{if [tns: pres] is the feature on } u \end{cases}$$

LEX-IV-UNTENSED If $u$ is a use of type $[V[\text{tns: } \alpha]]$ where $\alpha$ is an intransitive verb and $\alpha'$ is the situation theoretic relation corresponding to $\alpha$, then

$$[u] = \alpha'(X, T)$$

$$X \vdash \alpha'(X, T)$$

$$\text{We present an obvious rule for interpreting verb-phrases with intransitive verbs.}$$

PS-IVP If $u$ is a use of type $[VP[\text{tns: } \alpha] \ V[\text{tns: } \alpha]]$ with constituent $u_1$, then

$$[u] = [u_1]$$

9.3.6 Auxiliary verbs

LEX-PROGRESS-TENSED If $u$ is a use of type $[V[\text{tns: } \{ \text{pres} \}] \alpha]$ where $\alpha$ is a form of ‘be’, then
The intuition behind this is that if \( x \) is \( \rho \)'ing at time \( t \) in situation \( s \), then \( s \) is of some type \( \tau \) such that \( s \) supports that there are event times which include \( t \) such that \( t \) is a
preparatory phase of x ρ’ing with respect to those times. prep-ph, for “preparatory phase,” is a relation between situation-types (which may, of course, be infons). For example, the type of x’s laying bricks might be a preparatory phase of x’s building a house. What counts as a preparatory phase depends jointly on a theory of event structure, lexical semantics and whether the situation described supports the information that the appropriate type stands in the prep-ph relation to what is represented by the VP. Thus this is a point in the grammar where a module on event structure can be plugged in.

The treatment of perfect have and future will is similar.

LEX-PFCT-HAVE If u is a use of type [V[ins: \{pres\} \alpha] where α is a form of ‘have’, then

\[
[u] = \begin{array}{|c|}
\hline
X & DS \\
\hline
& \text{utt-time}(u, U) \\
& \text{ev-time}(u, T) \\
\hline
\end{array}
\]

\[T \ast U\]

\[\star = \begin{cases}
- \text{if [ins: pst] is the feature on } u \\
0 \text{ if [ins: pres] is the feature on } u
\end{cases}\]

Let f be an index assignment for ρ (an individual property abstract with ev-time roles only) and have domain \{r_1, \ldots, r_n\}. Then,

\[
s \models \langle \text{have'}, x, \rho, t \rangle \rightarrow \exists \tau(s : \tau \land s \models \exists(\lambda f(\text{conseq-st}(\tau, \rho, f[x])))
\]

\[
f(r_1) < t \\
\vdots
\]

\[
f(r_n) < t
\]

\[
s \models \langle \text{have'}, x, \rho, t; 0 \rangle \rightarrow \neg \exists \tau(s : \tau \land s \models \exists(\lambda f(\text{conseq-st}(\tau, \rho, f[x])))
\]

\[
f(r_1) < t \\
\vdots
\]

\[
f(r_n) < t
\]

This says that for x to have ρ’ed in situation s, s must be of a type that according to s counts as a consequent state of ρ’ing. Again, this is a point where a theory of event structure needs to be plugged in. In particular, we need to require that:

\[
s : \tau \land s \models \langle \text{have'}, \tau, \sigma \rangle \rightarrow \exists s's' : \sigma
\]

Intuitively, if τ is realized as a consequent state of σ then σ must have occurred.
LEX-FUT-WILL If $u$ is a use of type $\left[ V[\{ \text{pres} \} ] \text{ will} \right]$, then

Let $f$ and $\rho$ be as before. Then

This says that $x$ will $\rho$ in situation $s$ and means that $s$ must be of a type that indicates (according to $s$) that $x$ $\rho$’s at some time now or in the future. A theory of indication needs to be plugged in here. One may wish to require:

LEX-DO If $u$ is a use of type $\left[ V[\{ \text{pres, pit} \} ] \alpha \right]$ where $\alpha$ is a form of $\text{do}$, then
Let \( f \) and \( \rho \) be as before and for all \( r \in \text{dom}(f) \), \( f(r) = t \). Then,
\[
\begin{align*}
\Delta \models \langle \text{do}', x, \rho, t \rangle & \rightarrow s \models \rho. f[x] \\
\Delta \models \langle \text{do}', x, \rho, t; 0 \rangle & \rightarrow s \models -\rho. f[x]
\end{align*}
\]
To complete the picture we add a lexical entry for verbs taking infinitival complements.

**LEX-TV-INF** If \( u \) is a use of type \([v \alpha]\) where \( \alpha \) is a verb taking an infinitival complement (e.g. *want*), then

\[
[u] = \begin{array}{l}
\lambda f \left( \{ u_1 \}, f, \{ [x]([\exists \text{lobind}(\lambda f'([u_2], f'[x])].f)]) \right) \\
\text{where } f' \text{ is a mia for } \{ [u_2] \} \text{ and } f \text{ is a mia for } \{ [u_1], \exists \text{lobind}(\lambda f'([u_2], f'[x])) \}
\end{array}
\]

### 9.3.7 Negation

We provide only a very minimal treatment of negation in this grammar. We assume that the sentence *Smith did not hire Jones* is analyzed as in

\[
[S \text{ Smith } [\text{VP } [\text{V}+\text{past} \text{ did}] [\text{VP } \text{ not } [\text{VP}[\text{-tense}] \text{ hire Jones}]]]]
\]

We give *not* the same kind of meaning as auxiliary verbs, i.e. a verb phrase modifier.

**LEX-NOT** If \( u \) is a use of type \([\text{Neg not}]\), then

\[
[u] = \begin{array}{l}
\lambda f \left( \{ u_1 \}, f, \{ [x]([\exists \text{lobind}(\lambda f'([u_2], f'[x])].f)]) \right) \\
\text{where } f' \text{ is a mia for } \{ [u_2] \} \text{ and } f \text{ is a mia for } \{ [u_1], \exists \text{lobind}(\lambda f'([u_2], f'[x])) \}
\end{array}
\]

**PS-NEG-VP** If \( u \) is a use of type \([\text{VP } \text{Neg } \text{VP}]\) with constituents \( u_1, u_2 \) respectively, then

\[
[u] = \lambda f \left( \{ u_1 \}, f, \{ [x]([\exists \text{lobind}(\lambda f'([u_2], f'[x])].f)]) \right)
\]

where \( f' \) is a mia for \( \{ u_2 \} \) and \( f \) is a mia for \( \{ [u_1], \exists \text{lobind}(\lambda f'([u_2], f'[x])) \} \)
If it were not for the fact that we want indefinites to scope within negation the rule for negative VPs would involve application as usual, i.e.

\[ [u] = \lambda f[[u_1], f.[[u_2]], f] \text{ where } f \text{ is a mia for } \{[[u_1], [u_2]]\} \]

\( \exists_{\text{lobind}} \) existentially quantifies all those roles which are indefinite roles in the meaning of \( u_2 \) and \( f \) passes up the remaining context roles.

### 9.3.8 Relative Clauses

**PS-REL-CN** If \( u \) is a use of type \([CN, CN, Rel]\) with constituents \( u_1 \) and \( u_2 \), respectively, and \( \exists u' (wh, u') \in \text{roles}([[u_2]]) \), then

\[
[u] = \lambda f - ([wh, u'] \rightarrow X)
\]

\[
\begin{array}{c}
X \\
[u_1], f.[X] \\
\hline
R \\
[u_2], f
\end{array}
\]

where \( f \) is a mia for \( [[CN], [Rel]] \), \( f((\text{exploits}, u_1)) = R \) and \( f((\text{wh}, u_2)) = X \).

**PS-REL** If \( u \) is a use of type \([Rel, NP [ +wh ] S ] \) with constituents \( u_1 \) and \( u_2 \), respectively, and \( \exists u' < \text{gap}, u' > \in \text{roles}([[u_2]]) \), then

\[
[u] = \lambda f([u_1], f.[X]([[u_2]], [\text{gap}, u' \rightarrow X], f))
\]

where \( f \) is a mia for \( [[u_1], [u_2]], [\text{gap}, u' \rightarrow X] \)

**LEX-WH-NP** If \( u \) is a use of type \([NP, \alpha] \) where \( \alpha \) is who or what, then

\[
[u] = \begin{array}{c}
\langle \text{exploits, } u \rangle \rightarrow R, ds \rightarrow DS, \langle \text{wh, } u \rangle \rightarrow X
\end{array}
\]

\[
\begin{array}{c}
\hline
\text{DS}
\end{array}
\]

\[
\begin{array}{c}
\hline
\text{wh}(u, X)
\end{array}
\]

\[
\begin{array}{c}
R
\end{array}
\]

\[
\begin{array}{c}
\beta(X)
\end{array}
\]

\( \beta = \text{person} \) if \( \alpha = \text{who} \), \( \beta = \text{thing} \) if \( \alpha = \text{what} \).\(^{72}\)

**LEX-GAP-NP** If \( u \) is a use of type \([NP, \epsilon] \), then

\(^{72}\) This is, of course, a simplified treatment of gender.
There is no special treatment of aspectual classes of verbs in PT.

PT gives a nice treatment of the *de re-de dicto* distinction. Intensions, as used in the *de dicto*, reading are taken to be basic. Extension, used in the *de re* reading, are derived from the intensions. This means that the notion of equality with amongst intensions can be weaker than with possible worlds-style treatments. The *de re* and *de dicto* readings of:

\[
\text{Smith believes a competitor will win the contract.}
\]

are given in the truth conditions:

\[
\begin{align*}
\exists x (T(\text{competitor'}x) \& T(\text{believe'}(\text{will-win'}(\sigma\text{contract'}c)x))(\text{smith'})) \\
T(\text{believe'}(\exists x (\text{competitor'}x \& \text{will-win'}(\sigma\text{contract'}c)x))(\text{smith'}))
\end{align*}
\]

The copula “be” and light verbs such as “have” can be represented directly as be’, have’ in the semantics. Obviously, this does not tell us what information can be derived from their use. Aspects of the pragmatics of their use could be modelled with additional axioms. The weak typing of PT allows one term to take the different categories of arguments, as evident in:

\[
\begin{align*}
\text{Smith is a bankrupt.} \\
\text{Smith is bankrupt.}
\end{align*}
\]

In one PT implementation, copula and light verbs are disambiguated in all the ways that are permitted by the domain. For example, the interpretation of “be” is constrained by the domain to be equality for salaries: “Mary’s salary is £1000”, or some other relation, such as age in “Mary is 25”. The verb “have” is modelled with a three place relation “of”, giving the two individuals which are related and some aspect of their relation as described above in §2.4 [De Roeck et al., 1991a; De Roeck et al., 1991b].

Modal verbs, as yet, have no special treatment in PT.
9.5 Monotonic Semantics

Various properties of verbs are described in D2. Almost none of these properties are represented linguistically in the current CLE implementation.

**Aspectual classes**  No distinction is made between events and states, or between finer grained types of actions, at QLF or at RQLF. However, information about stativeness of predicates is sometimes used in reasoning carried out during further resolution in the context of a particular application.

**De Re/ De Dicto**  Sentential propositional attitude verbs like ‘believe’ are currently only given a de dicto interpretation, although this is determined merely by scoping declarations and could easily be changed. Infinitival intensional verbs like ‘try’ only get a de re reading. Again, this is not immutable.

**Copula-Light Verbs**  Light verbs like ‘have’ are in principle to be treated as vague relations to be contextually resolved. In practice this resolution currently takes place at the level out which linguistically motivated logical forms are mapped onto application predicates.

‘be’ is uniformly translated with different complements, in terms of a 3-place predicate ‘be’, of events/states, individuals, and 1-place predicates. The ‘be’ predicate is true of a state, individual and predicate if the state is one in which the predicate holds of the individual. Different complements to ‘be’ supply different predicates:

John is a cat.

```
[dcl, form(verb(pres,no,no,no,y),A, B^
   [B, [be,A,term(...John...),
        D^[eq,D,term(...a cat...)]]
    ,_])

John is happy.
```

```
John is in Cambridge.

[Dcl,
  form(verb(pres,no,no,no,y),A,
    B^,
    [B,
      [be,A,term(...John...),
      D^form(prep(in),-,
        E^term(...Cambridge...)]],
      _])]

**Modals** Modals are resolved to sentential operators. They are not disambiguated into epistemic or other uses, currently.

### 10 Attitudes

#### 10.1 Discourse Representation Theory

In the systematic part of this precis on DRT we have sketched the principal ideas behind DRT’s account of the attitudes and of the semantic representation of attitude reports. Not discussed were the processing principles which are to apply to the complement clauses of attitudinal verbs (and other attitudinal expressions). Of course, one would hope these principles to be largely the same as those which operate outside attitudinal contexts, in the spirit of Davidson’s largely rhetorical question about the words that make up the complements of attitude expressions: What are these words doing here? But it would be rash to hope for complete identity. For, after all, the context in which the complement clause of an attitudinal predicate must do its job is an unusually complex one. It involves not only the attitudinal state which the clause is meant to describe, but also the mental state of the speaker himself, who has to capture the attitude in words as best he can and who can do this only on the basis of his own information, as it is represented in his belief state. So one might well expect that the complement clauses of attitudinal predicates reflect some of the special complexities of the conditions of their use.

In fact, it is precisely in response to this complication that languages like English have developed interpretational options which make sense only within the attitudinal domain and which outside of this domain collapse into one. The most notorious of these options is that which is known in the philosophical literature as the difference between *de re* and *de dicto*.

There is a good deal of confusion about this distinction. In part this is a consequence of the tendency, which we mentioned in the systematic part of this report, to make no clear distinction between a theory of the attitudes themselves and a theory of attitude reports (i.e.
a theory about the semantics of the language in which we make explicit or implicit reference to the attitudes of others and of ourselves. When this distinction is made, and when it is made on roughly the lines we have sketched, then it becomes natural (not to say imperative) to distinguish between two de dicto-de re distinctions, one at the level of the attitudes themselves and one at the level of the attitude reports. At the level of the attitudes the distinction is between discourse referents (of DRSs acting as descriptions of attitudinal states) which are externally anchored to the things they represent (via a causal relation in which the bearer of the attitude stands to the represented thing) and the discourse referents that are without such an anchor. At the level of attitude reports the distinction is in the first place one between two modes of noun phrase interpretation. (The distinction can be extended to cover expressions of other categorial types, but we shall let that pass here.) As a first approximation, interpreting an occurrence of an NP inside an attitudinal complement as de dicto means that one takes all the information it would normally (i.e. outside attitudinal contexts) be taken to convey as part of the description of the attitude which the complement is meant to characterize; interpreting the NP as de re means that this information is interpreted as information which the speaker has as his own information about the referent of the NP.

This is only a rough description of the second distinction as it normally understood, but it is close enough to reveal some of the difficulties that attach to it. Originally, the distinction was conceived as applying to definite descriptions; this was at a time, when descriptions were considered the paradigms of referring expressions in natural language and at the same time were quite generally thought to function either along the lines of the reference theory of Russell or of the Frege-Strauss theory. Given either of these theories, at least the notion of a de dicto interpretation is clear enough. But even in this case more needs to be said - this brings us to the second difficulty - about interpretations de re. For if the identifying information which the description provides about the object which in some way enters into the attributed attitude is information that the speaker has about this object rather than the person to whom the attitude is attributed (call this person henceforth the bearer of the attitude), then the bearer must have other means of identifying this object and the question is: What can these be?

Philosophers have been debating this question for over thirty years now, but without much more tangible effect than that opinion seems to be persistently divided. For some, interpreting an NP in an attitude-describing clause de re implies that one takes the bearer to stand in a suitable causal relation (of “direct awareness”, or “acquaintance”) with the referent of the NP. For others there is in general no such implication, but only this one: that the bearer has information which he takes to be identifying information of some object and that as a matter of fact, but presumably beyond the bearer’s knowledge, this information happens to identify the same object that is identified for the speaker by the content of the description. Work in DRT has so far taken the former line, by assuming that when an NP is interpreted as de re, then the discourse referent it introduces into the DRS for the embedded clause must be de re in the first, attitude-related sense, and thus must be externally anchored. (However, it would be possible to drop this assumption about the connection between de re interpretation and anchoring without giving up any other important aspect of the theory.)

The second type of NPs to which the de re - de dicto distinction can be applied pretty much as we have stated it are the indefinite NPs. In connection with indefinites the distinction is
usually described as that between specific and non-specific (a result of historical serendipities which need not detain us). As a matter of fact, the effect of interpreting an indefinite description as specific and that of interpreting a definite description de re are very similar. In either case, the descriptive content of the NP is interpreted as information which the speaker takes to uniquely identify a certain object, while the bearer of the attributed attitude is understood to have identifying knowledge concerning this object which is either based on a suitable causal relation between him and the object (which is, we said, the view we decided to adopt), or else involves certain descriptive information (about which, however, the attitude report has nothing to say). The only difference between the specific indefinite and the definite description de re is, it seems, a matter of novelty as opposed to familiarity: If the speaker uses an indefinite NP, he implies that an object is at issue that is new to his addressee; if the addressee interprets the NP as specific, he will impute to the speaker the assumption that the individual for which he (the speaker) takes to be having identifying information (the information contained in the indefinite description he has used) is not yet familiar to the addressee. In contrast, if the addressee interprets a definite description as de re, then he will assume that the speaker thought the addressee to be already acquainted with the referent of the description. (Note that the novelty-familiarity distinction applies to descriptions occurring in the complement clauses of attitudinal expressions only when they are interpreted de re. When the description is interpreted de dicto, the difference between definite and indefinite indicates whether the bearer does or does not consider himself to have identifying information about the constituent of his attitude towards which the NP points.)

From what we have said it should be clear that the two interpretational possibilities we have mentioned do not exhaust the repertoire of possibilities. For one thing, why could the information contained in the description not be taken as being at the same time the identifying information for the bearer and for the speaker. In fact, for the definite description of the example (270)

(270) Smith believes a competitor will win the contract.

which we will treat presently, this seems the most plausible interpretation. (It has been argued notably by Loar that such "double-duty" interpretations are possible; but of course, even if one accepts this, there remains a further question whether this double-duty interpretation constitutes a separate logical form or is the result of a non-linguistically based inference which starts from one of the two duties and concludes that the description must, in this case, be doing the other duty too.)

It should also be evident from this discussion that it is anything but clear how the de re - de dicto distinction can be applied to NPs of other types, such as proper names, indexicals like I and you, or the third person pronouns and the demonstrative NPs. There is a lot of work to be done in this area that the philosophical discussions of the past decades have oddly neglected. But the present discussion is meant to focus on the one example (270) that we want to deal with here. This example involves an indefinite description (a competitor) and a definite description (the contract); as a basis for explaining how DRT deals with it what we have said so far will be enough.
As far as the general features of DRSs for attitudinal sentences are concerned we refer to the systematic part of this report. (Recall: the representation of an attitude report involves a state of affairs to the effect that the bearer’s attitudinal state has a part which is (fully or partially) described by the embedded clause. We will assume that the definite description is interpreted de re, and in fact that it gets the double-duty interpretation; but with regard to the indefinite description we will consider both the de re and the de dicto interpretation.

Assigning the NP the contract the “double duty” interpretation means within the present framework several things at once. First, the discourse referent that represents the NP within the DRS describing the attributed attitude must be anchored to some object, and within this DRS it must be accompanied by one or more conditions reflecting the descriptive content of the NP. Second, one would ideally also want to represent the intuition that in interpreting the NP de re the recipient attributes to the speaker the belief that the object in question can be identified by the descriptive content he has used.

There is a further problem connected with the particular definite description the contract. This is that the descriptive predicate contract can hardly be expected to identify a unique object all by itself, without support from other contextually implicit constraints - there are innumerable contracts in this world and only knowledge about which particular situation is at issue will make it possible to know which contract is meant. Thus a set of conditions that can properly be said to identify the object would have to include much more than just the condition that it is a contract. This is one of the places where non-linguistic knowledge plays a crucial part in interpretation. As we have said elsewhere, it is one of the important tasks of natural language semantics, if not to describe what such non-linguistic knowledge is and whence it comes, then at least to show how the linguistic system which it does describe interacts with it. However, this is not the place to address this point and so we will be content to use as a stop-gap condition the contract( ), in which the definite article is meant to indicate that the condition, when properly expanded, does uniquely identify some particular contract (or is thought to do so).

The de dicto (or non-specific) interpretation of a competitor simply has the effect of assigning the discourse referent for the NP to the universe of the (sub-)DRS which characterizes the content of the attributed belief; in this way the contribution of the NP is simply that of an existential quantifier with narrow scope (“inside the belief-operator”, as those would put it who advocate treating attitudinal verbs along the lines of classical modal logic). From a representational perspective this interpretation is straightforward. So in the DRS (271) below, which represents this reading, the focus of interest lies with the definite description.

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The square brackets around \( z' \) in the “belief DRS” indicate that this discourse represents for the bearer \( x \) of the attitude an object to which he himself takes himself to stand in a suitable causal relation. The bit of notation \( \langle z', z \rangle \) at the bottom of the DRS expresses that \( x \) does in fact stand in such a relation to the object \( z \), and that the role which \( z' \) plays in his attitudinal state is suitably connected with that relation. (Thus \( \langle z', z \rangle \) confirms, as it were, that \( x \) is entitled to his belief that he is suitably related to the object represented by \( z' \).)

As it stands, (271) is a representation of the content of (270) and so does not say anything directly about the beliefs and commitments of the speaker. However, we can also regard (271) as part of the speaker’s attitudinal state. In that case the condition the contract(\( z \)) expresses that the speaker also identifies the object in question by a set of conditions of which the contract(\( z \)) is one. (However, if the DRS is to reflect that the speaker also takes himself to stand in a relation of acquaintance to the contract in question, this should be indicated by placing square brackets also around \( z \).)

The \textit{de re} reading of a competitor gives rise to a DRS which no longer holds any real surprises. Even so, we give it explicitly, in the following (272):
The dynamic modal logic style already provides epistemic representations in a dynamic setting. According to De Rijke [Rijke, 1992] a proposition $\phi$ is believed by an agent whenever all extensions of the current state of the agent contain the information $\phi$. This is a clear difference with the update semantics in the style of Veltman. Here a belief is represented by a ‘local’ set of uncertainties. In Jaspars [Jaspars, 1994] the same choice has been made, but then states are complete possible world models with multiple accessibilities to deal with several agents. A similar choice has been made by Groeneveld [Groeneveld, 1993], which tries to stay as close as possible to the eliminative dynamic structure of update semantics.

Not much effort has been made to distinguish different epistemic attitudes. Once a possible worlds or information states semantics has been given for belief representation, a philosophically based classification of these multiple states would be a first step towards such a differentiation.

With respect to intentional attitudes like want, hope and intend, things look more complicated. For a proper treatment of such attitudes, information states and their corresponding dynamics need to be enriched considerably. In Veltman [Veltman, 1991] the notion of expectation patterns has been defined over the multiple word states in update semantics. They are employed for modeling default reasoning in the update style, but as we see it, they could also be used for preferential reasoning. Such preferential patterns may be useful to implement dynamic theories on the class of intentional attitudes.

In a manuscript of Van Bentham, Van Eijck and Frolova [Benthem et al., February 1993] a more general modal style for dynamic reasoning about preferences has been proposed. In Jaspars [Jaspars, 1994] the notion of ‘goal’-worlds of Cohen and Levesque [Cohen and
Levesque, 1990] has been used for defining dynamics over rational preferences. Here they are employed for implementing intentional updates among communicating partners.

Reportive attitudes like *say* or *announce* have not attracted much interest from dynamic semanticists. For a paper on dynamic treatment of circular propositions (such as the Liar paradox), see Groeneveld [Groeneveld, 1994]. Perceptive attitudes like *see* and *hear* have also stayed outside the scope of dynamic semanticists. Recent work of Muskens and Piwek [Muskens and Piwek, 1994] tries to put them on the stage of dynamic semantics. Here a combination of partial logical approaches such as [Barwise, 1981] and [Kamp, 1983] and the relational style of dynamic semantics is proposed.

**10.3 Situation Semantics**

Cooper and Ginzburg (e.g., [1994]) developed a compositional treatment of attitude reports based on three ingredients: (i) structured propositions, (ii) the notion of an agent’s mental *state* as a situation, and (iii) a ternary view of attitude reports as relations between agents, propositions, and mental states. We adopt their treatment here. By necessity, only a brief discussion of the issues can be included; we refer the reader to the original work for more details.

**10.3.1 Propositional Attitudes as Ternary Relations between Agents, Propositions and Mental States**

One might think that by translating the verb *believe* as a two-place predicate whose second argument is a structured Austinian propositions of the type presented in Chapter 2, one could solve the classical puzzles about belief. And indeed, a number of them are solved; logical omniscience is an example. From the fact that believe(*a*,*p*), where *p* necessarily entails *q*, we are not able to conclude believe(*a*,*q*) if *q* is a distinct proposition from *p* (in the sense defined here). Nor are we able to conclude that believe(*a*,*l*) where *l* necessarily true (i.e., true at all worlds).

Unfortunately, puzzles such as Kripke’s ‘London/Londres’ problem [Kripke, 1979] indicate that more than structured propositions is needed. According to Kripke, it is possible for both (273a) and (273b) to be true statements about the Pierre.

\[(273) \quad \begin{align*}
a. & \quad \text{Pierre believes that ILC is insolvent.} \\
b. & \quad \text{Pierre believes that Lonsdale is solvent.}
\end{align*}\]

These can represent rational beliefs on the part of Pierre even though, unbeknownst to him, *ILC* and *Lonsdale* denote one and the same company. Although the two embedded sentences represent contradictory propositions externally they correspond to different internal belief states of Pierre. We call these states mental states and claim that belief of a proposition is relativized to different mental states. Cooper and Ginzburg propose that belief is a relation between an agent, a proposition, and a mental *state*. 

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A mental state is a situation $ms$ such that a proposition of the following kind is true:

$$\begin{align*}
ms &= \\
&\alpha_1(a_1, ty_1, f_1, t_1) \\
&\ldots \\
&\alpha_n(a_n, ty_n, f_n, t_n)
\end{align*}$$

where $\alpha_i$ are internal attitude relations corresponding to believe, know, desire, $a_i$ are agents, $ty_i$ are types (possibly zero-place, i.e. propositions), $f_i$ are partial assignments appropriate to $ty_i$, and $t_i$ are times.\textsuperscript{74} The in-ons that characterize a mental state are systematically related to the in-ons that occur in the interpretation of attitude reports, as shown below.

The meaning for an utterance $u$ [$\text{Pierre}_1 \; \text{believes} \; [\text{that}_2 \; \text{Londres}_3 \; \text{is pretty}_4]$] proposed by Cooper and Ginzburg is shown in (274).

\textsuperscript{74}This proposal is related by Cooper and Ginzburg to Kamp’s proposal in [Kamp, 1990].
The connection between the meaning in (274) and the mental state that supports it is provided by constraints.

\[ s \models \langle \text{BELIEVE}, a, p, ms, t; 1 \rangle \rightarrow \exists T, f(ms) \models \langle \text{BELIEVE}\#, a, T, f, t; 1 \rangle \land \exists^* T f = p \]

\[ s \models \langle \text{BELIEVE}, a, p, ms, t; 0 \rangle \rightarrow \neg \exists T, f(ms) \models \langle \text{BELIEVE}\#, a, T, f, t; 1 \rangle \land \exists^* T f = p \]
The first constraint amounts to linking a positive belief attribution of proposition \( p \) relative to the mental situation \( ms \) with the existence of an \textit{internal} belief state, classified by the relation \textit{BELIEVE}\#, such that applying its type component \( T \) to its assignment component \( f \) yields \( p \). The second constraint supplies the required analogue for negative belief attributions.

The meaning in (274) is obtained compositionally by applying the following rules:

**LEX-PA** If \( u \) is a use of type \([V[S]] \alpha\) where \( \alpha \) is a verb taking a \textit{that}-complement, then

\[
[u] = \begin{array}{c}
\langle t, u \rangle \rightarrow T, \langle \text{mental-state}, u \rangle \rightarrow MS \\
Prpn \\
\alpha'(X, Prpn, MS, T)
\end{array},
\]

where \( \alpha' \) is the relation that interprets \( \alpha \).

**PS-THATS** If \( u \) is a use of type \([S' \text{ that } S]\) with constituents \( u_1, u_2 \) respectively, then

\[
[u] = \lambda f \cup (\text{concerns}, u) \rightarrow S(S : [u_2] : f) \\
\text{where } f \text{ is a mia for } ([u_2])
\]

**PS-VPSCOMP** If \( u \) is a use of type \([VP V[S]] S'\) with constituents \( u_1 \) and \( u_2 \) respectively, then

\[
[u] = \lambda f[u_1] : f, [u_2] : f \\
\text{where } f \text{ is a mia for } ([u_1], [u_2])
\]

Rules analogous to LEX-BELIEVE specify the meaning of other attitude verbs. The phrase structure rule for the \textit{that}-clause is a simplified version of the one proposed by Cooper and Ginzburg, and only produces the interpretation in which the object of belief is taken to be a proposition about a contextually determined situation; see [Cooper and Ginzburg, 1994] for a more complex version.

We use these rules also for perception verbs with \textit{that}-complements such as

\((0)\) Smith saw that Jones had signed the contract

### 10.3.2 Naked-infinitive perception complements

In order to treat

\((0)\) Smith saw Jones sign the contract
We allow NPs to combine with tenseless VPs to form tenseless sentences such as Jones sign the contract. The content of such a sentence is an infon. The content of the sentence (10.3.2) represented schematically is:

$$\text{see}(\text{Smith}, S) \quad \text{sign}(\text{Jones, the-contract}, t)$$

Where $S$ is determined by context. Compositionally, this is achieved by the rule **PS-N1-COMPC**.

**PS-N1-COMPC** If $u$ is a use of type $[\text{VP} \, \text{V}_{[\text{COMP: N1}] \, \text{S} \, \text{TNS}]}$ with constituents $u_1, u_2$ respectively, then

$$[u] = \lambda f \cup [(\text{perc-sit}, u) \rightarrow S] \quad [u_1], f, [S] \quad [u_2], f$$

### 10.4 Property Theory

These can be represented in PT along the lines given in PTQ, except with fine-grained intensionality. The sentence:

*It is true/false that itel won the contract.*

requires some more additions to the basic theory. We need to add a new term $\hat{i}$ such that:

$$\begin{align*}
P(s) &\rightarrow P(\hat{i}s) \\
P(s) &\rightarrow (T(s) \leftrightarrow T(\hat{i}s))
\end{align*}$$

This results truth behaving like an S5 modality [Turner, 1992]. This seems to be all that is required for the semantics of NL. Adding anything much stronger to a Frege structure, such as $\text{Pty}(\hat{i})$ leads to inconsistency. If examples can be found that suggest that truth and proposition-hood should be internalised as properties, then a stronger theory of properties, propositions and truth would be required than the one presented here.

Inferences with attitudes requires additional axioms such as those captured by Davies [Davies, 1990].

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75 In a more complete treatment an alternative of having the situation existentially quantified would also be allowed.
There is currently no special treatment of, for example, the distinction between “seeing” and “seeing that”.

10.5 Monotonic Semantics

The CLE has not implemented an illuminating account of attitude verbs. One might speculate that QLFs lend themselves to a structured-meaning approach to attitudes, but this is just speculation.

11 Questions

11.1 Discourse Representation Theory

As the introductory text to this section of D5 points out, it would seem that the primary task for a truth-conditional semantics in the realm of interrogative constructions is that of dealing with the semantics of embedded questions. For these may occur as parts of indicative sentences; and it is with the indicative sentences of a language that lies truth-conditional semantics’ primary responsibility. Nevertheless there has been, from the earliest attempts to come up with a plausible compositional account of the truth-conditions of question-embedding constructions, a pervasive conviction that the semantic value to be assigned to an embedded question should have something to do with the answers that can be given to the corresponding direct question. (Thus, the pioneers in this domain, Hamblin and Karttunen propose for this value the set of all possible answers and the set of all true answers, respectively. Later, proposals with the same over-all purpose show a similar orientation - cf. for instance the often cited proposals of [Engdal, 1986] and of [Groenendijk and Stokhof, 1984a].)

Proceeding along these lines has the potential benefit of a uniform account of direct and indirect questions: For that the “semantics” of a direct question should have something to do with the possible answers that it invites, and/or with those answers which are true - this is a view that could hardly be challenged. But unfortunately the yield of these theories has been rather meager. There is nothing very much wrong with defining the denotation of an embedded question as the set of its possible or its true answers, and then to treat question-embedding verbs like know, wonder, ask or tell as predicates of such objects. But when push comes to shove, it seems to buy you precious little. For it tells you next to nothing about the semantics of the individual question-embedding predicates.

In fact, it is curious that, notwithstanding the omnipresent intuition that the semantics of questions must have something to do with their answers, this intuition hasn’t been taken as seriously as it should have been. For a start, there are important semantic differences between question-embedding constructions involving such predicates as tell and know on the one hand and the constructions with ask or wonder on the other. (Cf. e.g. [Berman, 1991]). The reason for this difference seems quite clearly connected with the fact that the former verbs
are what one might call “answer-oriented”, whereas the latter two are “question-oriented” - thus to know who is going to take over CRC knows the answer to that question, he is not “knowing the question” (whatever that means). On the other hand, someone who asks who is going to take over CRC asks the question who is going to take over, he is not asking the answer (although he is asking for, i.e. requesting, the answer).

This observation is one of many that point towards a perspective on the problems posed by interrogatives which seems to be rapidly gaining currency today, viz that the central concepts needing theoretical explication are the various relations in which a question may stand to its possible answers. The perspective owes much to computational linguistics. Many computational applications turn on the mechanical generation of good natural language answers to natural language questions. Consequently the need for a sound and detailed analysis of the multifarious ways in which answers can relate to questions presents itself incessantly as a practical as well as a theoretical need.

The work that this perspective has generated has already led to a much more sophisticated understanding of the complexity of the question-answer relationship: in particular it has become patent that what we need to understand is not just which indicative sentences are possible answers to a given question, and which from among those possible answers is or are true. There are other dimensions to the question-answer relationship besides those of truth and logical form, which in actual practice are at least as important. To give but one obvious, but telling example: many wh-questions come with a uniqueness presupposition. If this presupposition is fulfilled, such a question can always be truthfully answered with “The one who did it.” You can’t go wrong this way. But it is unlikely to be a very useful answer to the person who asked the question. True answers can be very bad answers.

While notions such as the usefulness of an answer belong to pragmatics if anything does, semantics has an important part to play in their analysis. In fact, this is one of the areas of language where the interconnectedness of semantics and pragmatics has a particularly high visibility.

The role which DRT has so far played in these pragmatic, or pragmatically tinted, notions has been a comparatively modest one. But there is one aspect of the analysis of questions and answers that DRT is well-equipped to deal with: as even a brief look at question-answer pairs reveals - just look at the pairs cited as (157)-(160) in D5 - anaphora and ellipsis play a very large part in their interpretation. But anaphora is, one might say, DRT’s home turf, and what makes it a useful theory for dealing with anaphora is pretty much also what is needed for ellipsis.

The best way to substantiate these claims about the usefulness of DRT would be to build a question-answer fragment. Such a fragment should include the main grammatical categories of questions - yes-no questions, wh-questions and disjunctive questions - as well as a variety of types of answers that are not full sentences, such as yes, no, (perhaps) perhaps, NPs and PPs and, as possible answers to why- and how- questions, subordinate clauses, infinitival clauses and gerunds (because he wanted to see her, in order to minimize losses, by firing half of the work force). It should define the notion of a correct question-answer pair, i.e. which of the various types of expressions that it classifies as possible answers can be answers to which type
of questions. As always the DRT part would be to define a construction algorithm which converts question-answer sequences form the fragment into representations which reveal not only the propositional content of questions and answers separately, but also how they relate to each other. In particular, they should make the full propositional content transparent of the (typically elliptical) answers. (The simplest way to fulfill this last desideratum is to make the propositional content of the answer fully explicit in the part DRS which directly represents the answer. This is the option we have chosen also in the two examples below. However, in representations of exchanges which involve a succession of questions and answers (as for instance in the appointment-making dialogues currently studied in VERBMOBIL), this option leads to much repetition, and a representation format which avoids this by making heavy use of pointers appears to be much preferred.

To develop such a fragment is an immediate possibility, although to our knowledge it has not yet been done (at least not in the way we have just sketched). Here we can do no more than to show what the representations might look which such a fragment would produce for two of the question-answer pairs which D5 mentions.

We begin with a simplified version of example (157) in D5:

(277)  
A:  Who attended the meeting yesterday?  
B:  Smith.

To deal with this example the parser has to verify (i) that A’s utterance is a wh-question with one wh-element, and that this element is extracted from an NP position; (ii) that B’s utterance is an NP, and thus qualifies as a term answer to A’s question. We represent A’s question by a pair consisting of a question operator and a DRS. The question operator is one of a number of utterance mode indicators, which enable us to distinguish in our representations between different types of speech acts. Thus from now on the representations of assertions also will have to be marked, analogously, by an assertion operator. (With the introduction of utterance operators into a our representations we place ourselves squarely within the realm of pragmatics.) We will assume that the question operator can bind one or more discourse referent. To some this may seem anathema: an utterly damnable confusion of semantics and pragmatics. They may stick to the now classical model-theoretic treatment of interrogatives according to which they always denote characteristic functions of propositions, and then treat the question operator as always taking objects of this kind. We suspect it will be possible to make things work this way too, though we haven’t tried.

In trying to represent the sequence of the two utterances of A and B, we are taking our first step towards a theory of the representation of dialogue. The representation of dialogues, however, requires a much more careful separation of context and utterance than has been observed in standard DRT, just as it requires that one keeps a careful record of the distinct utterances and their utterers. So we will have to record, besides the mode of each utterance also the identity of its utterer. And we should allow for a background context that is distinct from any of the utterances the dialogue contains, including the very first one. In the case of (277) it seems reasonable to assume that the meeting to which A’s question pertains is known in advance to both A and B - we may even expect it to have been salient. So the meeting
will be part of the context and our representation of (278) will consist of three parts: (i) the initial context; (ii) A’s question, and (iii) B’s answer. We will make things a little easier for ourselves by analyzing *yesterday* in A’s question as an adjunct to *the meeting*.

Using “?” for the question operator and, following Frege, “⊥” for the assertion operator, we get for A’s utterance, together with the initial context, the representation

\[
\begin{array}{c|c}
\text{CONTEXT:} & z \\
& \text{the meeting yesterday}(z) \\
\end{array}
\]

(278)

\[
\langle A, ?x : \\
\neg x n \\
\neg < n \\
\neg e : \text{come to}(x, z) \\
\rangle
\]

B’s answer consists of the NP *Smith*. We assumed that the parser has recognized this as an answer that grammatically fits A’s question. This insight drives a construction rule which performs the following operations: (i) It introduces a discourse referent for the NP, together with the condition embodying the identifying information carried by the NP; (We assume that Smith is already part of the shared background of A and B (even if he may not have been salient until B mentions him), and introduce the new discourse referent accordingly into the context). (ii) It substitutes this discourse referent for the queried discourse referent of the question. (iii) It uses the DRS which results in this way as second component of the representation of the answer, the first component of which consists of the identifier of B and the assertion operator. In this way (278) is extended to

\[
\begin{array}{c|c}
\text{CONTEXT:} & z \\
& \text{the meeting yesterday}(z) \\
& \text{smith}(y) \\
\end{array}
\]

(279)

\[
\langle A, ?x : \\
\neg x n \\
\neg < n \\
\neg e : \text{come to}(x, z) \\
\rangle
\]

\[
\langle B, \neg: \\
\neg n \\
\neg < n \\
\neg e : \text{come to}(y, z) \\
\rangle
\]

The example (157) in D5 is very similar to (277), the only difference being that in (157) the answer is the plural NP *Smith and Jones*. 

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A: Who attended the meeting yesterday?
B: Smith and Jones.

This gives rise to a minor complication: should we think of Smith and Jones as a collective individual, a two-some which turned up at the meeting as a pair; or should we think of them “distributively”, as each having made it to the meeting on his own steam and perhaps unaware of the other’s intentions? The difference may not seem very significant here, but in other cases it is essential to distinguish between a distributive and a collective interpretation of clauses with plural NPs, which made it natural to introduce this distinction across the board. (The UDRT of Reyle offers the option of leaving the distinction underspecified, but this is not the point to switch to another version of the theory.) So the construction algorithm has to make a choice one way or the other, and thus forces upon B’s answer an ambiguity which may strike us as perhaps somewhat spurious.

Be this as it may, our theory returns two representations for the answer of B. Of these the collective has nothing new to teach us so we will ignore it. The distributive interpretation, however, has something mildly new to show, in virtue of the quantification it involves. As discussed in [Kamp and Reyle, 1993], Ch 4, the distributive reading of a universal quantification over a certain set, here the set consisting of Smith and Jones. Thus the crucial discourse referent, which is substituted for the queried discourse referent in the representation of the question, is now the bound variable of the universal quantifier. (The rule for NP answers will have to be stated in such a way that it correctly selects this discourse referent in quantificational cases like this.) The result will be as in (281):

\[
\begin{array}{|c|}
\hline
z \in U \\
\hline
\text{the meeting yesterday}(z) \\
\hline
\text{smith}(y) \\
\hline
\text{jones}(v) \\
\hline
U = z \oplus v \\
\hline
\end{array}
\]

\[
\langle A, \exists x : e < n \land e : \text{come to}(x, z) \rangle
\]

\[
\langle B, \forall u : e < n \land e : \text{come to}(u, z) \rangle
\]
11.2 Update and Dynamic Semantics

The semantics of questions is closely linked to the pragmatics of what counts as a correct answer to a question (see Groenendijk and Stokhof [Groenendijk and Stokhof, 1984b]). The theories of belief revision and knowledge update from Section 2.1.3.6 in D8 are directly applicable to the treatment of knowledge revision by means of asking questions and processing the answers. Again, fortunately, the present perspective does provide a general direction rather than specific guidelines for a treatment.

11.3 Situation Semantics

Although our current grammar does not handle questions, Ginzburg’s treatment [1992] could be easily incorporated. In this treatment, questions are ‘structured’ objects much like propositions are, written (s?σ).

11.4 Property Theory

There is a proposal for the treatment of questions in PT in which questions are taken to be a new class of terms. In place of truth conditions, such terms are given answerhood conditions which allow the felicity of a putative answer (either propositional or categorial) to be deduced. This should avoid some of the philosophical problems of extensional theories of questions and answers, where the semantics of a question embodies its possible answers [Groenendijk and Stokhof, 1984a; Groenendijk and Stokhof, 1990b].

11.5 Monotonic Semantics

Yes-no questions are given a QLF identical to that for the corresponding declarative, except that a functor ‘ynq’ is wrapped around this QLF. This is a signal to whatever inference mechanism is being used to interpret the resolved QLF that this is a query, not a declarative.

Indirect wh-questions get exactly the same analysis but are embedded as an argument to the verb.

>> Does John sleep?

QLF:

[ynq,
  form(verb(pres,no,no,sai_do,y),A, 
      B^)
]

EC Fellowship Proposal ERB4061GT933715.
[B,[sleep,A,term(\ldots John\ldots)]]

TRL:

ynq(exists([A,B],
and(and(sleep_BeNaturallyUnconscious(B,A),event(B)),
      name(A,John))).

\textbf{>> Bill wondered whether John slept.}

QLF:

[dcl,
 form(verb(past,no,no,no,y),A,
      B^B,
      [wonder,A,
       term(\ldots Bill\ldots),
       [ynq,
        form(verb(past,no,no,no,y),D,
             E^E,[sleep,D,term(\ldots John\ldots)],
             _)]]),
     _)]]).

TRL:

dcl(exists([A,B,C,D,E],
and(and(and(wonder(C,
     B,
     ynq(exists([F],
       and(sleep(F,A),
          and(event(F),
             exists([G],and(precedes(F,G),
                                      current_time(G))))))
       ))),
     name(B,Bill)),
     name(A,John))

These logical forms do not uniquely fix the intended interpretation of yes-no questions. The interpretation that is implemented is one in which if the content of the question can be proved from the database, the answer is yes; if the question involves only predicates for which it is known that the closed world assumption holds, and the content of the question cannot be proved, then the answer is no. The answer is 'not enough information', otherwise.

Indirect ynq questions are not currently interpreted in the general case: thus from the example above we would only be able to infer that John wondered something. There are exceptions to this in the case of verbs like 'know' and a few others, which are given a partial interpretation in terms of the closed world assumption. Thus the database may contain assertions like

\texttt{forall(x,knows\_whether(system,employee(x)))}
and if it does, then a question like

‘do you know whether Smith is an employee’, will be answered. (By ‘yes’. No indirect speech acts come with the basic system).

Constituent questions are signalled as such by a marker ‘whq’. Wh-phrases are treated as terms that are resolved to lambda-abstractions rather than quantifiers. Conversion through to TRL maps the wh-phrase onto an explicit command to display a tuple of objects in the case of direct wh-questions, but the abstraction is preserved in embedded questions:

>> Who sleeps?

QLF:

[whq,
  form(verb(pres,no,no,no,y),A, B^B,[sleep,A, term(q(tpc,wh,_),W,C^-[personal,C],_,_)]),
  _)]

TRL:

forall([A],
  impl(exists([B],and(personal(A),
    and(sleep(B,A),event(B)))),
  exists([C,D,E,F],
    and(current_time(D),
      and(date_before(strict,D,E),
        executable_action(C,display_tuple([A]),
          the CLARE system,
          user,E,F))))))

>> John wonders who sleeps.

QLF:

[dcl,
  form(verb(pres,no,no,no,y),A, B^B,[wonder,A,term(...John...),
    [vhq,
      form(verb(pres,no,no,no,y),D, E^E,[sleep,D,term(...who...)]),
      _)])
  _)]

TRL:

exists([A,B],
  and(wonder(B, A, whq(C^
and(personal(C),
    exists([D], and(sleep(D,C), event(D)))),
name_of(A,John)))

Multiple abstraction is possible, either when there are two or more wh-phrases:

>> Which man likes which dog?

QLF:
[whq,
 form(verb(pres, no, no, no, y), A,
    B^[B,[like,A,
      term(q(tpc,wh,sing),_),
      C^[man_MalePerson,C],_),
      term(q(ntpc,wh,sing),_,
      D^[dog_Animal,D],_)]],
_]

TRL:
forall([A,B],
    impl(exists([C],
        and(man(A), and(dog(B), and(like(C,A,B), event(C))))),
        exists([D,E,F,G],
            and(current_time(E),
                and(date_before(strict,E,F),
                    executable_action(D,display_tuple([A,B]),
                        the CLARE system,
                        user,F,G))))))

>> Bill wonders which man likes which dog.

TRL:
exists([A,B],
    and(wonder(B, A,
        whq(C[
            B^[B,
                and(man_(C),
                    and(dog_(D),
                    exists([E], and(like(E,C,D), event(E))))),
                    name_of(A,Bill)]))

or when a quantifier like each receives wide scope over the wh abstract (in which case the determiner is treated as an abstraction rather than as a quantifier).
At a more abstract level, the intended semantics of questions can be described in a way which is a version of the approach taken by Rayner and Jansen (1987), an approach which is similar in spirit to that of Groenendijk and Stokhof (1992). Wh structures correspond to lambda expressions which abstract over the wh phrase or its corresponding gap. The corresponding question (or, if you like, the contribution of the ‘whq’ functor) is an instruction to display the extension of this relation with respect to a given database.

If you think of the display of the extension of the relation as the creation of a proposition like ‘John sleeps, and Bill sleeps, ...’ then the meaning of a wh question is a function from databases to propositions, namely the proposition that is, for that database, a true and complete answer to the question. It might be stretching things a little far, but if databases are like worlds, then this is just the G and S analysis, where ‘who sleeps’ means:

\[ \forall w,w'.\forall x.\text{sleep}(w,x) \leftrightarrow \text{sleep}(w',x) \]

i.e. a function from a world to a proposition (set of worlds) where the proposition is determined by the extension of the relation corresponding to the wh-construct.

12 Events and Event Type Anaphora

12.1 Discourse Representation Theory

The topic of event type anaphora is one where one would expect DRT to make a significant contribution. If we have nevertheless failed to produce a contribution on this topic here, this is because an extensively documented account of these phenomena is already available in [Asher, 1993]. Although there is certainly still a large amount of work that needs to be done in this domain, there is no question of improving in the context of this review of the phenomena; nor did it seem possible, within the limited time we had, to summarize Asher’s theory in a concise and yet usefully transparent way. Therefore, a global reference to Asher’s book will have to do for now.
12.2 Update and Dynamic Semantics

Dynamic or update semantics does not offer prescriptions here. In any framework where entities of type event are allowed into the ontology, anaphoric reference to them can be handled in a dynamic way, along the lines sketched for nominal and temporal anaphoras. In Section 8.2 we have assumed a treatment of tense based on monolithic events. A more fine-grained treatment is also possible, and here the dynamic-modal perspective suggests zooming in and out to appropriate levels of granularity, distinguishing less or more structure as the need arises: see Blackburn, Gardent and De Rijke [Blackburn et al., 1994].

12.3 Situation Semantics

Although several of the required antecedents are made available, currently our grammar does not provide a treatment of event or event type anaphora.

12.4 Property Theory

Events can be added to PT as a new class of terms. The notion of an instant can be defined in terms of events. Intensional analogues of the ‘event’ predicate and relations can also be added to the theory, for use in intensional contexts. It should perhaps be noted that this a general notion of event, which need not exclude states. Such distinctions between classes of events can be added as required.

12.4.1 Events in PT\(^7\)

To the language of wff we can add E(t) (t is an event), t < s (t is before s), t o s (t overlaps s), with the following axioms:

\[
\begin{align*}
(i) & \quad (x < y) \rightarrow (x \not< y) \\
(ii) & \quad (x < y) \land (y < z) \rightarrow (x < z) \\
(iii) & \quad (x < y) \rightarrow (y < x) \\
(iv) & \quad x \circ x \\
(v) & \quad (x < y) \land (y < z) \land (z < u) \rightarrow (x < u) \\
(vi) & \quad (x < y) v (x \circ y) v (y < x)
\end{align*}
\]

Instances can be defined as maximal collections of overlapping events (maximally overlapping collections). This is given by \(\text{Ix}\), defined as the conjunction of the following:

\(^7\)This formalisation of events and instances in PT is taken from an unpublished manuscript by Ray Turner [Turner, 1988].
A temporal ordering of the instances $<$ can be defined by:

$$x \prec y = \text{def } I_x \& I_y \& \exists e (E_t \& e \in x \& \exists e'(E_t \& e' \in y \& e < e'))$$

We can add intensional analogues for $E$, $\circ$, $<$, $\bullet$, $\sqsubset$, with the following axioms:

(i) $E_t \& E_s \rightarrow P(t \sqsubset s)$
(ii) $E_t \& E_s \rightarrow P(t \bullet s)$
(iii) $E_t \& E_s \rightarrow (T(t \sqsubset s) \rightarrow t < s)$
(iv) $E_t \& E_s \rightarrow (T(t \bullet s) \rightarrow t \circ s)$
(v) $P(\xi t) \& T(\xi t) \rightarrow E_t$

The system of events can be strengthened with further axioms such as density. The density of instances would then follow.

The theory of events admits the notion of summed events. Summation need not be restricted to particular classes of events.

12.5 Monotonic Semantics

No contribution on Event and Event Type Anaphora.

A Property Theory: Dependent Types and Anaphora

This appendix contains just sufficient formal detail of the use of dependent types in natural language semantics for the reader with an acquaintance of PTQ to see how Geach’s “donkey” sentences can be treated in Property Theory.

We can translate NL constituents as follows:
Basic Categories | Examples | Translation
--- | --- | ---
**Determiners (D)** | every, a, some | $\lambda pq. \Pi p \lambda x. apq px$
 |  | $\lambda pq. \Sigma p \lambda x. apq px$
**Common Nouns (N)** | man, woman, donkey | man', woman', donkey'
**Proper Names (PN)** | John | $\lambda p. p(John')$
**Intransitive Verbs (IV)** | walk, whistle | walk', whistle'
**Transitive Verbs (TV)** | own, beat, love | owns', beats', loves'
**Pronouns (P)** | he, she, it, him, her | $\lambda p. phx$
**Relative Pronouns (RP)** | such that who, which, that | $\lambda pq. \Sigma p \lambda x q$
 |  | $\lambda pq. \Sigma p \lambda x apq px$

This is adapted from Davila’s work [Davila-Perez, 1994]. He also gives the types of the constituents. In this PT version of the theory, the types can be derived, assuming that nouns and verbs are represented by objects of the correct sort.

The term app should have the following behaviour:

$$app_y x v = \begin{cases} app_y a (fstv) & \text{if } x = \Sigma ab \\ y v & \text{otherwise} \end{cases}$$

The purpose of the app is apparent in relative clauses, where it effectively picks out the part of the proof, or context which is a witness to the main noun (rather than the parts of the proof which verify that the rest of the relative clause applies to it).

Davila defines app using Monomorphic Set Theory with the Universe of Small Sets. However, it is simple to define the behaviour of app outside the constructive type theory, in the wff of PT.

$$P(app)(y)(\Sigma ab)(v)h \to (h \varepsilon app)(y)(\Sigma ab)(v) \to h \varepsilon app(y)(a)(fstv)$$
$$P(app)(y)(x)(v)h \& \sim \exists ab(x = \Sigma ab) \to (h \varepsilon app)(y)(x)(v) \to h \varepsilon y v)$$

In his earlier work, Davila implemented the effect of app during the translation process.

We can give the following categorial style rules:\(^{78}\)

**Determiner-Noun Rule**

\begin{align*}
S2 & \text{If } \alpha \text{ is in } D \text{ and } \beta \text{ is in } N \text{ then } F_2(\alpha, \beta) = \alpha \beta \text{ is in } NP. \\
T2 & T(F_2(\alpha, \beta)) = \alpha' \beta'
\end{align*}

\(^{78}\) Rules 3a, 18, 19 are due to Davila-Perez.
Subject-Predicate Rule

S4 If \( \zeta \) is in \( NP \) and \( \delta \) is in \( IV \) then \( F_2(\zeta, \delta) \) is in \( S \)
T4 \[ T(F_2(\zeta, \delta)) = \zeta'\delta' \]

Transitive Verbs Rule

S5 If \( \alpha \) is in \( TV \) and \( \zeta \) is in \( NP \) then \( F_2(\alpha, \zeta) \) is in \( IV \)
T5 \[ T(F_2(\alpha, \zeta)) = \lambda w.\zeta'(\alpha'w) \]

Relative Clauses Rules

S3 If \( \delta \) is in \( N, \xi \) is in \( RP \) and \( \varphi \) is in \( S \) then \( F_3(\delta, \xi, \varphi) = \delta\xi\varphi \) is in \( N \).
S3(a) If \( \delta \) is in \( N, \xi \) is in \( RP \) and \( \sigma \) is in \( IV \) then \( F_3(\delta, \xi, \sigma) \) is in \( N \).
T3 \[ T(F_3(\delta, \xi, \varphi)) = \xi'\delta'\varphi' \]
T3(a) \[ T(F_3(\delta, \xi, \sigma)) = \xi'\delta'\sigma' \]

Pronoun and Proper Names Rule

S1(a) If \( \varphi \) is in \( P \) then \( F_1(\varphi) = \varphi \) is in \( NP \).
S1(b) If \( \xi \) is in \( PN \) then \( F_1(\xi) \) is in \( NP \).
T1(a) \[ T(F_1(\varphi)) = \varphi' \]
T1(b) \[ T(F_1(\xi)) = \xi' \]

Conjunction and Disjunction Rules

S11 If \( \varphi \) is in \( S \) and \( \psi \) is in \( S \) then \( F_{11}(\varphi, \psi) \) is in \( S \)
where \( F_{11}(\varphi, \psi) = \varphi \) and \( \psi \), or, \( F_{11}(\varphi, \psi) = \varphi \) or \( \psi \).
S12 If \( \beta \) is in \( IV \) and \( \eta \) is in \( IV \) then \( F_{11}(\beta, \eta) \) is in \( IV \).
S13 If \( \delta \) is in \( NP \) and \( \rho \) is in \( NP \) then \( F_{11}(\delta, \rho) \) is in \( NP \).
T11(a) \[ T(\varphi \text{ and } \psi) = \Sigma\varphi'\lambda x.\psi' \]
T11(b) \[ T(\varphi \text{ or } \psi) = \varphi' \oplus \psi' \]
T12(a) \[ T(\beta \text{ and } \eta) = \lambda z.\Sigma(\beta'z)\lambda x.\eta'z \]
T12(b) \[ T(\beta \text{ or } \eta) = \lambda z.(\beta'z) \oplus (\eta'z) \]
T13(a) \[ T(\delta \text{ and } \rho) = \lambda z.\Sigma(\delta'z)\lambda x.\rho'z \]
T13(b) \[ T(\delta \text{ or } \rho) = \lambda z.(\delta'z) \oplus (\rho'z) \]

Conditional Rule
S18 If \( \varphi \) is in \( S \) and \( \psi \) is in \( S \) then \( F_{18}(\varphi, \psi) = \text{if } \varphi, \psi \).

T18 \( T(F_{18}(\varphi, \psi)) = \Pi \varphi' \lambda x. \psi' \).

**Discourse Linking Rule**

S19 If \( \varphi \) is in \( S \) and \( \psi \) is in \( S \) then \( F_{19}(\varphi, \psi) = \varphi.\psi. \)

T19 \( T(F_{19}(\varphi, \psi)) = \Sigma \varphi' \lambda x. \psi' \).

**B Situation Semantics: Grammar-at-a-glance**

**B.1 Lexicon**

**LEX-PN** If \( u \) is a use of type \([\text{NP } \alpha]\) and \( \alpha \) is a proper name, then

\[
[u] = P[X] \begin{array}{l}
\text{DS} \\
\text{ref}(u, X) \\
\text{res}(u, R) \\
\text{named}(X, \alpha)
\end{array}
\]

**LEX-PN1** If \( u \) is a use of type \([\text{NP } \alpha]\) and \( \alpha \) is a proper name, then
LEX-DEF-ART If $u$ is a use of type $[\text{Det the}]$, then

\[
[u] = \begin{array}{c}
\text{ds} \rightarrow DS, \langle \text{ref}, u \rangle \rightarrow X, \langle \text{exploits}, u \rangle \rightarrow R \\
\end{array}
\]

LEX-INDEF-ART If $u$ is a use of type $[\text{Det a}]$, then

\[
[u] = \begin{array}{c}
\text{ds} \rightarrow DS, \langle \text{indefref}, u \rangle \rightarrow X \\
\end{array}
\]
LEX-QUANTDET If $u$ is a use of type $[\text{Det } \alpha]$ where $\alpha$ is a quantificational determiner and $\alpha'$ is the situation theoretic relation corresponding to $\alpha$, then

$$
[u] = ds \rightarrow DS
\begin{array}{c}
Q \\
\hline \\
P \\
\hline \\
\alpha'(Q, P) \\
\hline \\
\text{disc-sit}(u, DS)
\end{array}
$$

LEX-CN If $u$ is a use of type $[\text{N } \alpha]$ and $\alpha'$ is the situation theoretic property corresponding to $\alpha$, then

$$
[u] = ds \rightarrow DS, \langle \text{it, } u \rangle \rightarrow T, \langle \text{exploits, } u \rangle \rightarrow R
\begin{array}{c}
X \\
\hline \\
R \\
\hline \\
\alpha'(X, T) \\
\hline \\
\text{res}(u, R) \\
\text{ref-time}(u, T)
\end{array}
$$

LEX-PRO-NP If $u$ is a use of type $[\text{NP } \alpha]$ where $\alpha$ is the a singular pronoun with gender $\beta$, then

$$
[u] = ds \rightarrow DS, \langle \text{ref, } u \rangle \rightarrow X, \langle \text{exploits, } u \rangle \rightarrow R
\begin{array}{c}
X \\
\hline \\
R \\
\hline \\
\beta'(X) \\
\hline \\
\text{ref}(u, X) \\
\text{res}(u, R)
\end{array}
$$

where $\beta'$ is the gender property corresponding to $\beta$ (e.g. $\text{masc}' = \text{male}$).

The resolved meaning of the pronoun use depends on the covary-fact that it supports:

1. If $u$ is a use of of type $[\text{NP } \alpha]$, where $\alpha$ is a singular pronoun and $u \models \langle \text{covary, } u, \text{uNP} \rangle$, then

$$
[u]_{\text{res}} = \lambda f \cup \langle \text{par, } u_{\text{NP}} \rangle \rightarrow X \langle u \rangle \cdot \langle \text{ref, } u \rangle \rightarrow X \cdot f
$$

where $f$ is a mia for $\langle u \rangle \cdot \langle \text{ref, } u \rangle \rightarrow X$.

2. If $u$ is a use of of type $[\text{NP } \alpha]$, where $\alpha$ is a singular pronoun and $u \models \langle \text{covary, } u, < \rho, \text{uVP} > \rangle$, then

$$
[u]_{\text{res}} = \lambda f \cup \langle \rho, u_{\text{VP}} \rangle \rightarrow X \langle u \rangle \cdot \langle \text{ref, } u \rangle \rightarrow X \cdot f
$$

where $f$ is a mia for $\langle u \rangle \cdot \langle \text{ref, } u \rangle \rightarrow X$.

3. Otherwise, $u$ is a use of of type $[\text{NP } \alpha]$, where $\alpha$ is a singular pronoun, then

$$
[u]_{\text{res}} = \langle u \rangle
$$

\text{This is, of course, an oversimplified treatment of the relationship between grammatical and natural gender.}
**LEX-POSS-PRO** If \( u \) is a use of type \([\text{Det}[-\text{quand}]] \alpha \) and \( \alpha \) is a possessive pronoun with gender \( \beta \), then

\[
\begin{align*}
\text{ds} & \rightarrow DS, (\text{ref},u) \rightarrow X, (\text{posser},u) \rightarrow \text{Rel}, (\text{posser},u) \rightarrow Y, (\text{explicits},u) \rightarrow R \\
P & \rightarrow Q[X] \\
[u] & = \\
\begin{array}{c}
P[X] \\
\begin{array}{c}
\text{Q}[X] \\
\text{Rel}(Y, X) \\
\beta'(Y)
\end{array} \\
\begin{array}{c}
\text{DS} \\
\text{ref}(u, X) \\
\text{posser}(u, \text{Rel}) \\
\text{res}(u, R) \\
\text{posser}(u, Y)
\end{array}
\end{array}
\end{align*}
\]

**LEX-TV** If \( u \) is a use of type \([V\text{tns: } \text{ins: } \{\text{pres} \atop \text{psst}}]) \alpha \) where \( \alpha \) is a transitive verb and \( \alpha' \) is the situation theoretic relation corresponding to \( \alpha \), then

\[
\begin{align*}
\text{ds} & \rightarrow DS, <\text{utt-time},u> \rightarrow U, <\text{ev-time},u> \rightarrow T \\
Y & \rightarrow X \\
[u] & = \\
\begin{array}{c}
\alpha'(X, Y, T) \\
\begin{array}{c}
\text{DS} \\
\text{utt-time}(u, U) \\
\text{ev-time}(u, T)
\end{array} \\
T * U
\end{array}
\end{align*}
\]

\[
* = \begin{cases} 
1 & \text{if } \text{[ins: pst]} \text{ is the feature on } u \\
0 & \text{if } \text{[ins: pres]} \text{ is the feature on } u
\end{cases}
\]

**LEX-TV-UNTENSED** If \( u \) is a use of type \([V\text{tns: } \text{}]) \alpha \) where \( \alpha \) is a transitive verb and \( \alpha' \) is the situation theoretic relation corresponding to \( \alpha \), then
LEX-TEMP-PropName If $u$ is a use of type $[\text{NP} [+\text{temp}] \alpha]$ where $\alpha$ is a time (9:30, Sunday, ...), then

$$[u] = \alpha'(X, Y, T)$$

LEX-TEMP-AT If $u$ is a use of type $[\text{P} [+\text{temp}] \text{at}]$, then

$$[u] = T$$

LEX-TEMP-ON If $u$ is a use of type $[\text{P} [+\text{temp}] \text{on}]$, then

$$[u] = P$$

LEX-TEMP-FOR If $u$ is a use of type $[\text{P} [+\text{temp}] \text{for}]$, then
LEX-TCOMP If \( u \) is a use of type \([\text{TCOMP } \alpha]\), then

\[
[u] = \begin{array}{l}
\text{Prop} \\
\text{P} \\
\text{DS} \\
\text{ev-time}(u, T) \\
\text{T} = \text{Time}
\end{array}
\]

LEX-IV-TENSED If \( u \) is a use of type \([\text{IV TENSED } \alpha]\) where \( \alpha \) is an intransitive verb and \( \alpha' \) is the situation theoretic relation corresponding to \( \alpha \), then

\[
[u] = \begin{array}{l}
\text{Prop} \\
\text{P} \\
\text{DS} \\
\text{utt-time}(u, u), \text{ev-time}(u, T_1), \text{ref-time}(u, T_2) \\
\text{T}_2 * T_1
\end{array}
\]

Where \( * = \begin{cases} < & \text{if } \alpha \text{ is 'before'} \\ > & \text{if } \alpha \text{ is 'after'} \\ = & \text{if } \alpha \text{ is 'when'} \text{ (much simplified)} \\ \& & \text{if } \alpha \text{ is 'since'} \\ \& & \text{if } \alpha \text{ is 'until'} \end{cases} \)

Where \( t_1 \& t_2 \) iff \( \text{last}(t_1) < \text{first}(t_2) \)

\( t_1 \& t_2 \) iff \( \text{last}(t_1) = \text{first}(t_2) \)

LEX-IV-UNTENSED If \( u \) is a use of type \([\text{IV UNTENSED } \alpha]\) where \( \alpha \) is an intransitive verb and \( \alpha' \) is the situation theoretic relation corresponding to \( \alpha \), then

\[
[u] = \begin{array}{l}
\text{Prop} \\
\text{P} \\
\text{DS} \\
\text{utt-time}(u, U), \text{ev-time}(u, T) \\
\text{T} * U
\end{array}
\]

Where \( * = \begin{cases} < & \text{if } \text{[tense: pst]} \text{ is the feature on } u \\ 0 & \text{if } \text{[tense: pres]} \text{ is the feature on } u \end{cases} \)
LEX-PROGRESS-TENSED If \( u \) is a use of type \( \left[ V[ \text{ins: } \{ \text{pres} \} ] \alpha \right] \) where \( \alpha \) is a form of ‘be’, then

\[
[u] = \begin{array}{c}
\alpha' (X, T) \\
\text{ev-time}(u, T)
\end{array}
\]

\( \Rightarrow DS \xrightarrow{\langle \text{ev-time}, u \rangle} T \)

\( X \)

\( DS \)

\( \text{ev-time}(u, T) \)

\( \text{utt-time}(u, U) \)

\( \text{desc-sit}(u, S) \)

\( \text{ev-time}(u, T) \)

\( T \ast U \)

\( \ast = \begin{cases} 
< & \text{if } [\text{ins: pst}] \text{ is the feature on } u \\
\alpha & \text{if } [\text{ins: pres}] \text{ is the feature on } u
\end{cases} \)

We place the following constraints on be’ to connect it to a theory of the progressive.

Let \( f \) be an index-assignment for \( \{ \rho \} \) (where \( \rho \) is an individual property abstract whose roles are all of the form \( \langle \text{ev-time}, u \rangle \) for some \( u \), i.e., an abstract of the kind provided as an argument to auxiliary verbs according to AUX-VP). Let the domain of \( f \) be \( \{ r_1, \ldots, r_n \} \). Then

\[
s \models \langle \text{be'}, x, \rho, t \rangle \rightarrow \exists r (s : \tau \wedge s \models \lambda f(\text{prep-ph}(\tau, \rho, f[x])))
\]

\[
s \models \langle \text{be'}, x, \rho, t, 0 \rangle \rightarrow \neg \exists r (s : \tau \wedge s \models \lambda f(\text{prep-ph}(\tau, \rho, f[x])))
\]

LEX-PFCT-HAVE If \( u \) is a use of type \( \left[ V[ \text{ins: } \{ \text{pres} \} ] \alpha \right] \) where \( \alpha \) is a form of ‘have’, then
\[ [u] = \]

\[ DS \]

\[ \text{have}'(X, P, T) \]

\[ \text{ev-time}(u, T) \]

\[ \text{utt-time}(u, U) \]

\[ \text{T} \circ \text{U} \]

\[ s = \begin{cases} < & \text{if} \ [\text{t}ns: \text{pst}] \text{ is the feature on } u \\ 0 & \text{if} \ [\text{t}ns: \text{pres}] \text{ is the feature on } u \end{cases} \]

Let \( f \) be an index assignment for \( \rho \) (an individual property abstract with ev-time roles only) and have domain \( \{r_1, \ldots, r_n\} \). Then,

\[
\begin{array}{r|c}
\text{conseq-st}(\tau, \rho, f[x]) & \begin{cases} f(r_1) < t \\ \vdots \\ f(r_n) < t \end{cases} \\
\end{array}
\]

\[
\begin{array}{r|c}
\text{conseq-st}(\tau, \rho, f[x]) & \begin{cases} f(r_1) < t \\ \vdots \\ f(r_n) < t \end{cases} \\
\end{array}
\]

**LEX-FUT-WILL** If \( u \) is a use of type \( \left[ \text{V[ t}ns: \{ \text{pres} \} \text{ will} \right] \), then

\[
\begin{array}{r|c}
\text{conseq-st}(\tau, \rho, f[x]) & \begin{cases} f(r_1) < t \\ \vdots \\ f(r_n) < t \end{cases} \\
\end{array}
\]

Let \( f \) and \( \rho \) be as before. Then

\[ s \models \langle \text{will}', x, \rho, t \rangle \rightarrow \]
\[ \exists \sigma : \tau \land \sigma \vdash \exists (\lambda f(\text{indicate}(\tau, \rho.f.[x])) \quad t \leq f(r_1) \
\ldots \
 t \leq f(r_n)) \]

\[ s \models \langle \text{will}', x, \rho; t; 0 \rangle \rightarrow \]

\[ \exists \sigma : \tau \land \sigma \vdash \neg \exists (\lambda f(\text{indicate}(\tau, \rho.f.[x])) \quad t \leq f(r_1) \
\ldots \
 t \leq f(r_n)) \]

**LEX-DO** If \( u \) is a use of type \([V_{\text{ins: } \{ \text{pres, } \text{pit} \}} \alpha] \) where \( \alpha \) is a form of \( \text{do} \), then

\[
\begin{array}{c}
\text{ds} \rightarrow \text{DS. } <\text{ut-time}, u > \rightarrow U, <\text{ev-time}, u > \rightarrow T \\
\hline
\end{array}
\]

\[
\begin{array}{c}
[u] = \\
\hline
\end{array}
\]

\[
\begin{array}{c}
\text{do}'(X, P; T) \\
\text{DS} \\
\text{ut-time}(u, U) \\
\text{ev-time}(u, T) \\
T \ast U
\end{array}
\]

\( * = \langle \text{ins: } \text{pst} \rangle \) is the feature on \( u \)
\( o \) if \( \text{ins: } \text{pres} \) is the feature on \( u \)

Let \( f \) and \( \rho \) be as before and for all \( r \in \text{dom}(f), f(r) = t \). Then,

\[ s \models \langle \text{do}', x, \rho, t \rangle \rightarrow s \models \rho.f.[x] \]

\[ s \models \langle \text{do}', x, \rho, t; 0 \rangle \rightarrow s \models \neg \rho.f.[x] \]

**LEX-TV-INF** If \( u \) is a use of type \([V \alpha] \) where \( \alpha \) is a verb taking an infinitival complement (e.g. \textit{want}), then

\[
\begin{array}{c}
\text{ds} \rightarrow \text{DS. } <\text{rt}, u > \rightarrow T \\
\hline
\end{array}
\]

\[
\begin{array}{c}
[u] = \\
\hline
\end{array}
\]

\[
\begin{array}{c}
\alpha'(X, P; T) \\
\text{DS} \\
\text{ref-time}(u, T)
\end{array}
\]

**LEX-NOT** If \( u \) is a use of type \([\text{Neg } \text{not}] \), then
LEX-WH-NP If \( u \) is a use of type \([\text{NP } \alpha]\) where \( \alpha \) is \textit{who} or \textit{what}, then

\[
[u] = \begin{cases} 
\text{DS} \\
\text{desc-sit}(u, \text{DS}) \\
\neg P[X] 
\end{cases}
\]

\[
<\text{exploits}, u > \rightarrow \text{R}, ds \rightarrow \text{DS}, <\text{wh}, u > \rightarrow X
\]

\[
\beta = \text{person} \text{ if } \alpha = \text{who}, \ \beta = \text{thing} \text{ if } \alpha = \text{what}\]

LEX-GAP-NP If \( u \) is a use of type \([\text{NP } e]\), then

\[
[u] = \begin{cases} 
\text{DS} \\
\text{wh}(u, X) \\
\beta(X) \\
P[X]
\end{cases}
\]

LEX-PA If \( u \) is a use of type \([\text{V}+[S] \alpha]\) where \( \alpha \) is a verb taking a \textit{that}-complement, then

\[
[u] = \begin{cases} 
\text{DS} \\
\text{gap}(u, X) \\
X
\end{cases}
\]

\[
\langle \text{rt}, u \rangle \rightarrow T, \langle \text{mental-state}, u \rangle \rightarrow MS
\]

\[
\Prpn
\]

\[
\alpha'(X, \Prpn, MS, T)
\]

where \( \alpha' \) is the relation that interprets \( \alpha \).

B.2 Rules

PS-NONQUANT-NP If \( u \) is a use of type \([\text{NP } [\text{-quant}] \ N]\) with intermediate constituents \( u_1, u_2 \), respectively, then

\[\text{Det} \]

\[\text{Det} \]

---

\[86\] This is, of course, a simplified treatment of gender.
where \( f \) is a mia for \( \{[u_1], [u_2]\} \)

**DISC-RULE** If \( u \) is a discourse \( u_1, \ldots, u_n \), then

\[
[u] = \exists_{\text{lobind}}(\lambda f \cup [\text{desc}-\text{sit} \rightarrow S](S : [u_1]; f \wedge \ldots \wedge [u_n]; f))
\]

where \( f \) is a mia for \( \{[u_1], \ldots, [u_n]\} \).

**PS-NP** If \( u \) is a use of type \([\text{NP} \text{ Det} \text{ N}]\) with constituents \( u_1, u_2 \) respectively, then

where \( f \) is a mia for \( \{[u_1], [u_2]\} \)

\[
[u] = \lambda f([u_2], f([u_1]; f))
\]

where \( f \) is a mia for \( \{[u_1], [u_2]\} \).

**PS-S1** If \( u \) is a use of type \([\text{NP} \text{ Det} \text{ N}]\) with constituents \( u_1 \) and \( u_2 \), respectively, then

\[
[u] = \lambda f([u_2], f([u_1]; f))
\]

where \( f \) is a mia for \( \{[u_1], [u_2]\} \).

**PS-S1-res** If \( u \) is a use of type \([\text{NP} \text{ Det} \text{ N}]\) with constituents \( u_1 \) and \( u_2 \), respectively, then

\[
[u]_{\text{res}} = \mu(\lambda f([u_2]_{\text{res}}, f([u_1]_{\text{res}}; f)))
\]

where \( f \) is a mia for \( \{[u_1]_{\text{res}}, [u_2]_{\text{res}}\} \).

**PS-TVP** If \( u \) is a use of type \([\text{VP} \text{ [tms: } \alpha ] \text{ V [tms: } \alpha ] \text{ NP}]\) where \( V \) is a transitive verb and \( u \) has constituents \( u_1, u_2 \), respectively, then

\[
[u] = \lambda f([u_1], f([u_2]; f))
\]

where \( f \) is a mia for \( \{[u_1], [u_2]\} \)

There is one special case that we need to look at for resolution: where there is role-linking.

If there is a constituent of \( u \) (not necessarily an immediate constituent) \( u' \) such that \( u' \models (\text{covary}; u', < \rho, u >) \) then

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\[ [u]_{\text{res}} = \lambda f' (\lambda f \bigcup \left< \text{subj} u_1 > - X, \text{obj} u_1 > - Y \right> ( [u_1]_{\text{res}} f [Y] [X] [\left< \text{obj} u_1 > - [u_2]_{\text{res}} f' f' [\left< \text{subj} u_1 > - Z] f' ] ) \]

where:
- \( f \) is a mia for \([u_1] \).
- \( f' \) is a mia for \([u_2], \lambda [Z] ( \lambda f \bigcup \left< \text{subj} u_1 > - X, \text{obj} u_1 > - Y \right> ( [u_1] f [Y] [X] ) \), and
- \( f'' \) is a mia for \( \lambda f' (\lambda f \bigcup \left< \text{subj} u_1 > - X, \text{obj} u_1 > - Y \right> ( [u_1] f [Y] [X] [\left< \text{obj} u_1 > - [u_2] f' f' f' [\left< \text{subj} u_1 > - Z] f' ] ) \)

Otherwise, \([u]_{\text{res}} = [u] \).

**PS-TEMP-PP** If \( u \) is a use of type \( \text{TimeAdv} P \left< \text{ext} P + \text{temp} \right> \text{NP} \left< \text{ext} \text{NP} + \text{temp} \right> \) with constituents \( u_1, u_2 \), respectively, then

\[ [u] = \lambda f ([u_1] f [u_2] f) \]

where \( f \) is a mia for \([u_1], [u_2] \)

**PS-VP-TEMPADV-PAST** If \( u \) is a use of type \( \text{VP} \left< \text{tens: pst} \right> \text{VP} \left< \text{tens: pst} \right> \text{TimeAdv} \) with constituents \( u_1, u_2 \) respectively, then

\[ [u] = \lambda f \bigcup \left< \text{ev-time}, u > - T \right> ( [u_2] g f [u_1] g f ) \]

where \( \text{dom}(g) = \{ r | r \in \text{roles}([u_1]) \wedge \exists u(r = \text{ev-time}, u > ) \} \) and for all \( r \in \text{dom}(g), g(r) = T \); \( f \) is a mia for \([u_2] g, [u_1] g \)

**PS-VP-TEMPADV-PRES** If \( u \) is a use of type \( \text{VP} \left< \text{tens: pres} \right> \text{VP} \left< \text{tens: pres} \right> \text{TimeAdv} \) with constituents \( u_1, u_2 \) respectively, then

\[ [u] = \lambda f \bigcup \left< \text{utt-time}, u > - U \right> ( X T > U ) \]

where \( \text{dom}(g) = \{ r | r \in \text{roles}([u_2]) \cup \text{roles}([u_1]) \wedge \exists u(r = \text{ev-time}, u > ) \} \) and for all \( r \in \text{dom}(g), g(r) = T \); \( f \) is a mia for \([u_2] g g', [u_1] g g' \)

**PS-QUANT-TEMP-ADV** If \( u \) is a use of type \( \text{TimeAdv} \text{NP} \) with constituent \( u_1 \), then

\[ [u] = \lambda f \bigcup \left< \text{utt-time}, u > - U \right> ( P T \subseteq [u_1] f ) \]

\( f \) is a mia for \([u_1] \)
PS-TEMP-S If \( u \) is a use of type \([\text{T}_{\text{TimeAdv}} \text{TCOMP} \ S]\) with constituents \( u_1, u_2 \), respectively, then
\[
[u] = \lambda f(\exists g(\lambda x.[g.f.[u_1].g.f.[u_2].g.f])) \text{ or } \lambda f \cup g(\lambda x.[f.x].g.f)
\]
where \( \text{dom}(g) = \{ r \mid (r, ev-time, u_1) \lor (3u \text{ constituent-of}(u, u_2) \land r = (ev-time, u)) \} \)
\forall r, r' \in \text{dom}(g), g(r) = g(r')
\forall r \in \text{dom}(g), g(r) \text{ is a parameter not in } [u_1] \text{ or } [u_2]
\]
f is a mia for \([[u_1]] [[u_2]]\)

PS-IVP If \( u \) is a use of type \([V_P \text{ tns: } \alpha] \text{ V[ tns: } \alpha] \text{ }\] with constituent \( u_1 \), then
\[
[u] = [u_1]
\]

PS-AUX If \( u \) is a use of type \([V_P \text{ tns: } \alpha] \text{ V[ tns: } \alpha] \text{ }\] with constituents \( u_1, u_2 \), respectively, where \( u_1 \) is a use of \(\{\text{progressive} \cdot \text{be'}, \text{perfect} \cdot \text{have'}\}\), then
\[
[u] = \lambda f(\exists g(\lambda f'.(f'.[u_1].f'.[u_2].f)'), f')
\]
where \( f' \) is a mia for \([u_2] \) and \( f \) is a mia for \([u_1] \exists \text{lobind}(\lambda f'.(f'.[u_2].f'.[x])))\)

PS-NEG-VP If \( u \) is a use of type \([V_P \text{ Neg VP}] \) with constituents \( u_1, u_2 \), respectively, then
\[
[u] = \lambda f(\exists g(\lambda f'.(f'.[u_1].f'[x])), f'))
\]
where \( f' \) is a mia for \([u_2] \) and \( f \) is a mia for \([u_1] \exists \text{lobind}(\lambda f'.(f'.[u_2].f'[x])))\)

PS-REL-CN If \( u \) is a use of type \([\text{CN CN Rel}] \) with constituents \( u_1 \) and \( u_2 \), respectively, and \( \exists u'(<\text{wh}, u') \in \text{roles}([u_2]) \), then
\[
[u] = \lambda f - (\langle \text{wh}, u' \rangle \rightarrow X)
\]

where \( f \) is a mia for \([\text{CN}, \text{Rel}]\), \( f(\langle \text{exploits}, u_1 \rangle) = R \) and \( f(<\text{wh}, u_2>) = X \).

PS-REL If \( u \) is a use of type \([\text{Rel} \text{ NP[ +wh ] S}] \) with constituents \( u_1 \) and \( u_2 \), respectively, and \( \exists u'(<\text{gap}, u') \in \text{roles}([u_2]) \), then
\[
[u] = \lambda f(\exists g(\lambda x.[g.X][u_2].[<\text{gap}, u'] \rightarrow X], f))
\]
where \( f \) is a mia for \([u_1] [[u_2]].[<\text{gap}, u' \rightarrow X]\)

PS-THATS If \( u \) is a use of type \([S' \text{ that S}] \) with constituents \( u_1 \), \( u_2 \), respectively, then
\[
[u] = \lambda f \cup (\text{concerns}, u) \rightarrow S(S : [u_2].f)
\]
where \( f \) is a mia for \([u_2] \)

PS-VPSCOMP If \( u \) is a use of type \([V_P V_{[S]} S'] \) with constituents \( u_1 \) and \( u_2 \), respectively, then

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\[
[u] = \lambda w_1 \cdot f \cdot [w_1] f
\]
where \( f \) is a mia for \([w_1, w_2]\)

**PS-N1-COMPC** If \( u \) is a use of type \([VP \ V_{[COMP : N1]} S_1 \ \text{TNS}]\) with constituents \( u_1, u_2 \) respectively, then

\[
[u] = \lambda f \cdot ([\text{perc-sit}, u] \to S) \cdot [u_1] f \cdot [S] \cdot [u_2] f
\]

### B.3 Other Constraints

#### B.3.1 On Determiners

For each determiner relation \( \alpha \) there is a corresponding set theoretic relation between sets \( \alpha^* \) of the familiar kind from generalized quantifier theory. The \( \alpha \) and \( \alpha^* \) relations can be related in the following way:

\[
\exists s \vdash \langle \alpha, \tau, r; 1 \rangle \iff \exists s' \alpha^*(\{x \mid x : \tau\}, \{x \mid s' \vdash \langle r, x \rangle\})
\]

\[
\exists s \vdash \langle \alpha, \tau, r; 0 \rangle \iff \not\exists s' \alpha^*(\{x \mid x : \tau\}, \{x \mid s' \vdash \langle r, x \rangle\})
\]

#### B.3.2 Quantifier Scope

We first detail the kinds of facts about quantifier scope that utterances can support.

If \( u \) is an utterance then:

1. If \( u \) supports the fact that \( u_1 \) has scope over \( u_2 \) then \( u \) is either a sentence, a verb-phrase or a common-noun-phrase (\( \text{N} \)) and \( u_1 \) and \( u_2 \) are noun-phrases. In symbols:
   \[
   \exists u_1, u_2, u \vdash \langle \text{scope-over}, u_1, u_2 \rangle \rightarrow u \vdash \langle \text{cat}, \text{u}, \text{s} \rangle \lor \langle \text{cat}, \text{u}, \text{vp} \rangle \lor \langle \text{cat}, \text{u}, \text{cn} \rangle
   \]
   \[
   u_1 \vdash \langle \text{cat}, \text{u}_1, \text{np} \rangle
   \]
   \[
   u_2 \vdash \langle \text{cat}, \text{u}_2, \text{np} \rangle
   \]

2. If \( u \) supports the fact that \( u \) itself scopes \textit{in situ}, then \( u \) is a noun-phrase.
   \[
   u \vdash \langle \text{scope-in-situ}, u \rangle \rightarrow u \vdash \langle \text{cat}, u, \text{np} \rangle
   \]

   We include this clause in order to allow NPs to scope within intensional verbs.

3. If \( u_1 \) scopes over \( u_2 \) in the utterance \( u \) then \( u_1 \) is a constituent of \( u \) (not necessarily an immediate constituent). This means, that a noun-phrase that is quantified into an
utterance has to be a constituent of that utterance. \( u_2 \) is either \( u \) itself or another noun-phrase which is quantified into \( u \) and whose scope is within that of \( u_1 \). We take the fact that \( u_1 \) scopes over \( u_2 \) to mean that there is no \( u_3 \) which takes scope between \( u_1 \) and \( u_2 \).

\[
u \models \langle \text{scope-over}, u_1, u_2 \rangle \rightarrow \quad u \models \langle \text{ constituent-of}, u_1, u \rangle
\quad \text{and} \quad (u_2 = u \text{ or } u \models \langle \text{ constituent-of}, u_2, u \rangle)\]

4. If \( u_1 \) scopes over \( u_2 \) in \( u \) then there’s no other \( u' \) that it gets quantified into and no other \( u'_2 \) which it takes scope over. (Remember that we are dealing with actual utterance events here, not utterance types and that we take “scopes over” to mean takes immediate scope over.)

\[
u \models \langle \text{scope-over}, u_1, u_2 \rangle \rightarrow \exists u', u'_2 \text{ such that } u' \models \langle \text{scope-over}, u_1, u'_2 \rangle\]

5. If \( u \) takes scope in situ then it doesn’t scope over anything.

\[
u \models \langle \text{scope-in-situ}, u \rangle \rightarrow \neg \exists u', u'' : u'' \models \langle \text{scope-over}, u, u'' \rangle\]

6. An utterance \( u \) is completely specified with respect to quantifier scope just in case for all its NP constituents \( u_{NP} \) there’s some utterance which supports either a fact that \( u_{NP} \) scopes over something or a fact that \( u_{NP} \) scopes in situ.

\[
u \text{ is completely specified with respect to quantifier scope iff: } \forall u_{NP} \ u \models \langle \text{ constituent-of}, u_{NP}, u \rangle \rightarrow (\exists u', u'' \ u'' \models \langle \text{scope-over}, u_{NP}, u'' \rangle \quad \forall u_{NP} \ u \models \langle \text{scope-in-situ}, u_{NP} \rangle)\]

1. If, according to \( u \), \( u_i \) is the unique NP with widest scope, then \( \text{qresolve}(u) \) is \( \text{qresolve}'(u, u_i) \), i.e. the result of doing resolution as far out as \( u_i \).

If \( u_i \) is unique utterance such that \( \exists u_j \ u \models \langle \text{scope-over, } u_i, u_j \rangle \) (\( u_j \) may be \( u \) itself) and \( \neg \exists u_k \ u \models \langle \text{scope-over, } u_k, u_i \rangle \), and there are \( u_1, \ldots, u_n \) such that:

\[
u \models \langle \text{scope-over, } u_i, u_1 \rangle, \langle \text{scope-over, } u_1, u_2 \rangle, \ldots, \langle \text{scope-over, } u_{n-1}, u_n \rangle, \langle \text{scope-over, } u_n, u \rangle,\]

then \( \text{qresolve}(u) = \text{qresolve}'(u, u_i) \)

2. If \( u \) scopes in situ then \( \text{qresolve}(u) \) is the generalized quantifier meaning retrieved from the store, except that all the lobind context roles (i.e. those introduced by indefinites are existentially closed)

If \( u \models \langle \text{scope-in-situ, } u \rangle \land \langle \text{quant, } u, q \rangle \) then

\[
\text{qresolve}(u) = \lambda f' \left[ P \right] \exists_\text{lobind}(\lambda f(q.f'.[P])).f'
\]

where \( f \) is a mia for \( \{q\} \) and \( f' \) is a mia for \( \exists_\text{lobind}(\lambda f(q.f'.[P])) \)

3. Otherwise \( \text{qresolve}(u) = [u] \).
### B.3.3 Existential closure

If $\xi$ is a type abstract and $\ell \subseteq \text{roles}(\xi)$ and $g$ is an index assignment for $\xi$ with domain $\ell$ then

\[
\exists \xi (\ell) = \lambda f (\exists^\ell \lambda g (\xi, g, f))
\]

where $f$ is a mia for $\xi, g$

$\exists \text{lobind}(\xi)$ is the special case where $\ell = \{ p \mid p \in \text{roles}(\xi) \land \text{lobind}(\ell) \}$

We now define $\text{qresolve}'$

1. If $u_1$ is quantificational NP (e.g. with determiner every) as is indicated by the fact that it supports an infon of the form $\langle \text{asc-type, } u_1, \tau \rangle$ and it scopes over a sentence utterance $u$, then the resolution of $u$ up to $u_1$ is obtained by applying the quantifier stored in $u_1$ to an abstract of the form $\lambda [X] (\phi)$ where $X$ is the parameter which is the content of $u_1$ and $\phi$ is derived from (leaving aside a few details) conjoining $\tau. [X]$ and the meaning of $u$ and existential closing the lobind roles in this conjunction. Here is the precise representation in symbols.

If $u \models \langle \text{scope-over, } u_1, u \rangle \land \langle \text{cat, } u, s \rangle$ and $u_1 \models \langle \text{quant, } u_1, q \rangle \land \langle \text{asc-type, } u_1, \tau \rangle$ then

\[
\text{qresolve}'(u, u_1) = \lambda f - \langle \text{par, } u, \xi \rangle (q.f. \exists \text{lobind}(\lambda f'(\text{par}, [u], f')) \begin{array}{c} Y \\ \lambda f' \end{array} \begin{array}{c} [u].f' \\ \tau.f'.[y] \\ \end{array} \lambda f)
\]

where $f'$ is a mia for $\{ \tau, [u] \}$ and $f$ is a mia for $\{ q, [u_1], \exists \text{lobind}(\lambda f'(\text{par}, [u], f')) \}$ and $f(\langle \text{par, } u \rangle) = \xi$

Otherwise (i.e. if $u_1$ is not a quantificational NP and therefore does not support an infon of the form $\langle \text{asc-type, } u_1, \tau \rangle$), if $u \models \langle \text{scope-over, } u_1, u \rangle \land \langle \text{cat, } u, s \rangle$ and $u \models \langle \text{quant, } u_1, q \rangle$ then

\[
\text{qresolve}'(u, u_1) = \lambda f - \langle \text{par, } u, \xi \rangle (q.f. \begin{array}{c} \langle u_1, f \rangle \\ \text{par} \end{array})
\]

where $f$ is a mia for $\{ q, [u_1], [u] \}$ and $f(\langle \text{par, } u \rangle) = \xi$. 

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2. If \( u \models \langle \text{scope-over, } u_i, u_j \rangle \land \langle \text{cat, } u, s \rangle \) and \( u_i \models \langle \text{quant, } u_i, q \rangle \land \langle \text{asc-type, } u_1, \tau \rangle \), and \( \text{qresolve}'(u, u_j) = p \), then

\[
\text{qresolve}'(u, u_i) = \lambda f - \{ \langle \text{par, } u \rangle, \zeta \} \begin{cases} 
Y & \exists \text{lostand}(\lambda f'(p.f', \tau.f'[y]).f) \\
p.f & \end{cases}
\]

where \( f' \) is a mia for \( \{ \tau, p \} \) and \( f \) is a mia for \( \{ q, [u_i], \exists \text{lostand}(\lambda f'(\tau.f' \land p.f')) \} \) and \( f(\langle \text{par, } u \rangle) = \zeta, Y = [u_i].f \).

Otherwise, if \( u \models \langle \text{scope-over, } u_i, u_j \rangle \land \langle \text{cat, } u, s \rangle \) and \( u_i \models \langle \text{quant, } u_i, q \rangle \) and \( \text{qresolve}'(u, u_j) = p \) then

\[
\text{qresolve}'(u, u_i) = \lambda f - \{ \langle \text{par, } u \rangle, \zeta \} \begin{cases} 
Y & \exists \text{lostand}(\lambda f'(p.f').f) \\
p.f & \end{cases}
\]

where \( f \) is a mia for \( \{ q, [u_i], p \} \) and \( f(\langle \text{par, } u \rangle) = \zeta, Y = [u_i].f \).

### B.3.4 Constraints on Intensional verbs

We give here one example of a constraint which relates \texttt{seek}' and \texttt{find}'. Intuitively it says that if \( a \) seeks \( q \) in situation \( s \) at time \( t \) (where \( q \) is a quantifier such as

\[
\begin{array}{c}
P \\
\exists P[X]
\end{array}
\]

then any seek alternative for \( a \) and \( s \) at \( t \) is one where \( q \) is found by \( a \) at \( t' \) where \( t' \geq t \).

\[
s \models \langle \text{seek}', a, q, t \rangle 
\]

\[
\forall s', s' \text{ is a seek-alternative for } a \text{ and } s \text{ at } t \text{ iff } \exists t' \geq t \text{ and } s' \models q.:
\]

\[
\begin{array}{c}
X \\
\text{find}'(a, X, t')
\end{array}
\]

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B.3.5 Constraints on Extensional verbs

Our sample constraint for extensional verbs corresponds to Montague's meaning postulate for extensional verbs. If \( a \) finds \( q \) in \( s \) then \( q \) is such that it is found in \( s \) itself. Extensional verbs don't involve looking at alternative situations.

\[
\begin{align*}
\forall s', s' & \text{ is a find-alternative for } a \text{ and } s \text{ at } t \iff s = s' \text{ and } \\
\begin{array}{c}
\begin{array}{c}
\begin{array}{c}
X \\
\text{find'}(a, X, t)
\end{array}
\end{array}
\end{array}
\end{align*}
\]

References


[Booos, 1984b] Booos, G. 1984b. To be is to be a value variable (or to be some values of some variables). Journal of Philosophy 81:430–449.


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