Harmonizing the Approaches

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A Framework for Computational Semantics

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Abstract

Our preliminary work towards harmonizing the approaches to semantics that are studied in FRACAS has led, on the one hand, to the compilation of a list of *basic linguistic phenomena* that a semantic theory has to account for; this list has been used to arrive at the in-depth comparison among the semantic theories under study presented in Deliverable 8. On the other hand, we identified a set of *basic semantic tools* such as generalised quantifiers theory or abstraction that all of the theories under discussion make use of, although very often these tools are interpreted in different ways in the theories under discussion (e.g., although all theories have a notion of abstraction, the actual properties of the abstraction operation in these theories differ widely). Both the list of basic linguistic phenomena and the set of basic semantic tools are discussed in this deliverable.

We also address the issue of whether the problems that are important from a technical point of view are also important from the point of view of Natural Language Processing applications, by identifying a set of forms of natural language use that one could reasonably expect a NLP system will have to deal with, and by verifying whether the technically challenging data can be encountered in these forms of text.

Chapter 1

Introduction

A large part of the time of the members of the FRACAS consortium in this first year of the project has been spent in understanding the differences between the semantic theories under study.[1] This work has led, on the one hand, to the compilation of a list of *basic linguistic phenomena* that a semantic theory has to account for; this list has been used to arrive at the in-depth comparison among the semantic theories under study presented in Deliverable 8. On the other hand, we identified a set of *basic semantic tools* such as generalised quantifiers theory or abstraction that all of the theories under discussion make use of, although very often these tools are interpreted in different ways in the theories under discussion (e.g., although all theories have a notion of abstraction, the actual properties of the abstraction operation in these theories differ widely).

In this Deliverable we first of all introduce the set of semantic tools that are characteristic of virtually all modern semantic theories. We then discuss in detail some of the facts about the semantic interpretation of English sentences that have to be accounted for; these facts are what motivated the introduction of such tools, and we believe that any theory aiming at accounting these facts will need a similar set of tools.

Our list of core problems in semantics was also meant as an preliminary experiment meant to verify whether such lists could be profitably used as 'benchmarks' for semantic interpreters. With this goal in mind, we used a fairly restricted non-logical vocabulary in the example sentences, to keep the amount of lexical and world knowledge required to run such benchmarks at a minimum. One issue that had to be addressed in this evaluation perspective was whether the problems that are important from a linguistic point of view are also important from the point of view of Natural Language Processing applications. We began to address this issue by identifying some forms of natural language use

[1] These are Discourse Representation Theory, (the family of) Dynamic Logics, Monotonic Semantics, Property Theory, and Situation Theory.

that one could reasonably expect an NLP system will have to deal with, and by verifying whether the linguistically challenging data can be encountered in these forms of text. The preliminary answer to this question is clearly positive.

We also found useful for our 'harmonization' goal to compile a list of the definitions used in the semantic literature; this list, the 'Bluffer's Guide to Semantics', is contained in a companion document to this Deliverable.

Chapter 2

A Common Set of Semantic Tools

2.1 Preamble

Semantics is concerned with two properties of sentences. Firstly, we would like to be able to determine systematically from a sentence what its truth, or more generally, its appropriacy conditions are. Secondly, we would like to be able to tell when one sentence follows from another: that is, when an inference is valid. In computational semantics there is the further requirement that we should be able to mechanise all of this so as to be able to implement systems that display understanding of language and which are thus of practical utility.

For a limited and familar class of inferences, a long tradition of work in philosophy and logic has given us a formal system which allows us to reconstruct these notions in a way which is mathematically precise and computationally useful. First order predicate calculus provides us with a syntax and a semantics that allows us to represent the meanings of many expressions of natural languages in a way that allows us to say under exactly what circumstances the sentence is true or false, given some model.

The model theory and the proof theory of first order logic also provide us with the basis for procedures for determining whether one sentence follows from another. For example, if we take a classical syllogism like:

Every representative arrived	: $\forall$x.representative(x) $\rightarrow$ arrived(x)
Jones is a representative	: representative(jones)
Jones arrived	: arrived(jones)

we can show that the conclusion follows from the premise either by demonstrating set-theoretic properties of the interpretations of the sentences or by

applying rules of inference to the representations themselves. All of this is mechanisable, within the limits of the decidability properties of these formal systems, and our understanding of the relevant techniques is such that one can set as a student exercise the construction of systems which 'understand' syllogisms like the example above. In fact, useful systems with more complex behaviour can also be implemented using only these resources.

However, when one looks at contemporary semantic theories, the range of formal tools they employ seems to be rather far removed from those used in this simple example. The response of many people with a logical or computational training, but with no experience of natural language processing, is frequently to ask why the array of complex notations and formal devices to be found in these theories is actually necessary. What is wrong with first order logic? In first order logic we seem to have a set of concepts which provide a rational reconstruction of important properties of natural languages in ways which make possible the formal explication of truth and inference, and also have well-understood (if not always very efficient) computational interpretations. Why are these concepts not sufficient for computational semantics?

We shall take as the basis for our discussion in what follows the most basic constructs of first order logic: quantifiers, variables, predications, connectives, and a simple notion of truth-bearers or propositions. There is general agreement that we need at least this much machinery (whether or not it is presented in these terms) in order to carry out the types of inference illustrated above. To introduce and motivate some of the tools and concepts made available in current semantic theories, we shall point to linguistic phenomena which are either impossible to describe at all, or impossible to describe elegantly, using only these resources of first order logic. In some cases, the type of inference that we need to capture can be proved to require logical machinery which is more powerful than that of first order logic (e.g. those involving generalised quantifiers). In other cases, there might be a solution available in principle using only first order logic, but the solution is complicated and inelegant and can be captured much more succinctly and efficiently by using a more powerful logic. In such cases implementations might well compile out the succinct description to a verbose one using only first order power (e.g. Moore's treatment of knowledge and belief [Moore, 1979]). Finally, there are cases where there might be natural first order representations for the type of inference we want to capture, but where the extra methodological constraints imposed on us make it impossible to produce those representations in a satisfactory way. For example, the 'donkey sentences' that have played such a large role in semantic theorising have done so not because we cannot represent their most salient interpretations in first order logic, but because those representations cannot be obtained from motivated syntactic structures by purely compositional means.

In some cases the correct treatment of these linguistic phenomena requires the introduction of concepts which have no direct equivalent in a standard first order framework (e.g. abstraction, types, or context change). In other cases, familiar first order notions (e.g. quantification or predication) come to be seen as the simplest versions of more general concepts. The following sections try to provide a sketch map of some of the formal devices employed by current semantic theories, relating them to the observations about meanings and inference patterns that motivate them. The discussion is of course by no means exhaustive, either of the formal devices in current use, or of the phenomena which are not satisfactorily handled in a first order framework

2.2 Abstraction

Replacing a constant term in a complex expression by a variable is a form of abstraction. For example, $hire(x, smith)$ and $hire(itel, y)$ abstract away from the first and second argument term of the proposition *hire(itel, smith)*, respectively. The result is an expression which is open in one argument position. In contrast to First-Order Predicate Logic, where $hire(x, smith)$ and $hire(itel, y)$ are technically propositions, full NL semantic theories come with a means to explicitly represent the result of an abstraction. The classical version is provided by λ-calculus, where a lambda operator is employed to mark the open position. The result of abstraction in *hire(itel, smith)* is referred to as $\lambda x[hire(x, smith)]$, denoting the property of hiring Smith - technically: a function from objects to truth values, which yields "true" as a value if and only if the argument is a person or a company that hires Smith. Accordingly, abstracting over the second argument term accordingly yields $\lambda y[hire\ (itel, y)]$, the property of being a person hired by ITEL. In general, a lambda expression $\lambda x A$, where A is a proposition type expression, can be paraphrased as "the class of those x'es that satisfy A" or "to be an x such that A".

Syntactically, $\lambda x A$ behaves as a standard predicate: It can be applied to an individual term, as in $\lambda x[hire(x, smith)](itel)$, the result being of type proposition and truth-conditionally equivalent to the simple predication *hire(itel, smith)*. On the other hand, the predicate resulting from abstraction can be used as an argument in a higher order predication, to model the semantics of sentences as (2.1):

(2.1) To hire Smith was a brilliant idea.

The example illustrates one of the typical uses of abstraction in NL semantics: It allows to explicitly express complex properties (as well as functions of different types), which are not directly provided by the lexicon. Thus, one of its main functions is extension of the expressive power of the representation

language.

Abstraction is a very useful tool in the specification of the semantic composition process. Look, for example, at sentence (2.2), a case of a VP coordination; the syntactic structure is indicated in (2.3).

(2.2) John walks in the park and whistles.

(2.3) $John[_{VP}\ [_{VP}\ walk\ in\ the\ park]and\ [_{VP}\ whistles]]$

Assume that *and* is to be interpreted as the standard propositional connective &, and that the evaluation procedure is supposed to assign a meaning representation to each constituent. At the point where the value of the upper VP is to be computed, the NP *John*, which is semantically the argument to both the *walk-in-the-park* and *whistle* predicate, is not yet available. We can provide a meaning representation for the complex VP in this case by first supplying an individual variable x as the technical argument for both predicates, then combining the results by the propositional conjunction, and doing λ-abstraction afterwards, which results in the complex predicate expression denoting the property of "being an x such that x walks in the park and whistles" as meaning representation for the complex VP. The latter can in turn be applied to the subject denotation, yielding (2.4) as representation of (2.2), which is truth-conditionally equivalent to (2.5).

(2.4) $\lambda x(walk\ in\ the\ park(x)\ \&\ whistle(x))(john)$

(2.5) $walk\ in\ the\ park(john)\ \&\ whistle(john)$

Another kind of phenomenon where the abstraction mechanism allows a compositional interpretation in spite of a "missing" argument are cases of long-distance dependencies, where a constituent is dislocated from its argument position in the syntactic representation. Take relative clauses as an example:

(2.6) a consultant that ITEL hired

(2.7) $[_{NP}\ a\ [_{N'}\ consultant\ [_{S'}\ that_i\ [_{S}\ ITEL\ hired\ t_i]]]]$

(2.7) shows one way of representing the structural properties of the relative clause construction (2.6). The object position of the transitive verb *hired* is phonologically empty, since the object NP, the relative pronoun *that*, heads the relative clause. The relation between the dislocated pronoun and the empty argument position is indicated by co-indexing. In semantic interpretation, the empty object position provides an indexed variable for the semantic argument position, which is "re-opened" from outside later by abstracting with x_i (the index being provided by the pronominal NP). The result is the complex predicate (2.8):

(2.8) $\lambda x_i hired(ITEL, x_i)$

(2.9) $\lambda y(consultant/(y)\ \&\ \lambda x_i[hired(ITEL, x_i)](y))$

(2.10) $\lambda y(consultant(y)\ \&\ hired(ITEL, y))$

(2.9) and (2.10) show the N' denotation, which is obtained by combining the relative clause interpretation (2.8) and the head noun predicate of (2.6) in the same way as the two VP representations in (2.2) had been combined.

Further, abstraction is useful in the modelling of complex cases of context dependence, i.e. elliptic and certain anaphoric constructions.

(2.11) ITEL sent CRC a report. APCOM did, too.

The standard treatment of elliptic clauses like (2.11) goes as follows: By abstraction, we obtain (2.13) out of (2.12), the meaning representation of the first sentence of (2.11); (2.13) then is copied to the VP position of the second sentence, and applied to its subject, yielding (2.14), which is truth-conditionally equivalent to (2.15).

(2.12) $\exists x(report(x)\ \&\ send(itel,\ crc, x))$

(2.13) $\lambda y \exists x(report(x)\ \&\ send(y, crc, x))$

(2.14) $\lambda y[\exists x(report(x)\ \&\ send(y, crc, x))](apcom)$

(2.15) $\exists x(report(x)\ \&\ send(apcom,\ crc, x))$

The treatment of plural anaphora in DRT uses an abstraction operation which is used to form a pluralic discourse referent out of material occuring an a quantificational construction.

(2.16) Each department has a dedicated line. They are rented from BT.
They rent them from BT.

In the above examples, we gave a truth-conditionally equivalent "reduced" version together with the predication consisting of λ-expression and argument term . Actually, the λ-calculus provides a system of syntactic conversion rules that allow to perform the reduction mechanically (given that certain constraints are satisfied). The most important conversion rule for NL-semantic application is β-reduction, which consists in replacing all occurrences of the λ-variable by the argument term. The conversion mechanism is an extremely helpful tool, since it allows to compute compact meaning representation by the alternation of application and abstraction steps.

As mentioned above, all NL-semantic theories provide an abstraction mechanism in one or the other form, and likewise all of them would subscribe

to the fact that there are truth-conditionally equivalent "β-reduced" versions. There is a difference, however, with respect to the question whether extended and reduced versions really express the same meaning and are unconditionally intersubstitutable. The answer is dependent on the question whether meanings can be exhaustively described on the truth-conditional level. Theories as Property Theory and Situation Semantics would claim that meanings of complex expressions are structured entities, and that the different structures of (2.5) and (2.15) above may have denotations different from the ones of (2.4) and (2.14), respectively.

2.3 Quantification

The notation for quantification we find in standard predicate logic goes back to Frege [1879]. Frege's formulation of the Begriffsschrift (the precursor to predicate logic as we know it today) was largely motivated by the aim to reveal the "logical form" of propositions, especially in those cases where it seemed to be hiding behind overt syntactic form. In particular he was concerned to render transparent the logical difference between a quantificational sentence like (2.17) and a non-quantificational one such as (2.18)

(2.17) Every man is mortal.

(2.18) Socrates is mortal.

However, the representation of quantification Frege chose was more at variance with natural language than his central purpose called for. There was no need to represent universal quantification his way - as we find it today in the standard predicate logic translation of (2.17)

(2.19) $(\forall x)(\ man(x) \rightarrow mortal(x))$

rather than in a form closer to natural language, in which the quantifier is treated as a relation between what is expressed by its restrictor - in (2.17) this is the common noun phrase *man* of the quantifying subject NP *every man* - and its nuclear scope - given in (2.17) by the verb phrase *is mortal*:

(2.20) $\mathbf{every}_x(man(x), mortal(x))$

The quantifier **every** of (2.20) is to be seen as a relation between two sets - the set X of men and the set Y of individuals that are mortal. The quantifier asserts of these two sets that the former is included in the latter.

The quantifier in (2.20) is one instance of the general notion of a *generalized quantifier* used in contemporary semantics: In general a (generalized) quantifier is a relation between sets. In contrast, the Fregean quantifier $(\forall x)$ of (2.19) functions as a predicate of single sets; in (2.19) it is applied to the set of

all individuals which are, if men, then mortals; thus (2.19) analyzes (2.17) as saying that a certain boolean combination of the sets A and B has the property expressed by ($\forall$x)

For the quantifiers to which standard first order predicate logic restricts attention - universal, existential and those definable from them - a Fregean analysis as 1-place set predicates, while not very natural from a linguistic perspective, is otherwise unobjectionable. But for other quantifiers one finds in natural language this is not so. A well-known example is the determiner *most*. It can be shown fairly easily that no quantifier Q with the following (partial) truth conditions - which seem very plausible for most:

(2.21) Whenever A and B are finite, then Q(A,B) iff $|A \cap B| > |A \setminus B|$

can be expressed as a property of some boolean combination of sets. By similar arguments it can also be shown that there is no way of defining a generalized quantifier satisfying (2.21) within standard first order logic. Thus adding a device for representing most to first order logic amounts to a genuine (not just a definitional) extension.

It is to be noted that (2.21) does not fully determine the logical properties of such an extension. On the one hand it has long been known that if we drop the restriction to finite sets in the antecedent of (2.21), thereby fixing the extension of the new quantifier completely, the resulting calculus is no longer axiomatizable (there exists no algorithm for grinding out all logically valid formulas.) If however, we keep (2.21) as it is, or combine it with a weaker condition for the infinite case, such as in case A is infinite, then **most**(A,B) is not true if $|A \cap B| < |A \setminus B|$, then axiomatizability is preserved.

Generalized quantifiers, we said, are relations between sets; and we said this in relation to logical forms such as (2.20). But how exactly does (2.20) express a relation between sets? Well, it does so implicitly, one might say, in that the open formulas man(x) and mortal(x) can be considered as defining those sets. Nevertheless, these sets are not what the standard semantics for first order logic takes to be the denotations of these formulas. One way to get a logical form that directly and explicitly represents (2.17) as a relation between sets is to replace the formulas man(x) and mortal(x) by the corresponding l-abstracts λx.man(x) and λx.mortal(x). In this way (2.20) is turned into a formula of second order logic

(2.22) **every**(λx. man(x), λx. mortal(x))

It should be stressed, however, that this is not the only way to go. In general, systems with additional variable binding operators, such as eg. a binary quantifier **most**, do not have the expressive power of second order logic. And often, as we just saw, they succeed in avoiding the unpleasant logical properties that

make second order logic in principle unsuitable for purposes of implementation. From a linguistic perspective it is important to distinguish between those quantifier expressions (such as the English word *most*) which genuinely function semantically as operators which bind individual variables, and those quantifier determiners which head NPs - eg *fifteen representatives*, *several computers* - that must, in at least some cases, be construed as referring to sets, i.e., that act as irreducible arguments of collective predications. It is these that force semantic representations of NL sentences into the realm of higher order logic for real.

One important benefit of staying within the "first order logic + additional quantifiers" framework is the possibility of capturing much of the inferential properties of such systems by assuming that the new quantifiers have certain general properties. For instance, there are a number of natural language quantifiers, among them notably **many** and **few**, for which it is uncontroversial that they have some such properties, but whose meaning it does not seem to be possible to fix beyond that. By way of example, **many** is arguably *upward monotonic* in its second argument, i.e.

(2.23) if **many**(A,B) and B B', then **many**(A,B')

Classifying a quantifier as having one or more such properties is one way of constraining its formal semantics. For extensions of first order predicate logic with quantifiers whose semantics is constrained in just this way it is often possible to provide complete axiomatizations.

So far we have only discussed cases of nominal quantification. Equally common in natural languages such as English are adverbial quantifiers, exemplified in

(2.24) Socrates was mostly right.

(2.25) Men are invariably mortal.

(2.26) Personal computers are often expensive.

Adverbial quantification raises two problems that do not (or only marginally) arise in connection with nominal quantification: (i) What do adverbial quantifiers quantify over, i.e. which variables do they bind? (ii) How are restrictor and nuclear scope of the quantification determined; in particular, how is the semantic material that is contained in the sentence to be distributed over restrictor and scope? As regards (i), note that nominal quantification is always quantification over the bearers of the predication expressed by the head noun; it is always the variable that occurs as argument of the head noun predicate that the quantification binds. In contrast, with adverbial quantification identification of the bound variable is less obvious. Many current theories of semantics

assume that adverbial quantifiers bind variables that range over situations (either the situations which the verb phrase of the sentence itself describes or else situations which the VP in some sense presupposes). But the matter is still debated, as is the question of where and how these variables originate.

A question which has also received much attention in recent years is whether NL quantifiers can bind "unselectively," i.e. bind more than one variable at the same time. This is a question that can be posed also in relation to nominal quantifiers, but it arises in the first instance for quantifiers expressed by adverbs.

(ii) is one of two types of question known as questions of *scope*. The scope problem connected with adverbial quantifiers is illustrated by the following sentence pair

(2.27) a. Bill usually drinks a pint of LAGER.
b. Bill usually drinks a PINT of lager.

(Capitals indicate stress)

(2.27a) and (2.27b) invite distinct interpretations, (2.27a) the interpretation that usually when Bill drinks a pint of something, it will be a pint of lager and (2.27b) that usually when Bill drinks a certain amount of lager he drinks a pint of it. In any of the current semantic formalisms suited to the representation of quantification, this difference between (2.27a) and (2.27b) comes out as a difference in the way in which the material of the sentence is distributed over the parts of its semantic representation. For instance, a representation of (2.27a) would look something like (2.28a), while that of (2.27b) would be have the form (2.28b) :

(2.28) a. $\mathbf{usually}_{e,q}$(beverage(q) & e is an event of Bill drinking a pint of q, lager(q))
b. $\mathbf{usually}_{e,q}$ (quantity of lager(q) & e is an event of Bill drinking q, pint of lager(q)))

The difference between (2.28a) and (2.28b) is one of scope in that some of the material included in the restrictor in (2.28a) belongs to the nuclear scope in (2.28b), and conversely.

A different type of problem about scope arises when a sentence contains two or more quantifiers at once. Consider:

(2.29) In 1993 Microsoft presented at least five new word processing tools at most European trade fairs.

(2.29) is ambiguous between a reading which takes the quantification expressed by most European trade fairs to be part of the nuclear scope of (or, as one usually says: to be in the scope of) the quantification expressed by at least five new word processing tools and a reading in which the latter quantification is

in the scope of the former. Such scope ambiguities may arise not only when a sentence contains two quantifiers, but more generally when there are two or more "scope bearing elements;" these include besides the quantifiers also negation, conjunctions such as *and* and *or* and "intensional operators" such as *on purpose*, auxiliaries such as *might*, etc. Well-known examples of scopally ambiguous sentences involving elements other than quantifiers are:

(2.30) Every new product of this firm doesn't live up to customers' expectations.

(2.31) This product has been approved and is being marketed now or will soon be available in high street shops.

For computational purposes determining scope is crucial. However, determining scope has proved very difficult. Often, scope relations are constrained by syntactic, semantic and pragmatic factors. There exists as yet no satisfactory theory that accounts for all these factors and the ways they interact.

It is a well-known fact about quantificational (i.e. predicate) logic that quantification over higher order objects, such as properties, relations or sets, leads to a dramatic (and by some accounts disastrous) increase of its logical complexity: Adding such quantifiers leads to formalisms which can no longer be axiomatized; no algorithm will be able to generate all the logical theorems of such a formalism or be capable of carrying out all its valid derivations. In this respect they differ from first order quantification theory in which all quantification is over individuals. The axiomatizability of first order quantification theory has generally been looked upon as a virtue and much attention has been given to the question whether natural language shares this virtue. So, in particular there has been much concern over the question whether natural language contains expressions that must be construed as quantifiers over properties of sets.

This is what we believe can be ascertained in the light of current understanding of the semantics and logic of the various quantificational devices of a language like English. First, expressions which behave as genuine quantifiers over sets do, it would appear, not occur. (A possible counterexample to this claim might be NPs such as *every three books*, which are presumably to be construed as quantifying over sets consisting each of three books. But even if this were so, these quantifiers would be special in that they would not produce the non-axiomatizability mentioned above.)

Secondly, although genuine quantifiers over sets are absent or at best marginal, English contains both definite and indefinite set-denoting NPs. Since these NPs, and in particular the indefinite ones, can occur within the scope of other operators (e.g. of quantifiers, connectives, etc.), the over-all effect of their presence is that of set quantification; consequently they endow the language with

the kind of expressive power that is incompatible with axiomatizability.

There is a third point. While English does not, or only marginally, have second order quantifiers, it has many first order quantifiers that are non-standard in the sense that they cannot be defined with the help of the standard quantifiers $\forall$ and $\exists$ - well-known examples are, as we noted already, **many** , **few** and **most**. Adding such quantifiers to an axiomatizable formalism may well result in non-axiomatizability - whether it will or not depends on the precise semantic properties that the new quantifiers are supposed to have. (An example is the quantifier **most**(A,B) with the "standard semantics for most", according to which **most**(A,B) is true iff the cardinality of $A \cap B$ exceeds that of $A \setminus B$.) Whether natural languages contain non-standard first order quantifiers of this kind is a question that, at the present time, is still unanswered. (In particular it is in our opinion still an unsettled question what is the correct semantics of the English quantifier most.)

2.4 Propositions

The term *proposition* is used to indicate the semantic content of simple declarative sentences. The exact nature of propositions becomes important, however, when they are the argument of predicates or within the scope of operators. Most notable are the examples which involve attitude verbs such as *believe* or *know* followed by *that*-complements. These are illustrated in examples (2.32), (2.33), and (2.34). Another kind of example where the precise nature of propositions plays a crucial role is sentences containing modals. Such sentences are illustrated in (2.35)-(2.37).

(2.32) Smith { believed/knew / said/denied / feared/hoped } that ITEL had won a/the contract.

(2.33) It is true/false that ITEL won a contract.

(2.34) Smith saw that Jones had signed the contract.

(2.35) Any software that is used on the project will be given to CRC after the project finishes.

(2.36) CRC may also request any software that was not used.

(2.37) Software licences must be bought for CRC by ITEL.

From the perspective of natural language semantics first order predicate logic provides us with a very simplified notion of proposition, according to

which propositions are identified with truth values.[1] Why is it insufficient to equate propositions with truth-values? Consider a minimal adjustment to predicate logic which would introduce **believe** as a relation between individuals and truth values. This would mean that we would be able to represent (2.38a) as (2.38b).

(2.38) a. Smith believed that ITEL had won a contract

b. **believe**(**Smith**, $\exists x$[**contract**(x) $\wedge$ **won**((ITEL),x)])

Suppose that it is true that ITEL won a contract. Under this analysis (2.38a) would be true just in case Smith stood in the believe-relation to the truth-value T. This would mean that if we substituted in any other true sentence for *ITEL had won a contract* after *Smith believed* we would obtain another true sentence. But clearly we should not be able to infer from the fact that Smith believes one true proposition that he believes all true propositions. In fact treating propositions as truth-values in a fixed first-order model would mean that there are only two propositions, the true one and the false one.

The solution that is proposed in classical possible worlds semantics is that propositions are to be modelled as sets of possible worlds, those worlds in which the proposition is true. This successfully distinguishes between complements which are true in different possible worlds. However, the problem still remains for complements which are true in the same possible worlds. Consider the two sentences in (2.39).

(2.39) a. The manager attended the meeting in Cambridge

b. The manager was in Cambridge and attended the meeting in Cambridge

Given normal assumptions about what is involved in attending meetings (as opposed to teleconferencing) (2.39a) and (2.39b) are true in exactly the same possible worlds since attending a meeting in Cambridge involves being there. On the possible world theory this means that (2.39a) and (2.39b) represent one and the same proposition. And yet it seems wrong to require that both the examples in (2.40) are true under the same conditions. (We assume that *he* refers to the manager in both cases.)

(2.40) a. The manager was glad that he attended the meeting in Cambridge

b. The manager was glad that he was in Cambridge and attended the meeting in Cambridge

[1] The word "proposition" is often used in classical descriptions of first order logic for the sentences of the language, i.e. syntactic rather than semantic entities. They are the kind of syntactic expression which denote truth-values. In intuitionistic approaches to predicate logic propositions are regarded as specifications of proofs. A proposition is true if there is a proof of it.

It may well be the case that he was glad about attending the meeting in Cambridge but not glad about being in Cambridge (he might have preferred to be in Edinburgh that day so that he would be home in time to celebrate his daughter's birthday).

This kind of observation has led to proposals that propositions are more structured than sets of possible worlds so that finer distinctions can be made. The most fine-grained distinctions that can be made is to identify propositions with the sentences that intuitively express them. However, this seems to make a too fine-grained distinction and this has not been considered to be a serious alternative. It predicts, for example, that speakers of different languages cannot share beliefs or that it is possible to have an attitude to (2.41a) but not have that attitude to (2.41b).

(2.41) The secretary typed the report on the X2000
The report was typed on the X2000 by the secretary

A view which preserves the structure of language but avoids defining propositions in terms of the words of a particular natural language is that which has come to be known as structured meaning, originally proposed by Lewis [1970] and developed by Cresswell [1987]. This proposal assembles the intensions of the individual words in a tree structure which is parallel to the syntactic structure of the natural language sentence. Proposals have also been made to use the intuitionistic notion of proposition using Martin Löf's type theory. The different proposals presented in property theory, DRT and situation semantics are for treatments of the attitudes which give enough structure to the semantics of the complement but avoid making this structure so close to the syntax of natural language that it is difficult to do reasoning with the resulting structures. In property theory propositions are treated as atoms in the universe rather than sets of possible worlds. In situation theory propositions are structured in the sense that they are obtained by applying a predication operation to a type and some arguments. In DRT anchored DRS's do the duty of propositions as the objects of the attitudes. In situation semantics this aspect of the DRT analysis is captured by analyzing attitudes in terms of a pairing of a type (corresponding to a DRS) and an assignment (corresponding to an anchor). If the type is applied to the assignment then a proposition results.

Propositional attitudes are just one example of phenomena in natural language which require analysis in terms of something other than what is normally regarded as the extensions of natural language expressions. These phenomena are normally referred to as intensional. Another key example of intensional constructions is intensional verbs like *need*, *want* and *look for*. For example, consider the noun-phrases *a computer which can engage in unrestricted natural language dialogue* and *a secretary who has the mental capability of a supercom-*

puter. Currently, at least, these noun-phrases are extensionally equivalent – neither exist. However, needing or wanting one is dinstinct from needing or wanting the other.

2.5 Predication

Predication is the attribution of a *predicate* (*property* or *relation*) to one or more objects. Conventionally, if we write $P(a_0, \ldots, a_n)$ then we mean to say that the predicate P holds of $a_0, \ldots, a_n$. More precisely, however, the felicitous predication gives rise to a *proposition*, which in most semantic theories (other than first order logic) is not straight-forwardly equated with truth, as discussed in the previous section.

Given a particular semantic theory, we might question the specific nature of P, $a_0, \ldots, a_n$, and $P(a_0, \ldots, a_n)$. In classical first-order logic, the arguments of a predicate must be terms. The result of predication is a proposition that is equated with true or false. In standard models of first order logic, predicates denote set. Predication is then modelled by set membership.

For the semantics of natural language, however, this is not adequate. Concerning propositions: the attitudes in natural language requires that they are not equated with truth or falsity. Also, modifiers in natural language, such as adjectives and adverbs:

(2.42) John worked quickly,
but it was a slow project.

nominalisation and gerunds:

(2.43) The manager likes to order people around

and attitudes:

(2.44) The director thought that the project was late.

suggest that we need to have propositions, properties and relations appearing as arguments to predicates, and perhaps allow modification of predicates. Apparent "truth value gaps" in natural language seem to question the simple model of predication as set membership.

To allow properties, relations and propositions to appear as arguments motivates a move to higher order logics. This move is often accompanied by a change to possible worlds semantics, where propositions are equated with sets of possible worlds, rather than truth values. There are then more than two propositions. An alternative is to take propositions (together with properties and relations) as basic objects.

As discussed above, compositional semantics for natural language seems to require a notion of abstraction. With standard models, abstraction in a higher

order logic can lead to paradoxes unless there is a strong notion of *typing* used to constrain application. All expressions must be assigned exactly one type. When an abstract is produced, the type of the abstract must be a function from the type of the abstract, to the type of the original expression. Abstracts can only be applied to expressions belonging to domain. This prevents self application, and hence avoids certain logical paradoxes.

Predication in higher order logic is just a special case of function application; with a possible worlds semantics, predicates are modelled by functions from individuals to sets of possible worlds. However, philosophical and linguistic objections have been made to theories that take predication to be function application [Bealer, 1989]. Some versions of Situation Theory and Property Theory seek to keep predication distinct from functional application.

In natural language semantics, the types of higher order logic are often put in correspondence with syntactic categories. However, nominalisations, gerunds, and cross categorial phenomena, such as conjunction, suggest that this correspondence should not be taken to be rigid.

Types might be contrasted with *sorts* (*appropriateness conditions* in Situation Theory) which are usually taken to provide a *semantic* requirement, which does not rule out expressions syntactically, but it may limit what we can say about its truth conditions. The sentence:

(2.45) The computer died.

might have a representation in the semantic theory, but if we assume that there is a sortal constrain which requires that for things to die they must have been living, then further work will be needed in order to say something about its truth conditions. Other sentences may never have any coherent interpretation, such as:

(2.46) Aristotle is a prime number.

Sorts can be implemented by way of predicates, or properties, and conditional expressions within the representation language. As such, they maybe added to most semantic theories that are at least first order.

In many cases, apparently higher order logical representations can be modelled by a first order theory. For example, in higher order logic we might represent predicate modifiers as they occur in expressions such as:

(2.47) John worked quickly.

by $quickly'(worked')$:

$$(quickly'(worked'))(john')$$

or we could take $quickly'$ to be a predicate which takes $worked'$ as an argument,

together with *worked′*'s arguments:

$$quickly'(worked', john')$$

Either way, a first order representation of this is possible by way of a distinguished argument position such as an event variable, so we would have:

$$worked'(e, john') \& quickly'(e)$$

where e is the distinguished variable. This is the Davidsonian treatment of adverbial modifiers. If we can always reduce property modifiers to this form where all the arguments are terms, then the full power of higher order logic is not really being used. In general, if we never have a genuine case of unrestricted quantification over predicates, then the representation is only of first order power.

Genuine cases of higher order quantification may arise with collective readings of plurals. If we ever have a real case of universal quantification over arbitrary collections, then there is no logically equivalent first order representation. There are examples (such as natural language representations of second-order axioms in mathematics) where the intended reading requires full second order logic. However, some have questioned whether natural language representations of such axioms really do capture the intended meaning [Lonning, 1989].

If formal semantics is viewed as a scientific theory of the meaning of natural language, then methodological objections might be raised to the use of a powerful theory (like higher order logic) to model phenomena that do not use that power. It should be noted that if the full power of higher order logic is not realised in the representations, then the same expressiveness can be achieved without using higher order logics by treating (the individual correlates of) properties and relations as first class objects.

2.6 Connectives

There are several reasons to diverge from the standard FOL explanation of the meaning of the connectives in natural language semantics. In the first place, the set of FOL connectives is limited to 'and', 'or', 'not' and 'if then', with Boolean interpretations which can be rendered by the familiar truth tables. Natural language has a much wider repertoire. Also, the natural language counterparts to the Boolean connectives have more subtle meanings than the truth tables would predict.

2.6.1 Negation

In natural language, there are different ways to express negation. In the first place, not all negation is propositional. Next to sentential negation, as in 2.48, we have VP negation, as in 2.49 and NP negation, as in 2.50.

(2.48) It is not the case that some managers resigned.

(2.49) Some managers did not resign.

(2.50) Not every manager resigned.

For these particular examples, the negation is Boolean negation, and indeed, the meanings of the examples are expressible in FOL. In the FO translations the negations will all be propositional, of course; the issue here is not so much the expressive power of first order logic but the mechanism for reducing non-sentential negation to sentential negation. In other words, the issue is how to give a compositional analysis of non-sentential negation. This can be done by means of lambda abstraction. The VP negation operator now takes the form: like $\lambda P \lambda x \neg Px$. This combines with a VP meaning $\lambda y Ay$ to form a new VP meaning $\lambda x \neg Ax$.

In the second place, not all negation in natural language is Boolean negation. In (2.51) the negation is *weak*, because it closes a truth value gap.

(2.51) It is NOT the case that the king of Holland resigned (for Holland has no king).

This distinction between strong and weak negation is not present in FOL, as it emerges from admitting truth-value gaps. The former expresses that its argument is false, and the latter merely that its argument is not true (which is the case if the argument is false, but also if it suffers from presupposition failure).

Still other kinds of negation are defined in constructive and conditional logics (see also subsection 2.6.3), where the negation of a proposition ϕ is taken to mean that we are in a situation which cannot be extended with the information ϕ.

2.6.2 Conjunction and disjunction

Again, FOL only has conjunction and disjunction as propositional connectives. Formal interpretation of NL should allow a much wider employment for these connectives. Simple examples are VP- and NP-con/disjunction:

(2.52) IBM and Apple collaborated on the Power PC project.

(2.53) Some manager or some engineer resigned from the company.

(2.54) Some engineer resigned or was sacked.

Adding a mechanism for lambda abstraction to FOL enables one to express these constructs. The VP conjunction operator, for instance, looks like this: $\lambda P \lambda Q \lambda x \cdot Px \wedge Qx$.

Natural language conjunction and disjunction are not always Boolean operations. Often, natural language 'and' is to be read dynamically, as: first ..., and then .... Dynamic logic provides the tool to analyse this dynamic 'and', which shows up in examples like (one of the possible readings of) the following:

(2.55) The manager resigned and started his own company.

Or even more clearly:

(2.56) The manager was sacked and died in misery.

Dynamic theories of NL-semantics account for this by taking propositions as input output relations rather than sets of situations/worlds. This entails that dynamic conjunction is not commutative: changing the order of the conjuncts matters to the meaning.

This order-sensitiveness of conjunction also shows up in examples which refer to epistemic states by means of expressions like 'maybe':

(2.57) Maybe it is raining. It isn't raining.

(2.58) It isn't raining. * Maybe it is.

There are clear differences between conjunction and disjunction with respect to their anaphoric potential, which cannot easily be accounted for in FOL like formalisms, but which find a ready explanation in dynamic theories of anaphoric linking.

(2.59) A man and a boy walked in. They/*he smiled.

(2.60) A man or a boy walked in. He/*they smiled.

2.6.3 Implication

The most puzzling connective from the FOL repertoire is implication. Its boolean interpretation in FOL seems rather far removed from our intuitions about conditional sentences in natural language. In FOL, implication is equivalent to disjunction: $\phi \rightarrow \psi \equiv \neg\phi \vee \psi$. For natural language, such an interpretation has the rather weird consequence that the following sentence is true, because its antecedent is false.

(2.61) If Apple is owned by IBM, then Microsoft has gone bankrupt.

Natural language conditionals suggest some kind of meaning connection between antecedent and consequent, and in the truth functional analysis of FOL this connection gets lost. The law of contraposition, which holds in FOL,

looks weird in the context of NL conditionals. According to this law, 2.61 should be equivalent to 2.62, but intuitively, the sentences have different meanings.

(2.62) If Microsoft hasn't gone bankrupt, IBM doesn't own Apple.

The following very natural informal semantics for NL-conditionals was proposed by Ramsey.

> A conditional sentence 'if A then B' holds in some state of knowledge if adding A to the knowledge state leads to a new state of knowledge where B holds.

Formalization of this proposal requires the notion of expanding a state of knowledge. And then, Ramsey's rule only applies to *indicative conditionals*, i.e. conditionals whose antecedents are consistent with the current context. *Counterfactual* conditionals rely also on the notion of reducing a state of knowledge. The concept of addition requires removing certain information from the current state such that the antecedent can consistently be put in the context.

2.6.4 Other connectives

Natural language uses a wide range of further connectives, with meanings which are not even close to the Boolean repertoire of FOL. Connectives expressing temporal succession ('before', 'after'), causal connection ('because'), epistemic status ('maybe', 'possibly', 'definitely'), and many, many more have a clear logical meaning but not one which is approached by or easily expressible in FOL.

2.7 Variables

2.7.1 Introduction

In first-order logic, variables are used to indicate which arguments to predicates are bound by which quantifiers. In addition, they can be used to show when two different arguments are bound by the same quantifier. (Similarly for abstracting over argument places when abstraction is added.)

2.7.2 Variables and Anaphora

2.7.2.1 First-Order

In first order logic, the ability of variables to show when different arguments to predicates are identified suggests the use of variables in treating anaphora.

Bound variable anaphora thus corresponds to treating a pronoun as a variable that happens to get bound by an antecedent quantifier.

Free variables can also be deployed to treat certain kinds of (referential/deictic) anaphora, where the interpretation of the free variable depends on some contextually given assignment of values to variables.

2.7.2.2 Compositionality

Departures from standard first-order uses of variables have come about as a result of trying to give fully compositional treatments of inter-sentential anaphora through treating pronouns as variables. A pair of sentences like *A man walked in the park. He whistled.* can be given a straight-forward first-order representation:

$$\exists x\,.\, m(x) \wedge wip(x) \wedge w(x)$$

The problem is how to derive this representation compositionally.

In Dynamic Predicate Logic (DPL), notions of scope and binding are redefined so that the two sentences can be analysed as an existential conjoined with a formula containing a free variable (i.e. pronoun) that is nevertheless dynamically bound by the existential:

$$[\exists x\,.\, m(x) \wedge wip(x)] \wedge [w(x)]$$

(this is truth conditionally equivalent to the preceding formula).

Discourse Representation Theory (DRT) introduces variable-like terms called *discourse referents*. Unlike variables, discourse referents are not bound by quantifiers (or abstraction) in a standard way. Both quantifiers and connectives like *if* are treated in terms of possible extensions of partial functions assigning discourse referents to entities. Because of this they can 'bind' more than one discourse referent (non-selective binding). The difference between discourse referents and variables in DRT leads to a redefinition of the notions of scope and binding that is in many ways similar to DPL. However, at least in the original version of DRT, discourse referents were introduced as items in an intermediate level of semantic representation (discourse representation structures) in a way that was not clearly compositional.

In Dynamic Montague Grammar (DMG) both variables and discourse referents are employed. This can perhaps be seen as splitting the role of variable as bound argument place from that of variable as identifying different argument places. The latter, more overtly anaphoric role of variables is taken over by discourse referents. Discourse referents are subject to dynamic binding, while the ordinary variables in DMG are subject to static binding.

2.7.3 Representational Issues

Besides changes in the treatment of variables to deal with the composition of anaphoric sentences, there have also been changes motivated by more directly representational needs.

2.7.3.1 Plural Variables

An example is mixed distributive/collective quantification, where one appears to need both plural and singular entity denoting variables to account for the distributive and collective readings of a single NP: "The men who gathered in the park went home to their wives".

2.7.3.2 Sorted/Typed Variables

It may also be necessary to distinguish between variables ranging over different sorts of object (events, propositions, ordinary individuals, etc).

2.7.3.3 Free Variables and Meta-Variables

Introducing higher-order variables opens the possibility of treating ellipsis as a form of higher-order anaphora: a contextually given variable assignment deictically assigns some property to a free variable standing in for the ellipsis. Stump employed higher-order free variables for dealing with non-elliptical, but nevertheless contextually dependent, relations between clauses.

The use of meta-variables in QLF is similar, though here it is arguable that the variables are best seen as ranging over QLF expressions rather than directly over objects in some model.

2.7.3.4 Discourse Entities

In work by Karttunen and Webber, among others, it was argued that anaphoric relations cannot be expressed in terms of the notion of coreference, because often one can have expressions that are anaphoric on antecedents that do not refer, an example being the expression "a witch" in "Hob believes that a witch burned his barn, and Nob believes that she blighted his cow", where there isn't necessarily a witch. One needs a notion of 'discourse model' containing 'discourse referents' that are what serve as antecedents of anaphoric expressions, but do not necessarily refer to anything in the model. The discourse referents of DRT can be seen as going towards fulfilling this role.

2.7.3.5 Parameters

Models for first (and higher) order logic do not contain variable objects. Variables are expressions in the language whose denotations can range over different (non-variable) objects in the model. Parameters in situation theory, in contrast, are variable objects that may partake in situations.

Chapter 3

Some Basic Linguistic Data and Their Importance

3.1 Introduction

In this second Chapter of the Deliverable we will discuss in more detail some basic facts about semantic interpretation that have to a large extent motivated the development of the semantic theories under discussion. The work described here serves two related purposes:

- it collects in one place some of the core linguistic issues which any reasonably general computational semantics application has to face and presents them in an informal and non-technical fashion
- as far as possible it attempts to give a theory-neutral account of these phenomena to provide some kind of reference point or "common ground" for the treatment of (some of) these phenomena by the various approaches represented in FRACAS, thus allowing for a detailed comparison.

Since there was no hope to provide a concise summary of all known facts and questions about semantic interpretation, some areas of semantics that we felt were most fundamental had to be chosen. The topics we have identified as basic are the following:

- Generalized Quantifiers and Scope
- Plurals
- (Nominal) Anaphora
- Ellipsis

- Adjectives
- Comparatives
- Temporal Reference
- Verbs (Aspect and Intensional)
- Attitudes
- Questions
- Events and Event Type Anaphora

3.2 Generalized Quantifiers and Scope

3.2.1 Variety of Generalized Quantifiers

As discussed in the previous Chapter, in addition to the first-order determiners *every*, *some* and *no*, determiners such such as *most, many, few,* or the numerical quantifiers *two, three,* etc. may occur in quantified Noun Phrases (NPs):[1]

(3.1) Most/Few/A few/Many/No/All/Every/Each/A/ Some/Three/At most three/At least three/ Most of the/Few of the/Each of the/ At least three and at most five } representative(s) left.

The meaning of these determiners is not in general reducible to the meaning of first-order determiners; for example, there is no first-order translation of *Most V's are U's* [Barwise and Cooper, 1981]. A semantic theory must include a treatment of different kinds of quantified NPs. Such a treatment must include at least a language which can be used to express the truth conditions of these sentences; such a language, however, is only going to be useful to a Natural Language Processing (NLP) system to the extent that the system is actually able (i) to produce such a language from its input, and (ii) to draw the appropriate inferences from a database containing sentences in this language.

The fact that the scope of quantifiers is not determined by the syntactic structure of a sentence is an additional difficulty with quantifiers and other operators.[2] A sentence containing more than one operator may have as many interpretations as there are permutations of the operators. Sentence (3.2), for

[1] Here we the terminology that is traditional in formal semantics after [Barwise and Cooper, 1981], according to which the denotation of the quantified NP *most representatives* is called a *quantifier*, whereas the lexical item *most* is called a *determiner*.

[2] Expressions that change the parameters of evaluation

example, may have up to 10! readings. Some way of determining the relative *scope* of the quantifiers has to be determined that does not require generating all of the alternative interpretations. One way of doing this is by finding ways of constraining number of interpretations.

(3.2) A politician can fool most people on most subjects most of the time, but no politician can fool everybody on every single subject all of the time. (Hobbs)

3.2.2 Semantic Properties of Natural Language Quantifiers

The literature on the semantic properties of natural language quantifiers is rather large [Barwise and Cooper, 1981; Benthem and Meulen, 1985; Gärdenfors, 1987]; for excellent reviews of this work, see [Westerståhl, 1989; Eijck, 1991].

Quantifiers are generally taken to denote sets of properties of individuals. For example, the noun phrase *all representatives* denotes the set of properties that all representatives have, that is, the set of subsets A of the universe E such that the set **representatives** of individuals is a subset of A:

$$\{A \subseteq E \mid \textbf{representatives} \subseteq A\}$$

An equivalent way of saying this is to say that determiners denote relations between sets: thus, the determiner *all* may denote the relation that holds between two sets A and B just in case A is a subset of B:

$$\textbf{all}(A,B) \text{ iff } A \subseteq B$$

The adoption of this 'relational' perspective has allowed formal semanticists to state a number of interesting generalizations about determiners and quantifiers. For example, it turns out that all relations that serve as the denotation of natural language determiners are *conservative*:

conservativity (CONS): A relation R is conservative iff the following holds: for all A, B $\subseteq$E, $R_E(A,B)$ iff $R_E(A, A \cap B)$

The fact that all determiners are conservative means that the following equivalence holds for all quantifiers:

(3.3) All Italians are great tenors $\equiv$ All Italians are Italians and are great tenors.

A great deal of information about the inferential properties of a quantifier can be formalized in terms of *monotonicity* properties. For example, the (valid) inference

(3.4) Most representatives attended the meeting.
Everyone who attended the meeting supported the proposal.

Most representatives supported the proposal.

is an instance of a monotonicity inference scheme of the form:

quant A B
all B C
---
quant A C

which is valid provided that *quant* is *upward monotone* in the second argument. Determiners can be classified as either upward or downward *monotone* in either their first or their second argument. *All* and *some* are upward monotone (MON↑) in their second argument, meaning that they license the following inference patterns [Eijck, 1991]:

(3.5) a. All warriors are aggressive. →All warriors are aggressive or stupid.
b. Some peasants are rude. →Some peasants are rude or stubborn.

No is both left downward monotone (↓MON) and right downward monotone (MON↓):

(3.6) a. No warrior is aggressive or stupid. →No warrior is aggressive.
b. No human is rude. →No peasant is rude.

All is left downward monotone, *some* is left upward monotone:

(3.7) a. All humans are aggressive. →All warriors are aggressive.
b. Some peasants are rude. →Some humans are rude.

3.2.3 Scope Ambiguity and Scope Islands

Most proposed solutions to the puzzle originated by people's ability to process sentences such as (3.2) without apparent effort rely on a combination of, on the one side, syntactic or semantic constraints; on the other side, processing heuristics and common sense inference.

Scope Islands are constructions that prevent quantifiers from taking wide scope. It has been claimed that relative clauses set up scope islands. (3.8), which has no relative clause, has a reading where *every software company* takes wide scope over *the representative*, but the relative clause in (3.9) blocks this reading.[3]

(3.8) The representatives of every software company came to the meeting.

[3]This claim is often disputed. For example, Pereira [1990] cites the example *The slush fund that every minister needs is kept by his secretary* in which the quantifier translating *every minister* appears to take scope over the NP *the slush fund*.

(3.9) The representatives who worked for every software company came to the meeting.

The different degree to which quantified NP are subject to scope islands has been one of the reasons for arguing that these NPs fall in different classes. For example, indefinite NPs do not seem to be subject to scope island constraints in the same way that quantificational NPs are: in (3.10), for example, the indefinite NP *a software company* may take wide scope over *the representative* (i.e., all representatives may work for a particular company), whereas *every software company* in (3.8) cannot take wide scope (i.e., (3.8) does not have a reading in which there are different representatives for very company). Definite NPs can also violate scope islands, as in (3.11). These examples, together with the special anaphoric properties of definite and indefinite NPs, have been reason to argue that definites and indefinites are not quantificational.

(3.10) The representatives who worked for a software company came to the meeting.

(3.11) Every representative who worked for the software company came to the meeting.

3.2.4 Quantification and Coordination

Sentences in which quantified NPs and coordination interact are of interest both because they require a non-trivial syntax/semantics interface, and because of what one can learn about scope ambiguity.

A first case of interaction occurs when two verbs are coordinated in a sentence containing a quantified NP in subject position (as in (3.12)) or in object position (as in (3.13)-(3.15)).

(3.12) Every representative wrote or telephoned.

(3.13) ITEL developed and manufactured a computer.

(3.14) APCOM wants and needs a computer.

(3.15) ITEL wanted and hired a consultant.

Whether a quantifier gets wide scope over conjoined verbs sometimes seems to depend on the verb: In (3.13), where two referentially transparent verbs are conjoined, the only reading available is the one in which the same computer is developed and manufactured. In (3.15), instead, 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).

Two quantified NPs may also be conjoined, as in (3.16)-(3.17), or a quantified NP may be conjoined with a referential NP, as in (3.18):

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

(3.17) Three executives and two customers attended the meeting.

(3.18) Prof. Smith and most customers attended the meeting.

In order to treat these examples, a semantic theory is needed where objects other than propositional level objects may be coordinated, and where proper names and quantified NPs either denote the same kind of object, or may be made to (as in theories based on type raising, [Partee and Rooth, 1983; Hendriks, 1993]).

These examples are also interesting when studying scope ambiguity, because coordinating two quantified NPs does not create scope ambiguities: (3.16), 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.

The head noun may also be coordinated, as in (3.19)-(3.23):

(3.19) Every representative or client was at the meeting.

(3.20) Every representative and client was at the meeting.

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

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

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

The interest of these examples is, again, that there are some restrictions on the available readings. (3.19) 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.* (3.20), instead, 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.* Examples like (3.21)-(3.23) which have both readings complicate matters—it's not simply a case of whether the coordinator is a disjunction or a conjunction.

3.2.5 Possessives

Possessives such as *John's tie* or *his name* are extremely common in all forms of natural language text, yet their syntactic and semantic properties aren't completely understood. A particularly problematic aspect of the interpretation of possessives is that the relation between possessor and possessee in a possessive typically has to be determined by inference. Smith's name in (3.24) is *Smith*, but his report may either be one he possesses, one he wrote, or one that is about him.

(3.24) Smith signed his name on his report.

3.3 Plurals

That "plurals" should be considered a distinct topic of semantic concern is something which deserves comment. Why not have, in tandem with it, a topic called "singulars"? It hardly needs mention that there is no statistical basis for such a a view: A search in the Penn Treebank lists more than 400,000 noun forms with singular forms outnumbering plural forms by a factor of roughly 2 to 1. If there is any justification for treating plurals in such a way at all, it must therefore be a theoretical one.

No doubt the reason is in part historical: From time immemorial the prime examples that guided theorizing about reference, predication and quantification involved singular noun phrases. This led to certain conceptions which plurals do not fit and diverted attention from questions that are important for plurals but which are of no or only marginal relevance to singulars. In this way plurals came to be seen as the "marked" case, which requires special treatment on top of a general theory of reference, predication and quantification designed primarily to fit the needs of singular constructions.

Inasmuch as such a justification exists, it is not straightforward; and it's not being straightforward is connected with a problem about plurals which has no equivalent in the domain of the singular. It is this. On the one hand many plural noun phrases—*most boys*, *few girls*, *many arguments among them*—function as generalized quantifiers. Logically speaking these NPs act as binders of variables ranging over individuals; just as singular NPs like *every man* or *at most one woman*. (Thus, just as *Every man whistles* can be represented as $\mathbf{every}_x(man(x), whistle(x))$, *Most boys whistle* can be represented as $\mathbf{most}_x(boy(x), whistle(x))$).

If all plural NPs could be analyzed along these lines, then the semantic treatment of plurals might have been no more than a note in the margin of the general theory. From a logical point of view the plural (at least in a language like English, French or German) might still be seen a presenting a serious issue, since many of the quantifying plural NPs express non-standard quantifiers, which cannot be expressed with the means of standard first order logic. And not only that: There are serious indications that the addition of some such non-standard quantifiers to first order logic loses us axoimatizability (i.e. the possibility of defining a method of proof, or building a theorem prover, which captures all logically valid implications). This is something that has been argued explicitly for the quantifier expressed in English by *most*. It should be added, however, that the argument rests on certain assumptions about the meaning of *most* that may be questioned, while on the other hand it isn't entirely clear that

there are no singular quantifying NPs which do not pose a similar problem. (Notwithstanding the extensive research on natural language quantifiers, this is an area that remains clouded in uncertainties.)

As a matter of fact not all plural NPs can be analyzed as generalized quantifiers. Some can be analyzed - and in certain contexts they must be - not as expressions quantifying over individuals, but as terms referring to sets of them. An example is the subject NP of the sentence *The members of the board met on the 11-th floor.* The verb of this sentence, *meet*, is a collective verb; it acts as a predicate of groups of individuals, saying of those groups that their members come together. Indeed, a sentence in which the subject of *meet* denotes a single individual, such as, say, *Bill met*, is hardly grammatical. Thus the logical form of our sentence must be something like $meet(X)$, where X is the group of people denoted by the phrase *The members of the board.*

In some other cases it is not immediately clear whether a plural NP should be represented as denoting a set or quantifying over an individual variable. Thus it would seem that *The members of the board are on the 11-th floor* can be represented both as a predication of the set of board members - $be \cdot on \cdot the \cdot 11 \cdot th \cdot floor(X)$ - or as a quantification - $every_x(member \cdot of \cdot the \cdot board(x), be \cdot on \cdot the \cdot 11 \cdot th \cdot floor(x))$: This "ambiguity" in the logical representation of plural NPs is at the heart of many of the semantical problems that plural constructions in English and similar languages pose.

3.3.1 Indefinite, Definite and Quantified Plurals

Definite plurals tend to have universal force (though this is often context dependent, and may admit of exceptions). Definite plurals can also sometimes have more generic senses — *the Romans* — or be names — *the Beatles* — but we will not include such cases in the fragment. Indefinite plurals (*some questions*) are more like existentials.

(3.25) The minutes listed the people who attended.

(3.26) The minutes listed some questions raised

(3.27) The figures can be broken down by sales regions.

(3.28) Juliet hates the Montagues.

3.3.2 Existential Bare Plurals

Notoriously resistant to semantic analyses are the so-called bare plurals. Unlike for many other plural constructions the problem here is not just a problem of the syntax-semantics interface – why do those syntactic structures yield precisely

those semantic representations? – but also a problem of philosophical logic in the traditional sense: what is an adequate representation and what is the logic of the representational formalism to which these representations belong? For the examples of bare plurals cited in 3.3.2 - examples of "existential bare plurals" as we called them - this problem is readily solved. For instance

(3.29) Most representatives have cars.

appears to be truth conditionally equivalent to

(3.30) Most representatives have one or more cars.

with the overtly existential phrase *one or more*. With

(3.31) ITEL sold personal computers to APCOM.

however, the matter is already more complicated. This sentence has an episodic reading in which *personal computers* gets an existential reading. But at least as prominent is the reading according to which there existed, over some past period, a "practice" of ITEL selling personal computers to APCOM. Certainly, the representation of this practice must make clear that the events instantiating it involve *personal computers* existentially: they are events of ITEL selling *some* personal computers to APCOM. But this desideratum does not fully determine the form and content of the representation let alone the role the bare plural plays in generating it. This problem however if anything is more acute with sentences such as *Bill collects stamps* or *Maria is looking for mushrooms*.

3.3.3 Dependent Plurals

A notable feature of bare plurals which cooccur with another plural NP, as in (3.29) or (3.33), is that they can have a "quasi-referential" interpretation (in the sense in which singular indefinites are treated "quasi-referentially" in DRT) and yet be neutral between a set and an individual interpretation. Thus the sentence

(3.32) All analysts were asked to write subroutines which would keep them busy for the next fortnight.

would be considered true in a situation where some of the analysts were asked to write just one, rather complicated subroutine, while others were assigned several, individually less time-consuming subroutines per person.

(3.33) All the sales representatives have company cars.

(3.34) Most customers got the computers they wanted.

In (3.33), each representative has one (or more) company cars, and in (3.34) most customers got one (or more) computers. Thus, some plural NPs can have non-plural reference, their plural form merely reflecting that of a genuinely plural NP on which they depend.

3.3.4 Collective and Distributive Readings and Scope Ambiguity

The ambiguity of the sentences (3.39) and (3.40) is well-known. (3.39) for instance, has an interpretation, where there are five departments who jointly own 15 mainframes, so that only 15 mainframes come into play, and one according to which each of the five companies owns 15 mainframes on its own, so that the total number of mainframes is 75. A similar ambiguity is found with conjunctive subjects, as in

(3.35) Smith and Jones signed two contracts.

which can mean either that they signed two contracts together or that they signed two contracts each. Since the distributive interpretation evidently does exist for (3.35) it presumably also exists for

(3.36) Smith and Jones left London.

which thus can be paraphrased as *Smith left London and Jones left London.*

As far as set-denoting plurals are concerned, the inference theoretic implications are straightforward. Through their presence the expressive power is that of second order logic and logical validity is thus no longer capturable by proof theoretic means. Even fragments of English that are from a grammatical point of view comparatively simple are affected by this.

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

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

(3.37) has an interpretation where Smith and Jones leave separately but meet collectively. In (3.38), the companies may have hired consultants individually or grouped together to jointly hire a consultant.

(3.39)-(3.41)illustrate the interaction of collective–distributive readings with scope. There is arguably a cumulative reading for (3.39), so that a total of five departments owns a total of fifteen mainframes, but it is not clear that this is not just a collective reading. (3.41) has a bijective reading as a special case.

(3.39) Five departments own 15 mainframes.

(3.40) 4 men installed 3 computers.

(3.41) 4 men installed 4 computers.

3.3.5 Reciprocals

The problem presented by reciprocals can be roughly devided into two classes, those where the antecedent of the reciprocal expression denotes a set of two individuals and those where it denotes a larger set. Or, to be more accurate, all the problems arising for two membered antecedents also arise for antecedents denoting three or more members, but the latter involve additional problems, which is already visible in the simple sentence

(3.42) The representatives spoke to each other.

For this sentence to be true it, is it necessary that each of these spoke to each of the others? With a number as low as 3, this implication still appears to be very strong; but as the number becomes larger, the implication becomes weaker; how strong it is, moreover, depends on the meaning of the verb in question, possibly also on other factors. Notorious problems concerning antecedents denoting pairs of individuals have to do with long distance bindings. For instance, how do we account for the ambiguity of

(3.43) John and Mary say that they read each other's papers.

Furthermore, does *most* in (3.44) refer to possible representative pairs or simply to representatives?

(3.44) Most of the representatives spoke to each other.

3.4 (Nominal) Anaphora

One of the outstanding problems in syntax and semantics is the question how the different referential functions of pronouns are related to each other. Pronouns can be used deictically - to refer to an individual in the speaker's environment which s/he points at or demonstrates in some other way; they can be used in ways that are strongly reminiscent of the bound variables of quantification theory, as when a pronoun is anaphoric to a quantifying NP (e.g. (3.49)) and they can be used anaphorically without acting as bound variables of some quantifier; thus a pronoun may refer back to - and thus corefer with - a proper name, either in the same sentence (e.g. (3.48)) or in some other, usually earlier sentence in the discourse (e.g. (3.52)). While it seems difficult to find an analysis of pronouns which covers all these possibilities at once, much progress has been made with the task of isolating the similarities that they have in common.

The constraints on pronominal 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. the Accessibility Relation

of DRT) and partly a matter of discourse pragmatics (c.f. the work of [Asher, 1993] and others).

Plural pronouns pose certain special problems. First, it is often unclear whether a plural pronoun must be understood as referring to a set or an individual as in

(3.45) The lawyers bought computers which they had decided served their particular needs best.

Here *they* and *their* can be interpreted as referring to individual lawyers or to the relevant set of lawyers. A second problem plural pronouns pose is that the antecedents of a plural pronoun can in general **not** be identified with a simple NP. Examples of this are (3.58), and (3.59), assuming we interpret *they* as referring to the set which includes both John and his colleagues. A related type of case is that illustrated by (3.60), where the *they* and *them* relate in a sense to one 'antecedent' NP only, viz. *each department* and *a dedicated line*, but not in the sense of coreference. Such examples show that pronominal anaphora cannot in general be treated as a relation between a pronoun and another expression (its 'antecedent') in the manner of many syntactic treatments of pronominal anaphora. The ways in which the referent of an anaphoric plural pronoun may relate to the antecedent discourse are, however, curiously restricted, as shown by the plural variants (3.56) and (3.57) of Partee's famous ball example. A much underestimated topic are the anaphoric aspects of the plural pronouns in first and second person (*we* and *you*).

Besides pronouns there are various other types of NPs which can be used anaphorically, on the one hand there are the so-called "anaphors" of the theory of Government and Binding - reflexives and reciprocals - which, roughly speaking, must find an antecedent "nearby" (usually in the same clause; but compare the "long distance anaphors " of e.g. the Scandinavian languages [Hestvik, 1991]. "Anaphors" (in this sense of the word) share with regular pronouns the property that their antecedent must be realized by simple expressions so that there is no fundamential difficulty here with treating anaphora as a relation between expressions.

On the other hand anaphora is found with NPs such as definite descriptions and demonstratives. These can, like pronouns, refer to things introduced by earlier NPs as in

(3.46) When an airline buys an electronic net from a computer firm, the firm usually installs the network.

But it is also possible, for a definite description to refer to an individual that has not been introduced explicitly, but is related to an explicitly introduced individual in a systematic way (e.g. part-whole):

(3.47) I can't use my work station. The monitor doesn't work anymore.

where *the monitor* is understood as denoting the monitor of the mentioned work station.

(3.68) contains two examples of this. *The Chairman* refers to the chairman of the mentioned meeting (the referent of *the meeting* must be presumed to be clear from the context.) and the plural description *the small investors* is understood to refer to that subset of the set of shareholders present at the meeting which consists of those shareholders that satisfy the predicate "small investor".

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 (3.62). As Evans first noticed [1980], a two-sentence discourse such as (3.62) is not equivalent to the single sentence which says that GFI owns several computers that ITEL maintains, for this paraphrase is compatible with GFI owning other computers that are not maintained by ITEL, whereas (3.62) seems to assert that ITEL services all the computers that GFI owns. [Evans, 1980] 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 pronouns came to mean "pronoun that has to be analyzed 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.

The E-type analyses have been of particular importance in connection with so-called "donkey" pronouns, such as the *it* of (3.63) and (3.64). Another use of pronouns that is still a topic of linguistic argument and that has been argued to be a case of E-type pronouns is that of the so-called "paycheck pronouns", exemplified by the *it*'s of (3.61). In such cases the context suggest that there exists a map f from things of one kind D to things of another kind R. Thus in (3.61) 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 (3.61) 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.

3.4.1 Bound and Referential Anaphora

Is *her* a bound or referential anaphor in (3.48)? The weak-crossover distinction between (3.50) and (3.51) suggests that *her* is referential, but at least some people dispute the weak-crossover data. According to these people, *his* is bound by *every* in (3.49).

(3.48) Smith used her workstation.

(3.49) Every executive used his workstation.

(3.50) His advisor misled John.

(3.51) His advisor misled every executive.

3.4.2 Intersentential Anaphora

Pronouns can refer back across sentence boundaries. This is always possible with referential anaphora, or when the antecedent is an indefinite or definite NP, c.f. (3.52). 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 always possible, c.f. (3.53), though in some cases, often referred to as modal subordination type cases (3.54), anaphoric reference is fine.

(3.52) Smith attended a meeting. She chaired it.

(3.53) Every executive$_i$ attended a meeting. ??She$_i$ gave a good presentation.

(3.54) Every meeting had a chairperson$_i$. She$_i$ was selected from one of the participating companies.

3.4.3 Plural Anaphora

(3.55) is an example of a plural pronoun referring back to a plural quantified NP.

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

There are restrictions on which implicit plural antecedents can be referred to by pronouns. Set difference ("negative information") does not seem to be an available operation for antecedent construction, as shown by (3.57).

(3.56) Two of the ten machines are not in the office. They are in the lobby.

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

It is possible to sum over objects to build up plural antecedents.

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

They in (3.59) can either refer to John and his colleagues, or just the colleagues, but not just John.

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

A form of E-type anaphora is illustrated by (3.60). *Them* acts as a form of dependent plural pronoun.

(3.60) Each department has a dedicated line.
$\left\{ \begin{array}{l} \text{They are rented from BT.} \\ \text{They rent them from BT.} \end{array} \right.$

It refers to the dedicated line that the relevant department rents. Note that a department has to be singled out for this to work.

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

3.4.4 E-Type Anaphora

(3.62) can't be read as meaning there are several computers that GFI owns and ITEL maintains. Rather, ITEL maintains all the computers GFI owns.

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

3.4.5 Donkey Anaphora

'Donkey' sentences such as (3.64) are interesting because an indefinite like *a computer* in these cases behaves more like a universal quantifier than like an existential.

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

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

The *proportion problem* is illustrated by (3.65): Most computer owning customers have contracts on all their computers, not just on most of them. But non-specific binding theories tend to predict the latter reading.

(3.65) Most customers who own a computer have a service contract for it.

Does *an advisor* have universal force in (3.66)? Perhaps each representative brings just one of his advisors?

(3.66) Every representative who had an advisor brought him to the meeting.

(3.67) Most representatives who attended a meeting claimed expenses.

3.4.6 Subsectional / Functional Anaphora (Discussion Only)

(3.68) Lots of shareholders were at the meeting. The small investors objected to the chairperson

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*. Functional anaphora involve sophisticated knowledge representation techniques which are beyond the scope of the theories involved in the project. Although they are probably very common.

3.4.7 Simple Reflexives

(3.69) The director awarded himself a pay rise.

3.5 Ellipsis

3.5.1 Basic Kinds of Ellipsis

A proper treatment of ellipsis can be obtained only by a division of labor between syntax and semantics, where the contributions of the respective levels of linguistic processing may be different for different kinds of ellipsis. It is unclear yet what the status of ellipsis phenomena with respect to the syntax-semantics distinction is. Therefore, some attention must be paid to syntactic properties of ellipsis constructions.

This property of ellipsis phenomena makes them a true testbed for theories of the semantics-syntax interface, and raises important theoretical questions with respect to the nature and power of intermediate representations and composition operators used in the computation of meanings.

3.5.1.1 Gapping

Gapping is a form of ellipsis involving co-ordination of antecedent and elliptic clause, two or more overt constituents ("remnants"), but no finite verb in the elliptic clause, as in (3.70)-(3.71).

(3.70) Smith went to Paris by car, and Jones by train.

(3.71) Smith went to Paris by car. Jones by train.

3.5.1.2 VP Ellipsis

This is the form of ellipsis in which the elliptic clause contains subject plus inflected auxiliary.

(3.72) ITEL sent CRC a report, and APCOM did, too.

(3.73) ITEL sent CRC a report. APCOM did, too.

3.5.1.3 One Anaphora

One Anaphora is the NP counterpart to VP ellipsis. Since deletion of common nouns also occur in other constructions, the term CN-ellipsis is also used.

(3.74) Smith owns a white BMW, and Jones owns a red one.

(3.75) Smith owns a white BMW. Jones owns a red one.

3.5.1.4 Sluicing

Sluicing is the form of ellipsis where almost all of an embedded wh-question is deleted.

(3.76) Somebody won the contract, but we don't know who.

(3.77) Somebody won the contract. We don't know who.

3.5.2 Syntactic Constraints on Ellipsis

Different kinds of ellipsis observe different syntactic constraints. There are configurational constraints, concerning the kind of syntactic construction which links elliptic and antecedent clause, constraints on the syntactic status of remnants/correlates and elided parts, and constraints concerning the structural similarity between elliptic clause and antecedent.

3.5.2.1 Configurational Constraints

All kinds of ellipsis may occur as intrasentential constructions as well as in different sentences of a text or dialogue. However, Gapping and *Stripping*[4] occur in *parallel* constructions only (in coordination structures as well as in sentence pairs), and in all cases of syntactic ellipsis (including comparative ellipsis) antecedent and elliptic clause must be *adjacent*.

[4]Stripping is a form of ellipsis that deletes everything in a clause under identity with a preceding clause, except for one constituent: an example if *Gwendolyn smokes marijuana, but seldom in her own apartment* [Sag and Hankamer, 1976].

(3.78) *Bill sent a letter to Mary, whereas John to Sue

(3.79) *John wrote a paper last week, and Bill says Peter, too

(3.80) *John wrote a better paper than I expected Bill

No such constraints hold for VP ellipsis and related phenomena:

(3.81) Bill sent a letter to Mary, before John did

(3.82) John wrote a paper last week, and Bill says Peter did, too

(3.83) John wrote a better paper than I expected he would

In this respect, they behave like anaphora, but they are yet more liberal, since also the antecedent clause may be embedded. (This property is shared by event-type anaphora.)

(3.84) If everybody else submits a paper, I will, too

3.5.2.2 Identity

The classical theory of ellipsis was based on the "deletion under identity" assumption: Elliptic clause and antecedent clause must have identical structure, the deleted/reconstructed part of the elliptic clause must be identical with its antecedent correlate. The identity assumption must be relativized in different respects, however. There are problems with the identity assumption on the syntactic as well as on the semantic level. Here, some of the syntactic problems are mentioned.

Subject-Verb Agreement

(3.85) I am / Bill is writing a paper, and the students, too.

Word Order

(3.86) Peter was here at 3 p.m., and one hour later Bill

There is much more word-order variation between elliptic and antecedent clause possible in languages like German.

NP type

In order to observe binding constraints, proper nouns, personal and reflexive pronouns can not be copied in certain cases, but must be replaced by a different NP type ("vehicle change"); since this phenomenon is also semantically relevant, examples will be given below.

Tense and Adjuncts

Comparative Ellipsis is more flexible than Gapping/Stripping in that it does not necessarily require copying of tense and adjuncts:

(3.87) Five years ago, Anna was taller than Sarah (was five years ago / is now)

The examples show that "syntactic ellipsis" cannot be located simply on the surface level.

On the other hand, the more anaphora-like case of VP ellipsis must observe some kind of syntactic identity condition, in contrast to pronominal event-type anaphora ("surface" vs. "deep" anaphora; [Sag and Hankamer, 1976]):

(3.88) *The children asked to be squirted with the hose, so we did

(3.89) The children asked to be squirted with the hose, so we did it

3.5.3 Interaction of Ellipsis and Quantification

For Gapping and VP Ellipsis, scope relations must be identical in antecedent and elliptic clause.

(3.90) Every accountant contributed to a report on a project, and every executive did, too.

(3.91) Every accountant contributed to a report on a project. Every executive did, too.

This indicates that ellipsis reconstruction is not a purely syntactic operation. The "Antecedent-Contained Deletion" (ACD) cases show that syntactic deletion/reconstruction under identity cannot be the solution for ellipsis problem, in principle:

(3.92) Smith consulted everyone that Jones did.

Comparative ellipsis can be taken to be a special case of ACD.

3.5.4 Interaction of Ellipsis and Anaphora

3.5.4.1 Strict and Sloppy Readings

If pronouns are copied, they can either retain their original reference ("strict reading"), or reference can be shifted to the remnant which is the counterpart of the original binder. The classical example is:

(3.93) Smith represents his company, and Jones does, too.

(3.94) Smith represents his company. Jones does, too.

Strict reading: Smith and Jones represent the same company, though it might not actually be the company that employs Jones. Sloppy reading: Smith and Jones each represent their own companies.

Constraints on combinations of strict and sloppy interpretations

Occurrences of several pronouns:

(3.95) Smith believed that he represented his company, and so did Jones.

Each pronoun can have a strict or a sloppy interpretation, but only 3 out of 4 combinations are possible: there is no reading where Jones believes that Smith represents Jones' company. A clearer example is perhaps *Smith claimed he had verified his proposal, and so did Jones*, where Jones can clearly be construed as having verified the same proposal as Smith, but Jones can't be claiming that Smith verified an alternative proposal of Jones'.

Cascaded ellipsis:

(3.96) John realizes that his company will not win the contract, but Fred doesn't, even though Mary does.

This example is similar to (3.95), but only 2 out of 4 readings are possible.

3.5.4.2 Ellipsis and Plural Anaphora

While ellipsis resolution typically requires information of a syntactic nature, it sometimes requires information of other kinds as well. An example of this is given in (3.97). The point of this example is as follows. We concentrate on sloppy interpretations of the "elided" pronoun *they* (which will be part of the second conjunct after "reconstruction"), ignoring the strict reading. Even when the strict reading is ignored the sentence is still multiply ambiguous. This is so because the overtly occurring *they* (that of the first conjunct) can be interpreted in a number of different ways: as referring to Bill and Frank's boss, as referring to Frank and Frank's boss, as referring to Bill and Frank and as referring to

all three of them. However, once an interpretation for the overt *they* has been chosen, there appears to be no further freedom concerning the interpretation of the "elided" pronoun: it must in each case be interpreted "parallel" with the interpretation assigned to the overt pronoun: if the overt pronoun is referring to Bill and Frank's boss, then the elided pronoun must be interpreted as referring to Carl and Alan's wife, when the overt pronoun is interpreted as referring to Bill and Frank then the elided pronoun must be interpreted as referring to Carl and Alan, etc.

The problem that this example presents for a treatment which assigns sentences like (3.97) just the sloppy readings they have is the following. The interpretation of plural pronouns as referring to sets of individuals mentioned separately (i.e. by separate NPs) in the sentence or text is unequivocally a principle of "discourse semantics", if only because it operates in general at the suprasentential level. But only when this principle has been used to interpret the overt pronoun (and to form, as a means to that end, the sum set that is to serve as the pronoun's referent), is it possible to assign the parallel interpretation to the elided pronoun. But to compute the parallel referent for the elided pronoun we need not only to know the referent of the overt pronoun, we must also know which elements are the parallel counterparts of the members of that set, and this last information appears to be configurational. If indeed this last information is essentially syntactic, then the computation of the possible readings for (3.97) requires a "data structure" in which syntactic and discourse-semantical information are simultaneously present and a certain interleaving of syntactic and discourse-semantic information would thus be indispensible.

(3.97) Bill suggested to Frank's boss that they should go to the meeting together, and Carl to Alan's wife.

3.6 Adjectives

Intersective adjectives (3.98) and measure phrases (3.99) are much easier to treat than scalar restrictive adjectives (3.100), because the latter are higher-order and intensional in their nature.

(3.98) ADCOM is bankrupt.

(3.99) The ITEL-XZ is 2 years old.

(3.100) The ITEL-XZ is fast.

But if scalar restrictive adjectives are used in the comparative form, the intensionality disappears, because a comparison standard is explicitly given:

(3.101) The ITEL-XZ is older than the PC-6082.

Note that intersective adjectives cannot really be put into comparative form:

(3.102) ?ADCOM is more bankrupt than ITEL.

3.7 Comparatives

3.7.1 Phrasal Comparatives (Comparative Ellipsis)

(3.103) The PC-6082 is faster than the ITEL-XZ.

(3.104) ITEL won more orders than APCOM.

(3.103) is an adjectival, (3.104) a nominal comparative. Both have an overt NP complement, and it is still debated whether the complement is "base generated" or the remnant of an elliptic construction, with "than the ITEL-XZ is d-fast" and "than APCOM won d-many orders" as respective underlying complement clauses. ACD cases of ellipsis demonstrate basically the same problems (see (3.92)).

3.7.2 Clausal Complement (Comparative Deletion)

(3.105) ITEL won more orders than APCOM lost.

The degree-containing phrase (d-many orders) is not realized ("deleted") in the complement clause, thus this is a case of CN Ellipsis, like One Anaphora (section 3.5.1.3).

3.7.3 Measure Phrase

(3.106) The PC-6082 is faster than 500 MIPS.

3.7.4 Zero Complement

(3.107) APCOM won several orders. ITEL won more.

3.7.5 Differential Comparatives

(3.108) ITEL sold 3000 more computers than APCOM.

Differential Comparatives specify the distance between two objects with respect to a given scale. They are of great theoretical importance, because they show that comparative constructions cannot be interpreted as comparing "degrees of truth" (since a scale and a distance is given):

3.7.6 Attributive Comparatives

(3.109) APCOM has a more important customer than ITEL.

Ambiguous between a wide reading (*a more important customer than ITEL has*), and a narrow reading (*a more important customer than ITEL is*).

3.8 Temporal Reference

The importance of temporal reference for natural language semantics needs little arguing. For the tenses of the verb are quite literally ubiquitous, as any well-formed sentence contains at least one tensed verb. Of course, this does not entail that every well-formed sentence involves temporal reference in a tangible sense, for even intuitively timeless propositions such as those of pure mathematics are expressed by means of finitely tensed sentences. (Indeed, philosophers such as Russell and Quine have gone so far as to express their irritation at this feature of natural languages in print.) Nevertheless, it will be no belittling the importance of pure science, to observe that the semantic vacuousness of tense, which one finds in sentences that are used to assert what is timelessly true, is an epiphenomenon; the central use of tense, and the one dominant in ordinary speech, is surely that which carries non-vacuous information about the time of the described states or events.

English differs from most other European languages in having a fairly restricted use of the simple present tense. Roughly speaking (and ignoring significant exceptions) the simple present tense is acceptable only with stative verb phrases, as in (3.113). With non-stative VPs the right form is the present progressive, as in (3.114); when the simple present is used nevertheless with this kind of VP, the only possible interpretation is usually an iterative or habitual one, as in

(3.110) Fred smokes.

or

(3.111) Bill visits his aunt on Sunday.

There is one notable exception to this principle, where the simple present can be used to refer to a future event. For instance, (3.115) 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".

This aspect of the use of the English present tense directly reveals something that is true much more generally, viz. the interaction between tense and aspect:

the interpretation of tense is in part dependent on the aspectual properties of the verb or verb phrase to which it attaches.

A second context in which this interaction becomes visible is that of the anaphoric dimension of tense. Sequences of past tense sentences are typically interpreted according to principles which relate the events or states described by the later sentences to those described by their predecessors. Thus there is a tendency for the next mentioned event to be understood as following the one preceding it (let us call this the "succession principle". Although this is anything but a firm rule, as the matter is intimately connected with the rhetorical connections that are understood to obtain between the describing sentences). Even as a default rule, however, the succession principle is only tenable as a rule concerning successively described events. When at least one of a pair of successive sentences describes not an event but a state, the relation between it and what is described by the other sentences is typically that of temporal overlap, not of succession. Insofar as the distinction between state-describing and event describing sentences is also a matter of aspect, we observe here another interaction between aspect and tense.

In the form just stated the succession principle only holds for sequences of sentences all of which are either in the simple past or the past progressive. When other tenses are involved, other interpretation principles come into play. An example is (3.130), where a sentence in the simple past is followed by three sentences in the past perfect. The events and states described in these past perfect sentences are understood as lying before the signing event described in the first sentence. When the discourse resumes in the simple past, the described events/states are interpreted as following or temporally overlapping the signing event.

Often the temporal location of the described state or event is given not (or not only) by the tense of the verb but by a temporal adverbial. One example of this is the phrase *at 9.30* in (3.115). While the interpretation of some temporal adverbs is unproblematic (examples would be *on the first of February,1946* or *during the Second World War*) more often than not such adverbials contain an indexical or context-dependent element. An illuminating example is the phrase *on Sunday* as we find it in (3.116) and (3.117). In general *on Sunday* refers to the nearest Sunday to some contextually salient day, with the day of the speech time playing the role of default time. In particular, we will, if not further context is available to us, be inclined to interpret (3.116) and (3.117) as referring to the last Sunday before and the first Sunday after the utterance times of these sentences.

Other examples of context sensitive adverbs are: *now, tomorrow, the next day, the morning after, the third, at 10 o'clock, three weeks later, in three week's time, ever since.* These adverbs are subject to varying contextual constraints.

For instance, *tomorrow* nearly always refers to the day following that of the utterance time, whereas *the next day* refers to the day following some contextually salient day, which is not interpreted as the day of the utterance time.

Often a temporally locating adverbial has the form of a subordinate clause, as in (3.118) - (3.122). Where this is so, we typically find a kind of "agreement" between the tense of the main and that of the subordinate clause, with the effect that the tense in subordinate clauses sometimes allows for interpretations that would not be available in main clauses. An example is the present tense in a when-clause such as that of the sentence:

(3.112) I will tell you when you come to see me.

A particularly irksome problem concerning the use of tense in English are the constraints on tense choice imposed by particular types of temporal adverbs such as for instance those beginning with the preposition *since*.

Referential locating adverbials, which refer to some particular point or interval of time, must be distinguished from quantifying adverbials such as *always, usually, often, never* , etc. Such adverbs - often referred to as "frequency adverbs" - stand to the referential temporal adverbials in a somewhat similar relation as the quantifying NPs, such as *at least one man* or *every dog*, stand to referential NPs, such as *Bill* or *the President*. But the parallel is only partial. The perhaps most important difference between the two types of quantifiers concerns the computation of the logical forms for sentences containing adverbial as opposed to nominal quantifiers. Whereas the restrictor of a nominal quantifier is always given by the content of the common noun phrase constituent of the quantifying NP, determination of the restrictor of an adverbial quantifier is a much less straightforward matter, many different aspects of the sentence and its context - word order, focus and presupposition among them - interact to yield the interpretations such sentences are perceived to have. Because of this a satisfactory theory of adverbial quantification is bound up with, among others, the theory of presupposition and the theory of focus and a satisfactory solution is premissed on success in these adjacent domains.

Both locating adverbs and frequency adverbs concern the position of the described events or states in time. They must be distinguished from two types of adverbials which serve to indicate the duration, or temporal extent, of the the described state or event: the "in-adverbials" and the "on-adverbials". The difference between them is a matter of aspect. In-adverbials like the PP *in a month* of (3.124) are used to assert of an event that is conceived as having a natural conclusion, and, thus, an intrinsically defined duration, that this duration is less than or equal to the amount of time denoted by the embedded NP *a month*. For-adverbials, such as *for a month* in (3.123), do not combine with clauses which describe events whose duration is determined independently,

but with those describing states or activities come to an end only because they are, at some non-intrinsically determined time, broken off or interrupted. Thus (3.123) says of the work which ITEL did last year, that it was stopped one month after it was begun. But for all the sentence says, the work need not have been finished by that time and could have been carried on for longer.

3.8.1 Standard Use of Tenses

(3.113) ITEL has a factory in Birmingham.

(3.114) Smith is writing the report.

(3.115) The meeting starts at 9:30.

Our list of examples 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. We will not cover generic uses of the tenses, but will cover uses of the present tense to refer to a planned or predetermined future, as in (3.115), as well as reference to the present (3.113)–(3.114).

3.8.2 Temporal Adverbials

3.8.2.1 Indexicals

(3.116) The conference started on Sunday.

(3.117) The conference will start on Sunday.

Without additional context, the tense determines whether *Sunday* is understood as last Sunday or next Sunday. Indexicals include adverbials like *today*, *yesterday* etc.

3.8.2.2 'Before', 'After' (Temporal Subordinate Clauses)

(3.118) Smith was present after Jones left the meeting.

(3.119) Jones left the meeting before Smith was present.

(3.120) Smith left when Jones arrived.

(3.121) Jones has been here since Smith left.

(3.122) Smith will be here until Jones arrives.

The connectives turn out to have fairly complex semantic properties; this is especially the case with *when*. For example, (3.118) and (3.119) are not synonymous. In general the eventuality described in the temporal subordinate clause is used to locate the eventuality of the main clause.

3.8.2.3 'In', 'For' and 'On' Temporal Adverbials

(3.123) Last year ITEL worked on the project for a month.

'For' adverbials are durative / measure adverbials, and can modify only states of activities (see Section 3.9.1 for an explanation of the terminology 'activity', 'accomplishment', 'achievement' and 'state').

(3.124) ITEL will write the report in a month.

Either ITEL will take a month to write the report, or will start / finish writing the report in a month's time. The first (durative) reading is only possible with accomplishments.

(3.125) Smith drew up the contract on Sunday.

(3.126) Smith was in Paris on Sunday.

Inclusion of the writing event in the time period 'Sunday' in (3.125). Overlap of the state with the time period 'Sunday' in (3.126).

3.8.2.4 Quantificational Adverbials

(3.127) ITEL sent a progress report every month.

More than one sending event, and probably more than one report.

3.8.3 Anaphoric Dimension

An example of sentence anchored to some contextually salient reference time is provided by (3.128).

(3.128) Smith did not travel by air.

The next example illustrates that the contextually salient reference time can be provided by a previous sentence in the same text. A narrative progression describes a succession of events each of which typically follows the previous one in the narrative:

(3.129) Smith left the house at a quarter past five. She took a taxi to the station and caught the first train to Luxembourg.

A more complex example of narrative progression is in (3.130). Sentences 2 and 3 introduce an embedded perfect narrative; the stative in sentence 4 does not advance narrative. It's not clear whether state in sentence 6 advances narrative or not. 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).

(3.130) 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 adminstrator was incompetent. But ITEL finished the project on time and under budget. They fired the financial administrator.

3.8.4 Adverbs of Quantification

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. (3.131) doesn't mean that at any time in 1990 ITEL was late with its reports. Separation problem. (3.132) requires unselective binding reading while (3.133) requires selective reading.

(3.131) In 1990 ITEL always delivered reports late.

(3.132) Mostly a customer who owns a computer has a service contract for it.

(3.133) Most customers who own a computer have a service contract for it.

3.8.5 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 (3.136) 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. (3.134) and (3.135) are slightly more complicated illustrations of the same phenomenon: in (3.134) the time of evaluation of *executive* and that of *student at the Harward 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.

(3.134) Every ITEL president has been a student at the Harvard Business School.

This sentence admits both a reading according to which all current and past presidents had previously been students, and a contextually absurd reading where the ITEL president is always a student.

(3.135) Every executive was a student at the Harvard Business School.

This sentence instead only has the reading according to which all present executives were students.

(3.136) The wife of the president worked for APCOM in 1975.

This sentence doesn't have a reading according to which *the wife of the president* refers to the current wife of the 1975 president.

3.9 Verbs

3.9.1 Aspectual Classes of Verbs

Vendler [1967] classified verbs according to their aspectual class into statives, activities, accomplishments and achievements. Moens [1987] and Moens and Steedman [1988] analyzed these classes in terms of a structured view of events. Recognizing the different classes is important because they correspond to different inference patterns and various patterns of acceptability, for example, with different tense forms and adverbs. (For a classical account of this see Dowty, [1979].)

(3.137) ITEL wrote the report.

The verb phrase *wrote the report* in (3.137) is an accomplishment. According to Moens and Steedman's analysis an accomplishment consists of a preparatory phase followed by a culmination. If ITEL wrote the report over a time interval t there cannot be any smaller interval over which it is true that they wrote that report. There is a preparatory process, the activity of writing the report and there is a definite endpoint, the culmination, where the report is finished. Sentences representing accomplishments can be easily put into the progressive tense and combined with adverbs such as *in three days*. In this case the adverb would allow us to conclude that the duration of the writing event was three days.

(3.138) Smith noticed a loophole in the contract with ITEL.

The verb phrase in this example is an achievement. According to Moens and Steedman's analysis an achievement differs from an accomplishment in that it has no preparatory phase, only a culmination. Natural language appears to behave as if achievements occur in an instant. Thus if this achievement sentence is combined with an adverb like *in three minutes* it does not mean that the event of noticing took three minutes but rather that three minutes elapsed before the noticing event took place. Achievements do not naturally occur in the progressive.

(3.139) ITEL employed Smith.

This is an example of a stative. Stative sentences describe states. If a stative sentence holds over a time period t it also normally holds for each subinterval of t. This is known as the subinterval property. Stative sentences do not naturally go into the progressive, or mean something non-stative if they do. They do not naturally occur with adverbs like *in three days* but rather adverbs like *for three days*.

(3.140) Smith talked to Jones.

This is an activity. Activities consist of just a preparatory process according to Moens and Steedman. Activities also have a version of the subinterval property. If Smith talked to Jones during time period t, then for every subinterval of t it is true that Smith talked to Jones. Some people prefer a weaker version of the subinterval property for activities: if Smith talked to Jones during time period t, then there is some period within t during which Smith talked to Jones. Activity sentences do not naturally occur with adverbs like *in thirty minutes* but rather *for thirty minutes*.

3.9.2 De Re–De Dicto

(3.141) Smith believes a competitor will win the contract.

There are usually considered to be two readings for this sentence which in Montague's semantics are treated as a scope ambiguity. The *de re* reading: there is a particular competitor (ITEL perhaps) of whom Smith believes that it will win the contract. The *de dicto* reading: Smith believes the proposition that some competitor will win without having the belief about any particular competitor.

3.9.3 Copula and Light Verbs

(3.142) ITEL has a new computer.

(3.143) Smith has a new computer.

Light verbs are verbs which do not have much meaning in themselves but rely on context for their content. Thus *has* in these examples may mean "just bought", "sells", etc.

(3.144) Smith is the managing director.

(3.145) Smith is a bankrupt.

(3.146) Smith is bankrupt.

A copula can take nominals for identity statements (3.144), predicate nominals (3.145) or predicates (3.146). Copulas do not convey much meaning in themselves but act as "syntactic glue" to enable predication.

3.9.4 Modals

(3.147) Any software that is used on the project will be given to CRC after the project finishes.

(3.148) CRC may also request any software that was not used.

(3.149) Software licences must be bought for CRC by ITEL.

Modals can be either epistemic or deontic. For example, in (3.148) *may* can be either epistemic (there is a possibility that) or deontic (are permitted to). Modals are also dependent on context for a "modal base" [Kratzer, 1977]. For example, (3.149) does not mean that in any logical possible world software licences are bought for CRC by ITEL but rather, perhaps, in any situation which is consistent with CRC's contract.

3.10 Attitudes

The semantic representation of 'attitudes' is a distinct and important issue in formal semantics and philosophy of natural language. Attitudes express a relation of 'being attuned' between an agent and a certain type of semantical object. Most research in this field has been devoted to the class of *propositional attitudes*, which express a 'mental' relation between an agent and a proposition (S). In this class, we find *epistemic* attitudes, like those expressed by the verbs *know* and *believe*, *perceptive* attitudes, like those expressed by *see* and *hear*, and *reportive* attitudes, like those expressed by *say* and *announce*.

Another important class is formed by attitudes which express a mental relation between agents and actions expressed by VP-complements. Many attitude verbs that take propositional complements can else take 'to VP'-complements. Compare sentences of the form "a is believed / said to VP". Another category which appears most often with a VP argument are *intentional* attitudes, like *intend*, *hope* and *want*.

Generally speaking, the semantic study of attitudes focuses on the transparency / opacity distinction of the arguments. The problem of semantic representation of attitudes comes with the philosophical differentiation of *ontological* and *epistemological* objects. The representation of the attitude complements somehow expresses a relation to the real world (i.e., it has an ontological component), but it also depends on the internal subjective representation of the complement for the agent whose attitude is described (i.e., it has an epistemological component). Reformulating this in a compositional setting; if A is an attitude which takes an agent a and an argument ϕ to make a sentence, then the meaning of this sentence $A(a, \phi)$ is a function of the ontological meaning of A and the meaning of ϕ *for* a.

It seems fair to say that the semantic analysis of the attitudes has been a matter of controversy ever since the days of Frege. There exists an extensive literature of proposals for solving the philosophical problems that this involves. The most 'fine-grained' approaches are the so-called *representational* theories. They treat the arguments of attitudes as primitive semantic objects, and additional transparency can be supplied by means of extra axioms or postulates about these subjective objects. In this way, assigning deductive capacity to individual agents is then left to the user of such theories.

The most 'coarse-grained' theories appear in epistemic logics, where standard modal logics are used for reasoning about different epistemic attitudes. Many non-standard variations of modal logic have been proposed in this field as alternatives in order to avoid complete logical idealization of agents.

'Medium-grained' theories try to account for differentiation of referential transparency. The need for shifting the transparency becomes most clear from the analysis of perceptive and reportive attitudes. The distinction of two sentences like (3.153) and (3.154) resides in the greater opacity of the former. In many theories of perceptive attitudes, one takes the former to express a relation of the agent to a situation, while the latter expresses a relation of the agent to a proposition.

(3.150) Smith { believed/knew / said/denied / feared/hoped } that ITEL had won a/the contract.

(3.151) ITEL { managed / tried / wanted } to win a/the contract.

(3.152) It is true/false that ITEL won a contract.

(3.153) Smith saw Jones sign the contract.

(3.154) Smith saw that Jones had signed the contract.

Our fragment includes attitude verbs taking sentential complements, control verbs and perception verbs with naked infinitive and sentential complements.

3.11 Questions

Providing a treatment of non-assertional sentences, such as interrogatives, is becoming more and more of a fundamental requirement for a semantic theory, especially at the light of the increased emphasis on the 'dynamics' of discourse and the context-change potential of sentences, in addition to (or instead of) their 'static' truth conditions.

In fact, a characterization of at least the meaning of embedded questions is necessary even when only declarative sentences are considered:

(3.155) Smith knows whether ITEL won the contract.

(3.156) Smith knows who won the contract.

Accomodating questions within a truth-conditional framework is a non-trivial task, although by now a large literature exists [Karttunen, 1977; Belnap, 1982; Groenendijk and Stokhof, 1984; Engdahl, 1986; Groenendijk and Stokhof, 1989; Berman, 1991; Lahiri, 1991; Ginzburg, 1992]. Among the many issues to be addressed, two seem especially important. The first question is whether embedded questions and interrogative sentences ought to have the same denotation (which would of course make for a simpler theory) or different denotations. The second key issue in providing clues for a treatment of interrogative sentences is that not all answers to a question are equally felicitous; questions appear to impose constraints (*answerhood conditions*) on the context.

(3.157) A: Who attended the meeting yesterday?
B: Smith and Jones./ Several representatives from CRC./ Nobody / # Jones is an ITEL representative.

(3.158) A: Did Jones attend the meeting yesterday?
B: Yes/ No/ Probably./ ?Jones is an ITEL representative.

The theories of questions based on the idea the the meaning of an interrogative sentence can be reduced to its answerhood conditions can be further divided in two classes: theories that take *short answers* such as *John* in (3.159) or *At 5pm* in (3.160) to be the basic form of answer, and theories that take them to be elliptical for complete answers (such as *John left the meeting*, hence define the answerhood conditions in terms of the (propositional) denotation of the longer answers.

(3.159) Who left the meeting? Jones.

(3.160) When did he leave? At 5 pm.

3.12 Events and Event Type Anaphora

It is a widely accepted thesis of current natural language semantics that verbs (or at any rate the vast majority of them) act as descriptions of states or events - of "eventualities", to use Bach's familiar term to cover them both. This means that eventualities are part and parcel of semantic representation; they will turn up in the representation of every or almost every complete sentence.

The thesis is well-entrenched and, in view of the many linguistic considerations and observations which support it, well-neigh inescapable. But it is not clear that it is one with which we should feel particularly happy. For events and states are among the most problematic ontological categories, the identity criteria of which are difficult to apply not just in a few marginal cases, thought up by ill-meaning philosophers bent upon showing their ultimate fragility, but in perfectly ordinary, run-of-the-mill cases as well. And it is not just identity between events or states that is metaphysically problematic; the same is true of the relation of part-and-whole: when is one event to be considered a part of some other event? In some cases we have strong intuitions: the event of rinsing the laundry is a part of the event of doing the laundry; the event of making the dough part of that of baking the cake etc. But here too we soon find cases where our intuitions no longer seem at all reliable. a similar uncertainty exists with respect to the question when there exists, for a given collection of events, a single event which contains them all as part events or even a "sum event", which contains just these part events and no others.

Because of these uncertainties - which, for all we now know, can only be resolved by some measure of stipulation - the semantics of representations containing explicit references to eventualities is fraught with an element of vagueness and indeterminateness far greater than is the case for representations in which such references do not occur. But the problem is not only that the model theory and therefore the logic of such representation languages is not as firmly rooted as we might wish. There are also problems at the level of representation construction. Consider for instance (3.11). How does the referent of the NP *the collaboration* occurring in the last sentence relate to the eventualities mentioned in the preceding sentences? Are those eventualities to be considered as part events of this referent? Is the referent the sum of those eventualities? These are questions which are still unresolved and which need resolving urgently.

A similar problem arises in connection with a sentence like (3.164). Clearly (3.164) has a reading according to which each of the reports was written quickly, i.e. for each report the event of writing it qualifies as a quick writing. This reading is uproblematic, but there appears to be also another reading according

to which it is the writing of all the reports together that is described as quick. But what is it that is quick in this case? Arguably the sum event of all the individual report writings. But then, can we be sure that such a sum event exists? Which general principle guarantees that it does, and how general is this principle?

Another problem is the difference between events and states. Which eventualities are events and which are states? It isn't even clear that this is a coherent question. Perhaps this is a difference that often exists only in the mouth of the describer - perhaps we often just present the eventualities we speak of as event- or state- like through the way we look at them and the words we use, without there being any real properties inherent in the eventuality that make it one thing rather than another. This is a problem that touches directly on that of aspect touched upon in 3.8. There we spoke of aspectual properties as properties of verbs, VPs and full clauses, without addressing the question whether aspectual properties are properties of the eventualities described by those expressions or properties of something else. It would be nice if we could avoid addressing this matter, but it is clear that eventually we cannot.

If we assume that differences in aspect are differences in the kind of entity described, then many of the traditional problems about aspect are relevant to the present section no less than to the discussion of 3.8. In fact one such question is touched upon here. This is the question what sorts of eventualities are described by negated event descriptions. The probably most widely held view of this matter is that negated eventuality descriptions are descriptions of states irrespective of whether the the nonnegated description is a state- or an event description. This assumption explains the contrast between (3.165) and (3.166).

Another notorious complex of difficult and insufficiently understood questions concerns pronominal anaphora (by means of the pronoun *it*) to such entities as events, states, facts, propositions, properties of events, etc. (3.168) and (3.169) are indicative of the problems that a systematic theory of such kinds of anaphora will have to cope with. (A substantial number of problems in this domain are discussed in the work of Asher; see in particular [Asher, 1993].)

3.12.1 Lexical Nominalisations

(3.161) Hard work is hard work.

(3.162) Fun is fun.

Nominalisation of properties.

3.12.2 Summation

(3.163) ADCOM and ITEL signed the agreement in 1989. ADCOM did not deliver the software they had promised. ITEL did not have sufficient manpower for the project. Then ADCOM withdrew from the project. The collaboration was a disaster.

Summation over different types of eventualities (states, events) to construct a referent for the definite NP in the discourse final sentence.

(3.164) Jones wrote the reports quickly.

This sentence has a reading where *quickly* distributes over each individual writing event or simply applies to the sum of all such events.

3.12.3 Closure Properties: Negation

(3.165) The meeting did not start for two hours.

(3.166) (?)The meeting started for two hours.

Negation of an event sentence (3.165) permits a durative 'for' adverbial. But it is less acceptable without the negation (though (3.166) has a reading where the meeting started and then continued for two hours).

(3.167) Smith didn't sign the contract. I saw it with my own eyes.

It is sometimes argued that negation applies to facts and not events. But if one sees events and not facts, then (3.167) poses problems for this argument.

3.12.4 Pronominal Reference

(3.168) The meeting took several hours. Jones didn't believe it.

(3.169) The presentation took several hours. Jones didn't believe it.

In the first discourse the referent for the pronoun in the second sentence is the proposition expressed by the first sentence. The second discourse is ambiguous between a reading where the pronoun refers to the presentation event and where it refers to the contents of the meeting.

Chapter 4

Rooting the FRACAS Fragment in Real Data

4.1 Formal Semantics and Real Applications

The issues in semantic interpretation illustrated by the suite of examples presented in the previous Chapter were chosen not only because historically they motivated much work in formal semantics, but also because they illustrate very fundamental facts about the semantics of natural language. These facts about natural language are going to affect all sorts of large-scale natural language processing systems, and therefore are best addressed in a formal way.

In order to substantiate this claim, we searched for occurrences of these phenomena in the kind of text we expect an NLP application may have to deal with in the next 5 to 10 years. We present in this chapter the results of this search, together with an indication of the frequency with which these data occur in typical texts. We also briefly motivate our choice of the texts to search.

We would like to stress that this work is only a first step. In order to verify the usefulness of formal semantics for NLP applications (or lack thereof), one cannot simply check whether formal semantics focuses on data that may be encountered in the forms of natural language use that NLP applications have to deal with; one also has to make sure that the problems of semantic interpretation discussed in formal semantics have to be addressed by the developers of NLP systems, and therefore techniques of the sort developed by formal semanticists can make a contribution towards the development of real applications. In this chapter we discuss in general terms why an NLP system may need to include a formal treatment of these phenomena; the question of how important it is for an application to borrow the techniques developed in formal semantics in order to deal with a particular phenomenon will be addressed more extensively in later deliverables.

4.1.1 Methods

Finding a way to focus our search was necessary both because of the growing amount of natural language data available on line and their great variety (testified even by an evaluation as limited in scope as Deliverable D3), and because of the limited availability of some of the existing corpora. Given the goals of FRACAS, it seemed reasonable to assume that a form of natural language use is relevant for our purposes if it is *technologically interesting*, that is, if there is a need for applications processing that form of natural language now, or in the next few years. Some applications that are using NLP technology now, or are likely to use in in the near future, are:

- Text generation systems. Existing applications for such systems include systems that generate weather forecasts and instruction generators, e.g., system that may assist the users of tools or software.

- Translation systems. Technological manuals and trade regulations are an example of text that calls for automatic, or semi-automatic, translation because of the large volume of text and the short time available for translating it. An application of translation technology that is also the focus of much interest is the development of multi-lingual scheduling assistants. Prototypes of this kind of systems have been developed by a consortium between ATR in Japan, Carnegie-Mellon University in the USA, and Siemens and the University of Kaiserslautern in Germany. The VERBMOBIL project in Germany is also concerned with the development of such a prototype.

- Spoken-language interfaces to services such as airline reservation or telephone operators. ARPA's spoken language initiative is concerned with the development of systems of this kind. The data that are relevant for this kind of applications are task-oriented conversations in spoken language. Spoken language is also of interest because it is a fundamental mode of natural language interaction, and therefore the results deriving from this study are likely to be useful in different kinds of applications.

- Systems that store and retrieve information. The kinds of texts that are typically stored and retrieved include scientific articles, financial information, technical manuals (e.g., online information), trade regulations and other legislative material. Information retrieval systems incorporating NLP technology are currently under development. The Message Understanding Initiative in the US is concerned with the development of systems able to extract certain kinds of information from text.

Unfortunately, the corpora illustrating some kinds of text we would like to study are not easily accessible;[1] we adopted therefore in this study a variety of strategies besides extensive searches by automatic means. (And anyway, our search could only be made partially automatic, since what we were looking for weren't just illustrations of particular syntactic constructions, but cases of syntactic constructions to be interpreted in a certain way.)

We did extensive searches by means of automatic tools whenever we had the opportunity to do so, i.e. whenever an online corpus of relevant natural language data was available. In particular, because all sites had access to at least part of the Wall Stree Journal corpus, and usually to collections of other newspaper articles as well, we were able to do a relatively extensive search of newspaper and magazine articles. This is the kind of text to be processed by information extraction applications such as those developed in the MUC project; certain kinds of articles are also relevant for information retrieval applications, and other articles (e.g., scientific articles) are examples of texts that may be useful to translate.

Some of the corpora that we do have access are also worth searching in that they illustrate forms of natural language use that are very close to those processes by real applications, therefore we can assume that a large number of phenomena occurring in the 'interesting' form of data appear in the kind of data we have available. For example, the TRAINS corpus—a collection of transcripts of conversations between a 'user' that has to develop a transportation plan and a 'system' that helps in developing the plan, that is freely available—illustrates a form of natural language use that is fairly close to scheduling conversations such as those of the ATIS corpus or the VERBMOBIL corpus. To make another example, the large amount of data about recipes that are available on-line at various sites have been used to study instruction-giving text.

Finally, we searched the library and/or texts available via the World Wide Web for texts not illustrated in the corpora we have available, such as scientific articles, or trade regulations.

The searching tools we have used include, in addition to the usual UNIX search facilities (especially `grep` and `perl`) the HUM suite of text-searching programs developed at the University of California, Berkeley, and the IMS corpus workbench.[2]

[1] The corpora accessible to the participants in FRACAS are documented in Deliverable D3.

[2] The IMS corpus workbench is a system designed to administer text corpora and to retrieve information from such corpora. It consists of two major parts: the query processor CQP (Corpus Query Processor) [Schulze and Christ, 1994] and the front-end graphical user interface XKWIC (X11 Key Word in Context) [Christ, 1993].

The corpus workbench provides tools to preprocess and index corpora. In the case of the UP corpus sentence boundaries and lemma information were added to the UP part of speech tags while syntactic structure information was removed. The query processor CQP

We supplemented the information about the frequency of particular classes of contructions that we could get from our corpora with information about the relative frequency of word items in the Brown Corpus collected by Francis and Kucera in [Francis and Kucera, 1982]. The Brown Corpus is a relatively small (1,014,000 words) tagged corpus collected around 1962, that includes 500 examples of text from 15 different genres, including reportage, scientific articles, general fiction, and so forth. Francis and Kucera collected various statistics about this corpus; we will be mostly interested here with word counts and the number of genres in which a particular word occurs.

4.2 Generalized Quantifiers and Scope

Of the expressions sometimes classified as quantifiers, indefinite NPs such as *a shallow pan* or *managers* (as in *managers must take risks*) and definite NPs such as *the average VISA card* are encountered in all forms of natural language use, and generally are among the most common expressions in any corpus.[3] Examples of both definites and indefinites can be found in most of the examples reported in this deliverable.

Quantifiers such as *every first grader* or *most kindergartners* are less frequent than indefinites or definite NPs, but can still be found relatively easily. We can get a rough idea of their frequency from Francis and Kucera's study: they found a total of 20853 instances of quantifiers or cardinal determiners in the Brown corpus, among which: 2758 examples of NPs with *all*, in all genres and all both 2 samples; 1821 examples of *no*-NPs; 1335 examples of *any*; 997 instances of *many*; 878 examples of *each*-NPs; 601 examples of NPs with determiner *several*; 492 examples of *every*-NPs, in all 15 genres; 478 examples with *most*; and 378 of *several*. Quantified NPs are relatively infrequent in spoken conversations[4], but

works on preprocessed corpora. Its query language consists of regular expressions over strings and non-recursive attribute-value structure expressions over the available tags. (Currently, depending on the corpus, this includes part of speech, lemma, morpho-syntactic, sentence boundary, bigram, trigram etc. information.) The graphical user interface XKWIC is based on OSF/Motif and provides a front end to CQP.

[3] Francis and Kucera count a total of 26802 instances of indefinite NPs of the form *a/an P* in the Brown corpus; such indefinites can be found in all genres. They count 69975 instances of definite NPs, and indeed the word *the* is by far the most common word in the corpus. All together, they count 123321 instances of articles and determiners—about 12% of the total number of word tokens in the corpus. Articles and determiners can be found approximately with the same frequency in the 'informative' and the 'imaginative' parts of the Brown corpus. We counted the number of occurrences in the corpora we searched of plural definite and indefinites, and singular definites. These counts are reported in the section on plurals and in the section on anaphora.

[4] A quick search through the 91 TRAINS conversations resulted in four instances of *every*, always used in *everything*; two instances of *each*, always used as part of the reciprocal *each*

are fairly common in scientific prose. The following example (from a randomly chosen experimental psychology article in *Cognitive Science*[5]) illustrates on use at which various kinds of quantified NPs (including some that are not first order) are put in such kind of text:

(4.1) Table 2 indicates the percentage of subjects of each age who used each rule at least once. As shown, most kindergartners knew how to win, and almost half could block. Every first grader could win, almost all could block, and a few could set up forks. All third graders could win and block, and most could set up forks. Undergraduates were the best tic-tac-toe players, but they were not perfect. Almost 20% showed no evidence of being able to set up forks, and 35% showed no evidence of knowing how to block potential forks.

The paragraph in (4.1) is used by the writers of the paper to summarize the results of their experiment. These results are also presented in a table, but the table only provides the raw data, not the scientists' interpretation of them. This use of quantified NPs as a way of summarizing the results of a scientific article can be found in fields other than psychology. The following excerpt is from a biology article: [6]

(4.2) In the α-neurexins, the repeats coincide with the left and right arms of the three larger repeats and form two subclasses, depending on whether they are from the left or right arms of the three larger repeats. Each of the right arm repeats but none of the left arm repeats contains an alternative splice site. Together, the repeats account for more than half of the neurexin Iα and IIα proteins.

Quantified NPs, including vague quantifiers such as *many*, are also encountered in financial texts, as shown by the following extract from the *Wall Street Journal* corpus:[7]

(4.3) Many investment bankers and major institutional investors say the current crunch in the junk market will have long-lasting effects on the volume and pace of corporate mergers and buy-outs, which so dramatically reshaped the face of corporate America in the 1980s and which were often fueled by junk bonds.

Further examples of plural quantified NPs are reported in Section 4.3.

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other; and 15 instances of *no*.

[5] The example reported is at p. 538 of K. Crowley and R. S. Siegler, "Flexible Strategy Use in Young Children's Tic-Tac-Toe," *Cognitive Science* v.17, n.4, October-December 1993, 531–563.

[6] From *Science*, v.257, 3 July 1992, p.54.

[7] This example is from the ACL/DCI CD-ROM.

One example of NLP application that needs to process texts such as those in (4.1), (4.2), or (4.3), and therefore need to have a treatment of quantifiers, are translation systems. Another example are applications that provide a natural language summary of the results of a table, such as report generation systems that produce descriptions out of databases. Quantified statements provide a succinct way to encode information that could otherwise be expressed only in a very cumbersome way. A text-generation system that can't make use of quantification could only generate statements of the form *We are open on Monday, Tuesday, Wednesday, Thursday, Friday and Saturday* instead of the more effective *We are open every day except Sunday.*

(4.1) also indicates that the information provided by a scientific article is not all contained in the tables; future information storage systems able to extract information from articles therefore need to be concerned about the text as well.[8]

4.2.1 Scopal Ambiguity

The sentence *Each of the right arm repeats but none of the left arm repeats contains an alternative splice site* in (4.2) includes an example of the phenomenon of scopal ambiguity discussed in the previous two chapters (examples illustrating this problem are discussed in section 3.2.3). The NP *an alternative splice site* is 'in the scope' of the NP *Each of the right arm repeats*: there is one distinct alternative splice site for each right arm repeat.[9]

[8]More advanced information retrieval systems in the not-so-near future may also have to answer questions that require inferring information that is only implicitly contained in a database. The kind of questions one may ask of a data base containing this information in (4.1) include:

1. Is it the case that all subjects knew how to win?
2. Is it the case that all third graders could win?

Answering these questions will require knowledge about monotonicity inferences of the sort that is discussed in formal semantics (compare example (2) in section 2.2 of the previous chapter):

1. The answer is no, because even though it is the case that *Every first grader could win* and that *Every first grader is a subject, every* is downward monotone in its first argument, that is, *every P is a Q* and *every P is a R* does not entail *every R is a Q.*
2. The answer is yes; in order to answer question 1, a system needs to know that *all* is upward monotone in its second argument, that is, from *all Ps are Qs and Rs* one can infer that *all Ps are Qs*; the answer to the question can then be obtained from the statement *All third graders could win and block.*

[9]That simple techniques such as assigning wide scope to the leftmost operator do not always work is illustrated by sentences such as *A conserved 30-amino acid sequence in the right arm of the C repeat is differentially spliced in all neurexins* from the same article, that admits of both readings although the reading in which *A conserved 30-amino acid sequence*

4.2.2 Quantification and Coordination

Finally, the text in (4.3) illustrates several ways in which non-sentential constituents can be coordinated (compare section 3.2.4 in the previous Chapter); in particular, it includes cases of coordination among different constituents of NPs. Thus, the NP *Many investment bankers and major institutional investors* has two readings, depending on whether we take it to be composed by two quantified NPs (*many investment bankers* and *major institutional investors*) coordinated to result in a new quantified NP, or by two head nouns (*investment bankers* and *major institutional investors*) coordinated to get a single predicate quantified by *many*. The NP *the volume and pace of corporate mergers and buy-outs* is another example of head noun coordination; the sentence constituent *which so dramatically reshaped the face of corporate America in the 1980s and which were often fueled by junk bonds* is an example of relative clause coordination. The frequency of these examples ilustrates the need for non ad-hoc techniques of meaning composition, allowing for *generalized conjunction*, i.e. coordination of arbitrary sentence constituents [Partee and Rooth, 1983; Hendriks, 1993].

4.2.3 Possessives

Examples of possessive descriptions such as the following are easy to find:

(4.4) Independence Party (280,000 members) and *Mr. Harry Nkumbula's African National Congress* (400,000) will meet in London today to discuss a common course of action.

(4.5) As Reagan policy has collapsed in its final years, however, so has *America's ability to promote democracy even in our own hemisphere.*

(4.6) ... the drivers pointed out they still had space on their machines for *another sponsor's name or two.*

The variety of relations that can hold between possessor and possessee is illustrated by the following examples:

(4.7) the latest results appear in *today 's New England Journal of Medicine*

(4.8) *the nation 's manufacturing titans* typically jet off to the sunny confines of resort towns like Boca Raton and Hot Springs

in the right arm of the C repeat takes narrow scope is preferred.

4.3 Plurals

The examples in this section were found by searching the Penn Treebank corpus, a corpus of newspaper articles tagged with their syntactic structure.

4.3.1 Indefinite, Definite and Quantified Plurals

Definite plural NPs are very common in the Penn Treebank. A search of the corpus using the regular expression

```
("The"|"the") [pos != "N.*"]* [pos = "NNS"]
```

that matches plural NPs whose pre-modifiers are not allowed to contain an occurrence of a nominal part of speech[10] results in more than 15500 matches.

Usually, definite plurals are associated with (context dependent) universal force; this universal force is sometimes explicitly indicated, as in (4.10).

(4.6) ...*the drivers* pointed out they still had space on their machines for another sponsor's name or two.

(4.9) Unless *the questions* are answered, I will keep on going.

(4.10) *All the senators* say they merely were trying to ensure fairness for a constituent.

Definite plurals with generic meaning (*the girls, a lot of the the guys, the Germans, the Japanese*) can also be found in the corpus.

(4.11) The Germans were astounded .

Definite plural constructions are often part of complex quantifying expressions, as in (4.10) and in the following examples:

(4.12) *The two developments* leave the airline with several problems, ...

(4.13) If *one or more of the semi-finalists' plans* looks especially promising, ...

(4.14) In recent weeks, world attention has focused on *the tens of thousands of disgruntled East Germans* ...

Indefinite plural NPs seem to be less common that definite plural NPs, by a factor of roughly 1 to 7. Generally they are associated with existential force.

[10] This query misses definite plural NPs like *the top money funds* etc. that do occur in the corpus. The query could be changed into `("The"|"the") [pos != "NNS"]* [pos = "NNS"]`, i.e. definite plural NPs whose pre-modifiers are not allowed to contain an occurrence of a plural nominal part of speech. Such a query, however, would match the string *the asbestos fiber, crocidolite, is usually resilient once it enters the lungs.*

(4.15) Some estimates have gone as high as 80.000 members.

A significant number of indefinite plural NPs (roughly 10 percent) are partitive constructions of the form *some of* + definite plural NP.

(4.16) some of the managers, some of those workers, some of their projects

The Penn Treebank corpus has roughly 2500 occurrences of plural NPs involving vague (*a few*) or context dependent (*few*, *many*) determiners and second order (*most*) determiners both in simple and partitive constructions.

(4.17) many bad movies, most political campains, few contests, many of the risks, most of the cases, few of the yuppies

Partitive constructions involving *most* or *many* have roughly 150 occurrences each. By contrast, partitive constructions involving *few* are few and far between: they are attested about 10 times.

Universally (*all*) quantified plural NPs are attested roughly 1000 times. These NPs fall into two major groups: simple universally quantified constructions

(4.18) all remaining uses, all restrictions

and partitive constructions of the form *all* + definite plural NP and *all of* + definite plural NP

(4.19) all the contracts, all of the changes

Constructions of the form *all* + definite plural NP show up roughly 300 times, constructions of the form *all of* + definite plural NP about 100 times.

The Penn Treebank corpus has a high frequency (more than 20 thousand occurrences) of plural noun phrases involving cardinal number determiners both in simple and in partitive constructions:[11]

(4.20) 55 years, 400 taxable funds, 16.7 million shares, 20 consecutive winning seasons, four of the five surviving workers, one of the few industrialized nations

4.3.2 Existential Bare Plurals

Strings representing bare plurals are difficult to specify exhaustively in the regular language of the query tool,[12] hence no precise quantification of the

[11] This large number of occurrences of plural noun phrases involving cardinal number determiners might be to some extent genre specific.

[12] The problem is posed by the need for a negative specification in the query.

frequency of the phenomenon has been attempted. However, they seem to be very common.[13] Here are some illustrative examples from the corpus.

(4.21) The asbestos fiber , crocidolite , is unusually resilient once it enters the lungs , with even brief exposures to it causing symptoms that show up decades later , *researchers* said .

(4.22) Although *preliminary findings* were reported more than a year ago , the latest results appear in today 's New England Journal of Medicine , a forum likely to bring new attention to the problem.

(4.23) We 're talking about *years* ago before anyone heard of asbestos having any questionable properties.

(4.24) Boeing Co. said it is discussing *plans* with three of its regular Japanese suppliers to possibly help build a larger version of its popular 767 twin-jet .

In most of the examples in the Penn Treebank corpus like in the examples listed above bare plurals seem to have existential import. However, they can also be universal, generic or kind denoting as the following example illustrates:

(4.25) We have no useful information on whether *users* are at risk, ...

4.3.3 Dependent Plurals

Dependent plurals are plural NPs which despite their plural grammatical form can have a singular reference, their plural form merely reflecting that of a genuinely plural NP on which they depend. The following example has a plausible reading where for each team there is one won-lost record under .500:

(4.26) Most-Remarkable Performance by a Division – On May 23 , with more than one-fourth of the season gone , all seven teams in the American League East had *won-lost records* under .500 .

4.3.4 Collective and Distributive Readings and Scope Ambiguity

The following two examples favour collective readings of the subjects of the *meet* and *gather* events:

[13] The fact that all but one of the examples listed below are from one and the same article in the Penn Treebank corpus may serve as indication that bare plurals is indeed a very widespread phenomenon.

(4.27) *The economic and foreign ministers of 12 Asian and Pacific nations* will meet in Australia next week to discuss *global trade issues* as well as *regional matters* such as transportation and *telecommunications.*

(4.28) The agreement was announced by Costa Rican President Oscar Arias Friday , as *President Bush and other leaders from the Western Hemisphere* gathered in the Central American nation for a celebration of democracy.

By contrast, the following sentence favours a distributive reading:

(4.29) *More than 20 new managing directors and senior vice presidents* have been hired since January .

The preferred reading of the following sentence is probably a cumulative reading where a total of eight men tried to smuggle a total of 111 snakes

(4.30) *British customs officers* said they 'd arrested *eight men sneaking 111 rare snakes into Britain* – including one man who strapped a pair of boa constrictors under his armpits .

4.3.5 Reciprocals

The Penn Treebank corpus attests roughly 100 occurrences of the reciprocal *each other*. Often the reciprocal simply establishes disjoint reference between the two members of a *single* pair as in (4.31):

(4.31) When two parties engage in an interest-rate swap , they are betting against *each other* on future rates .

Examples involving sets of pairs which are semantically vague as to whether all possible pairs actually stand in the specified relation are quite frequent:

(4.32) Fed funds is the rate banks charge *each other* on overnight loans;

(4.33) Nam Angels shows Angels fighting with *each other* and also depicts them as showing no remorse when a member is killed .

4.4 (Nominal) Anaphora

Referential expressions (pronouns, demonstratives, and definite descriptions) are common in all genres of natural language text. The texts discussed in the section on quantifiers, for example, include anaphoric expressions such as the definites *the α-neurexins* or *the repeats* in (4.2), the singular pronoun *it* in (4.105a) or (4.106d), or the plural pronoun *they* in (4.1). Eight example sentences in the section on Plurals contain occurrences of 3rd person singular

and plural personal pronouns ((4.6), (4.10), (4.16), (4.21), (4.24), (4.30), (4.31), (4.33)). Indeed, in the Brown corpus, the definite article *the* is by far the most common word token (it makes up for about 6.5% of the word tokens), and in the TRAINS corpus, it is the second most common word token, after *ok*. About 6.59% of the word tokens in the Brown corpus, and 8% of the word tokens in the LOB corpus, are instances of pronouns [Francis and Kucera, 1982; Johansson and Hofland, 1989]; the Penn Tree Bank corpus lists more than 55,000 occurrences of pronouns.[14].

Texts like (4.34), one of the texts used to verify semantic annotation methods in the SEMEVAL initiative, give an idea of the abundance of referential expressions in texts targeted for information extraction:

(4.34) MUC-4 Terrorist Report Corpus (Message 99 of the TST1 corpus)

> Police have reported that terrorists tonight bombed *the embassies of the PRC and the Soviet Union. The bombs* caused damage but no injuries. A car-bomb exploded in front of *the PRC embassy*, which is in *the Lima residential district of San Isidro.* Meanwhile, two bombs were thrown at a USSR embassy vehicle that was parked in front of *the embassy* located in Orrantia district, near San Isidro. Police said *the attacks* were carried out almost simultaneously and that *the bombs* broke windows and destroyed *the two vehicles.* No one has claimed responsibility for *the attacks* so far. Police sources, however, have said *the attacks* could have been carried out by *the Maoist "Shining Path" group* or *the Guevarist "Tupac Amaru Revolutionary Movement" (MRTA) group. The sources* also said that *the Shining Path* has attacked Soviet interests in Peru in *the past.* In July 1989 *the Shining Path* bombed a bus carrying nearly 50 Soviet marines into *the port of El Callao.* Fifteen Soviet marines were wounded. Some 3 years ago two marines died following a Shining Path bombing of a market used by Soviet marines. In another incident 3 years ago, a Shining Path militant was killed by Soviet embassy guards inside *the embassy compound. The terrorist* was carrying dynamite. *The attacks* today come after Shining Path attacks during which at least 10 buses were burned throughout Lima on 24 Oct.

The interpretation of anaphoric expressions is also a concern for NLP applications systems that translate a language with reduced morphological marking of gender (such as English) into a language with a richer gender system (such as French), or that translate between two languages in which the same concept may be expressed with nouns that have different gender (such as German and Italian). These systems need to identify the antecedent of anaphoric expressi-

[14]This count does not distinguish between individual (group) denoting and event type pronouns and anaphoric and non-anaphoric use of pronouns.

ons before translating. The French paragraph in (4.35b) is the translation of the English paragraph in (4.35a) (the italics are mine):[15]

(4.35) a. Individual reports undergo a comprehensive review by the Tranportation Division. *Traffic patterns* are studied to see if *they* are consistent with historical trends and carloads are compared against tonnages, on an individual commodity basis, to ensure that the weight reported per car is within acceptable parameters.

b. Chaque report est étudié très soigneusement par la Division des Transports. *Les trafics* sont étudiés pour voir s'*ils* sont conforment aux tendances historiques, les chargements et les tonnages sont comparés par produits afin de s'assurer que le poids par wagon est dans les limites acceptables.

The pronoun *they* in the second sentence of the English text is translated as *ils* instead of *elles* because its antecedent, *les trafics*, is masculine.

These high frequencies make it unlikely that any application doing some form of interpretation of natural language input can do without a model of anaphoric processing. This opinion is clearly shared by the participants to the ongoing discussion of the SEMEVAL proposal for semantic annotation; information about reference is one of the three kinds of semantic information that has to be extracted from texts.

Anaphoric phenomena in discourse have also been one of the main topics of study in formal semantics in the past 15 years, as discussed in section 3.4. Indeed, the study of these phenomena has led to a new perception of the role of sentences, in which a sentence's potential for changing a context (for example, by introducing new discourse referents) is seen as as important, if not more important, than the relation between that sentence and the world. Work on natural language systems such as the TRAINS project has demonstrated that the phenomena studied in the formal semantics literature have to be faced by implementors of NLP systems as well. Consider for example the short transcript from the TRAINS conversations in (4.36):

(4.36)

UU #	Speaker:Utterance
1.1	M: okay, the problem is we better ship a boxcar of oranges to Bath
1.2	: by 8 A M.
2.1	S: okay.
3.1	M: now ... umm ... [5sec]
3.2	: so
3.3	: we need to get a boxcar to Corning where there are oranges.
3.4	: there are oranges at Corning

[15] The two texts are from the Catalogue 52-211 Annual published by the Statistics Council of Canada, *Railway Transport in Canada*, Commodity Statistics, 1987, page viii. The report includes both English and French text, in parallel columns, aligned by paragraph.

3.5 : right?
4.1 S: right.
5.1 M: so we need an engine to move *the boxcar*
5.2 : right?
6.1 S: right.
7.1 M: so there's an engine at Avon
7.2 : right?
8.1 S: right.
9.1 M: so we should move *the engine at Avon*
9.2 : engine E
9.3 : to ... —
10.1 S: engine E1
11.1 M: E1.
12.1 S: okay
13.1 M: engine E1
13.2 : to Bath
13.3 : to... /
13.4 : or we could actually move *it* to Dansville to pick up *the boxcar there*
14.1 S: okay
15.1 M: um
15.2 : and hook up *the boxcar* to *the engine*
15.3 : move *it* from Dansville to Corning
15.4 : load up some oranges into *the boxcar*
15.5 : _and_ then move *it* on to Bath.
16.1 S: okay.
17.1 M: how does _*that*_ sound?
18.1 S: *that* gets us to Bath at 7 AM
18.2 : and .../
18.3 : so that's no problem.
19.1 M: good.
20.1 S: ok.

Conversations concerned with the development of schedules or plans, such as the one in (4.36), provide real life examples of two of the aspects of anaphoric reference most studied in the formal semantics literature in recent years, *modal subordination* (the use of anaphoric expressions whose antecedent occurs in the scope of a modal) and *reference to abstract objects* (such as events, plans, or propositions). The definite *the boxcar* in 5.1 has the boxcar introduced in 3.4 as its antecedent. Note that this boxcar does not refer to any particular boxcar in the domain; in fact, it may be the case that no boxcar is available for the transportation (say, if all boxcars are already in use). The demonstrative *that* in 18.1, instead, refers to the plan being elaborated: clearly, techniques similar to those discussed in [Asher, 1993] are needed.

4.4.1 Bound-Referential

More in general, we were able to find in the Penn Treebank examples illustrating each of the facts about anaphora discussed in the previous chapters. The bound–referential anaphora distinction in section 3.4.1 is illustrated by the following two examples. In the first sentence the pronoun *he* refers to the denotation of the proper name *Dave Fenimore*. In the second sentence the occurrences of *him* and *her* are bound by the quantifier *every*.

(4.37) After Dave Fenimore of Washington , D.C. , graduated from law school this spring , *he* took a trip around the world , hashing nearly every place *he* went , including Katmandu .

(4.38) Every intelligent man and woman should use most efficiently the meager means available to *him* or *her* to get rid of the faults of the system and to improve *it* .

4.4.2 Intersentential

The following two sentence discourse shows an instance of intrasentential anaphora in the first sentence and intersentential anaphora in second.[16]

(4.39) Mr. Gorbachev badly needs a diversion from the serious economic problems and ethnic unrest *he* faces at home . American officials have said that a meeting with the leader of the U.S. could help bolster *his stature* among Soviet politicians and academics , whose support *he* needs .

4.4.3 Plural Anaphora

The following example shows a variety of anaphora related phenomena interacting. The plural pronoun *them* refers back to the group-denoting definite plural NP *the participants*. The phrase *one of X* selects some (arbitrary) member of *X* (in the present case *the participants*) which is then referred to by the discourse final personal pronoun *him*. Thus we have a case here of singular referent constructed from a plural entity.

(4.40) Corporate committee meetings and professional football games have a lot in common : the participants are well paid , highly motivated , very competitive – and every time *one of them* grabs the ball and tries to run with *it* , 11 other people jump on top of *him* .

[16] The occurrences of the two personal pronouns in the second sentence are ambiguous in that they could also be resolved intrasententially against the NP *the leader of the U.S.*.

Alternatively, plural referents can be constructed out of singular entities as the following example illustrates.

(4.41) The company said Mr. Stronach will personally direct the restructuring , assisted by Manfred Gingl , president and chief executive . Neither *they* nor Mr. McAlpine could be reached for comment .

4.4.4 Simple Reflexives

The Penn Tree Bank corpus lists about 850 occurrences of reflexive pronouns. Often reflexives are simply used appositively for special emphasis as in

(4.42) Mr. McGovern *himself* had said repeatedly ...,

'Proper' uses of reflexives are also encountered frequently:

(4.43) The gene thus can prevent a plant from fertilizing *itself* .

4.4.5 Other

The Penn Treebank corpus attests occurrences of cataphoric reference. Currently, we are not in a position to say anything precise about the frequency of such phenomena.

(4.44) When it 's time for *their* biannual powwow , the nation 's manufacturing titans typically jet off to the sunny confines of resort towns like Boca Raton and Hot Springs .

We also found the following example of 'donkey' anaphora, from Harold Pinter's play *Betrayal* and in the ACL/DCI corpus, respectively:

(4.45) For example, when you're with a fellow in a pub, or a restaurant, for example, from time to time he pops out for a piss, you see, who doesn't ...

(4.46) A married man typically pursues paid employment aggressively when he is the family's primary breadwinner.

The antecedent of the pronoun *he* in (4.45) is the indefinite NP *a fellow*, that gets (quasi)-universal force from the implicit adverb of quantification *often* or *usually*. This sentence, in other words, has the same logical structure of sentences such as *When a farmer owns a donkey, he thrives.*

4.5 Ellipsis

An example of application in which a proper treatment of ellipsis is crucial are question-answering systems, where elliptic questions are frequent and make a

conversation efficient. For example, the user of an airline reservation system may ask the question *When does the first flight to Luxembourg leave today?*, and continue with the elliptic question *And tomorrow?*. But ellipsis is not a phenomenon limited to spoken language: all example sentences in the sections on Ellipsis were found through extensive automated or semi-automated search of portion of the Wall Street Journal corpus (henceforth, WSJ) found on the ACL/DCI CD-ROM.

4.5.1 Gapping

As the following example (WSJ, Nov. 2nd 1989) shows, systems that try to extract information from written news articles (e.g. summary generation systems) will need to be able to treat the phenomenon of gapping properly:

(4.47) The Perch and Dolphin fields are expected to start producing early next year, and the Seahorse and Tarwhine fields later next year.

4.5.2 VP Ellipsis

VP ellipsis is more frequent in English than in other European languages such as German or Norwegian, where the use of an explicit anaphor (a pronoun) is more common. VP ellipsis may then call for a somewhat deeper analysis when doing e.g. English to German automatic translation, Here's a rather complicated example of VP ellipsis (WSJ, Mar. 16th 1987):

(4.48) I have nothing against golden retrievers – I support one myself – but I had difficulty in my first viewings figuring out the dog's function. Apparently *the show's producers did too*, and so the dog has been riffed – along with more than 200 producers and reporters who worked for CBS News.

4.5.3 One Anaphora

The following example of intrasentential one-anaphora is from WSJ, Mar. 16th 1987:

(4.49) The indications appear to be that, irrespective of what stand North Korea finally takes once the IOC's Sept. 17 deadline has passed, the political factor will largely be transcended by *the sporting one*.

An example of intersentential use of one-anaphora was found in WSJ, Mar. 20th 1987:

(4.50) That chunky Rolex diving watch that James Bond and JFK popularized in the '60s, Mr. Weitz notes, was made to say: "Stay down here

at 140 feet for another four minutes, and a meteor storm of nitrogen bubbles will soon make cottage cheese out of your brain." If you want to say that around the office, wear *one*. If your brain is already cottage cheese, wear the solid gold version.

4.5.4 Sluicing

An instance of sluicing with *why* (from WSJ, Mar. 16th 1987):

(4.51) If it's different from the yield, *ask why.*

An example with *when* (WSJ, May 27th 1987):

(4.52) Kodak said it plans to sell the rest of its Viratek stock, but *it didn't indicate when.*

Another example with *why*, in which the elliptical portion has to be recovered from discourse rather than from the current sentence: (WSJ, April 27th 1987):

(4.53) Other research suggests that nicotine's chemical ghost haunts the body for months, even though nicotine itself remains in the blood for only a few hours after smoking. *Hormones may partly explain why.*

4.5.5 Interaction of VP ellipsis with quantification

It has been noted in the literature that when the antecedent of a VP ellipsis contains a quantified expression such as *a passing grade*, the only available reading for the sentence containing the ellipsis is the one in which the quantified expression takes narrow scope. (See section 3.5.3.) The following example (WSJ, March 10th, 1987), gives a nice illustration of the interaction of VP ellipsis, quantifiers and scope:

(4.54) Even those citizens and opinion leaders who consider themselves reasonably well informed about the economy probably wouldn't score a passing grade on the nearby quiz. (See related story: "A Closed-Books Test" – WSJ March 10, 1987.) What's worse, *no member of Congress probably would either. Nor would the president himself.*

4.5.6 Interaction of VP ellipsis with anaphora

In the following example (WSJ, May 4th 1988) the *strict* reading is preferred, that is, the sentence *so has America's ability to promote democracy even in our own emisphere* is interpreted as *America's ability to promote democracy even in our own emisphere has collapsed in the final years of Reagan's policy.* The (unlikely) *sloppy* reading according to which America's ability to promote democracy in *America's* final years has collapsed is not easily available.

(4.55) But the Reagan administration also played a role by renewing U.S. confidence and economic vitality in a way that also renewed America's global influence. As Reagan policy has collapsed in its final years, however, so has America's ability to promote democracy even in our own hemisphere. The Ortegas and Noriegas can follow Congressional votes, too.

The strict-/sloppy- distinction poses a special problem in Machine Translation systems with certain languages (e.g. Norwegian and Serbo-Croatian) which have syntactic means of marking the preferred reading, e.g. reflexive-possessive pronouns (with a preferred sloppy reading).

4.6 Adjectives

The most obvious need for a treatment of adjectives is in natural language front-ends to databases, and in systems that generate text from such databases. Adjectives describe properties of things and individuals, and thus many database relations correspond to adjectives in natural language: consider for example *I need a reservation on the* next *flight to Chicago.*

Intersective adjectives are fairly easy to treat, since they may be translated into simple individual properties (WSJ, March 20th 1987):

(4.56) When they buy the *blue* suits, *white* shirts and *red* ties they favor, they're most likely to get them at Brooks Brothers.

More difficult to treat are the vague *scalar restrictive* adjectives (WSJ, March 20th 1987):

(4.57) Japan's shipbuilders, meanwhile, have spent $23 million to build a *fast* ship propelled by superconducting magnets.

A proper treatment of measure phrases is also crucial to database front-ends, since many queries ask for measures. The following examples is from WSJ, Mar. 19th 1987:

(4.58) The legislation is aimed at those who have been on dependent children or refugee assistance for two continuous years and those recipients who are *under 22 years old* and have not completed high school.

Francis and Kucera counted 68641 instances of 'base form' adjectives in the Brown corpus (about 6.77% of the total of word tokens in the corpus).

4.7 Comparatives

1996 instances of comparatives were found in the Brown corpus. (4.59) is an example of an adjectival phrasal comparative (WSJ, Mar. 23rd 1987). (4.60) is an example of a nominal comparative (WSJ, Mar. 12th 1987):

(4.59) Dr. Graor told the New Orleans group that clots dissolved in 61 of 65 such patients, although 76% of them also required later surgery or angioplasty. He believes TPA is *safer* than streptokinase.

(4.60) When it comes to conjuring up 'firsts,' few have shown *more imagination* than Mr. Gillette, who remains determined to row his Sea Tomato to Antarctica.

4.7.1 Clausal Complement (Comparative Deletion)

This example (from WSJ, Mar. 3rd 1987) shows how ellipsis occurs in comparatives:

(4.61) The people who have the trade deficit – who *are buying more abroad than they are selling* – are doing so voluntarily.

4.7.2 Measure Phrases

Comparative measure phrases are also likely to occur in the kind of text to be processed by interfaces to databases. The following example is from WSJ, Mar. 20th 1987:

(4.62) In a time when it seems that all sorts of things from automobiles to relationships don't last as long as they used to, *more than 80% of the CEOs have been married only once*, and roughly the same percentage have been married longer than 20 years.

4.7.3 Zero Complement

The following example is from WSJ, Mar. 23rd 1987:

(4.63) The average Visa card also carries a $15 annual fee, but it has a stiffer 17.5% rate, and several big banks charge even *more*.

4.7.4 Differential Comparatives

From WSJ, Nov. 17th 1988:

(4.64) Sears's $15.96 price on a one-ounce spray bottle of Vanderbilt toilet water is *46 cents higher than Penney's* and *$2.12 higher than Wal-Mart's*.

This example may also illustrate another possible application area of semantics for comparatives: summary generation from tables. One may imagine (4.64) having been generated from a table listing different goods and their prices in several stores.

4.7.5 Attributive Comparatives

In this example (from WSJ, Oct. 11th 1989), *a more difficult constituency than Bradley* is not ambiguos, the reading *a more difficult constituency than Bradley is*, is ruled out by its absurdness.

(4.65) "Wilder has a more difficult constituency than Bradley because Wilder is running in a real Southern state where there are still remnants of resistance to the civil-rights movement," says Eddie Williams, the director of the Joint Center for Political Studies.

4.8 Temporal Reference

The examples in this section are taken from the Penn Treebank corpus.

4.8.1 Standard Use of Tenses

Uses of the present tense such as those discussed in section 3.8.1 are of course to be found in every sort of text. The following examples illustrate the use of the present tense to refer to a time which includes the present time.

(4.66) It has no bearing on our work force today.

(4.67) The screen *shows* two distorted , unrecognizable photos , presumably of two politicians.

(4.68) " Compare two candidates for mayor , " *says* the announcer.

(4.69) All of the changes *require* regulatory approval , which is expected shortly.

(4.70) But Mexico urgently *needs* more help.

The habitual use of the present tense, which refers to a regular patterning of eventualities on a time axis, is illustrated by:

(4.71) The young president so admires Japanese discipline that he *sends* his children to a Japanese school in Mexico City.

(4.72) Mesa *flies* to 42 cities in New Mexico , Arizona , Wyoming , Colorado and Texas.

An example of present tense referring to a future time is given in:

(4.73) Unless the Federal Reserve *eases* interest rates soon to stimulate the economy , profits could remain disappointing .

There is ample illustration of the use of present tense progressive to refer to present time:

(4.74) Who 's telling the truth ?

(4.75) But the market *is changing* .

(4.76) The government *is funding* several projects to push PC use .

The 'standard' use of the simple past tense is illustrated by the following selection:[17]

(4.77) Late yesterday , the company *said* it *agreed* in principle to buy two radio stations from Sandusky Radio .

(4.78) The company *gave* a presentation yesterday at a health-care conference for institutional investors and analysts .

The 'standard' use of the present perfect is to refer to an eventuality located somewhere in the past which is still felt to bear some relation to the present (or utterance time):

(4.79) The Latin American nation *has paid* very little on its debt since early last year .

(4.80) Cray Computer *has applied* to trade on Nasdaq .

The 'standard' use of the past perfect is to refer to an eventuality located somewhere in the past of another described past eventuality:

(4.81) The city *had expected* to pay about 11 million yen ($ 77,000) , but Fujitsu essentially offered to do it for free .

(4.82) But by the early 1980s , its glory *had faded* like the yellow bricks of its broad facade.

The following example shows an interaction between the 'standard' uses of a past and a present perfect form:

(4.83) Scientists *had obtained* even higher current-carrying capacity in thin films of the new superconductors , but *have had* problems increasing the amount of current that bulk crystals could carry .

Sentence (4.83) has a reading where the past perfect refers to a time prior to some point in the past while the present perfect refers to a state of affairs which is located in the past but extends to the present.

[17] Example (4.77) is also an illustration of the phenomenon of *embedded tense*—a simple past verb in the complement clause of a matrix verb in the past.

Finally, we list some examples involving instances of the simple future tense *will* + base form of the main verb:

(4.84) In addition , the Cray-3 *will contain* 16 processors –twice as many as the largest current supercomputer .

(4.85) No one else *will watch* out for you .

4.8.2 Temporal Adverbials

4.8.2.1 Indexicals

The Penn Treebank corpus contains a large number of indexical expressions establishing temporal location.[18] Often a temporal location is fixed in terms of both the indexical and the tense of the verb:

(4.86) The tension was evident *on Wednesday evening* during Mr. Nixon 's final banquet toast , normally an opportunity for reciting platitudes about eternal friendship .

(4.87) The Treasury said the U.S. will default *on Nov. 9* if Congress doesn't act by then .

The interpretation of indexicals like *today*[19] is sometimes rather general as in

(4.88) It has no bearing on our work force *today* .

(4.89) .. more than a third of the ringers *today* are women .

(4.90) " *Today* , a banker is worrying about local , regional and money-center banks , as well as thrifts and credit unions , " says Ms. Moore at Synergistics Research .

4.8.2.2 'Before', 'After', 'When' (Temporal Subordinate Clauses)

In general the eventuality described in temporal subordinate clauses is used to locate the eventuality described in the main clause. Examples of this are:

(4.91) We 're talking about years ago *before* anyone heard of asbestos having any questionable properties .

(4.92) *Until* Congress acts , the government has n't any authority to issue new debt obligations of any kind , the Treasury said .

[18] There are between 20 and 100 instances each of expressions such as *Wednesday* or *January* in the Brown corpus.

[19] Francis and Kucera counted 330 instances of *today*, 89 instances of *yesterday*, and 67 instances of *tomorrow*.

(4.93) *When* it 's time for their biannual powwow , the nation's manufacturing titans typically jet off to the sunny confines of resort towns like Boca Raton and Hot Springs .

(4.94) *After* Mr. Ramsey was fired , for instance , he was treated as a pariah by former co-workers .

The relative frequencies reported by Francis and Kucera for these adverbials (both as coordinators and as heads of PPs) are: 1060 instance of *after*, 858 istances of *before*, 600 instances of *since*, and 463 instances of *until*.

4.8.2.3 'In', 'For' and 'On' Temporal Adverbials

The next example shows a temporal adverbial *in the 1950s* which has durative interpretation. Durative interpretations are only possible with accomplishment verbs.

(4.95) About 160 workers at a factory that made paper for the Kent filters were exposed to asbestos *in the 1950s* .

By contrast the next example involves a temporal adverbial of the form *in* + NP together with the achievement verb *receive*. Here the temporal adverbial has a non-durative locating interpretation:

(4.96) Under terms of the spinoff , Cray Research stockholders are to receive one Cray Computer share for every two Cray Research shares they own in a distribution expected to occur *in about two weeks*.

For + NP adverbials together with activity verbs *continue* have a durative interpretation:

(4.97) Compound yields assume reinvestment of dividends and that the current yield continues *for a year*.

On + NP adverbials express temporal inclusion of an event or overlap with a state. Inclusion is illustrated in (4.98)

(4.98) *On weekends* , she came to work to prepare study plans or sometimes , even to polish the furniture in her classroom .

Francis and Kucera do not make a distinction between the different interpretations of adverbials such as *in*, *for* and *on*, therefore, although such prepositions are very frequent (20870 instance of *in* were found, for instance), we don't know the relative frequency of the temporal cases we are interested in.

4.8.2.4 Quantificational Adverbials

Quantificational adverbials are frequently attested in the Penn Treebank corpus.

(4.99) The monthly sales have been setting records *every month since March* .

(4.100) Don't wait –a savings institution needs your help now . *Every day* you delay , a savings institution's health –and the federal budget deficit –grows worse .

(4.101) That sounds neat , but this government – any government – propagandizes its own people *every day* .

(4.102) The computer can process 13.3 million calculations called floating-point operations *every second* .

4.8.3 Anaphoric Dimension

The following example from Harold Pinter's *Betrayal*, 1978, gives a simple, almost prototypical example of narrative progression involving the description of a succession of events with intermittened descriptions of states (progressive forms):

(4.103) I was driving through Kilburn. Suddenly I saw where I was. I just stopped, and then I turned down Kinsale Drive and drove into Wessex Grove. I drove past the house and then stopped about fifty yards furhter on, like we used to do, do you remember? .... People were coming out of the house. They walked up the road. .... Then I got out of the car and went up the steps. I looked at the bells, you know, the names on the bells. I looked for our name.

4.8.4 Adverbs of Quantification

Adverbs of quantification or frequency adverbs (the class includes *always*, *often*, etc.) are relatively common in most types of relevant texts. The Brown corpus includes 694 instances of *never*, 456 instances of *always*, 369 instances of *often*, and 34 instances of *seldom*, all found in all genres. Recognizing these adverbs is crucial for information extraction applications: clearly, the meaning of *never* in *the meeting never took place* cannot be ignored. Example (4.3) from §4.2, repeated here, illustrates their use in financial articles:

(4.104) Many investment bankers and major institutional investors say the current crunch in the junk market will have long-lasting effects on the volume and pace of corporate mergers and buy-outs, which so dramatically reshaped the face of corporate America in the 1980s and which were *often* fueled by junk bonds.

The use of *always* and *never* in instruction-giving spoken language conversations is illustrated by the following examples from the MapTask corpus:

(4.105) a. ...You turn round to a abandoned cottage, so *always* keeping it on your left-hand side

b. ...I'm not that far away, I *never* knew.

Adverbs of quantification are generally common in intruction-giving text, as shown by the following examples from recipes:[20]

(4.106) a. Use enough oil that the potatoes will not need to be stirred *often*, and thus avoid breaking them up.

b. Add oil and cook more, stirring *often*, to roast the carrots well.

c. Start with less wine rather than more–you can *always* add some.

d. Mix it all together, and spread in a shallow pan (I *always* used a circular pan just to get that "pie" effect.) grease it first with pam spray..bake it at 350 for about 40-45 minutes

e. American Swiss cheese is *seldom*, if ever, sufficiently matured to make a proper fondue.

This last example is interesting in that it provides an example of adverb of quantification quantifying over entities (or entity kinds) rather than over times/situations, a problem also widely discussed in the formal semantics literature [Lewis, 1975].

Examples of adverbs of quantification in the Penn Treebank corpus are shown below.

(4.107) Financial planners *often* urge investors to diversify and to hold a smattering of international securities.

(4.108) They argue that U.S. investors *often* can buy American depositary receipts on the big stocks in many funds;

(4.109) players must abide by strict rules of conduct even in their personal lives –players for the Tokyo Giants , for example , must *always* wear ties when on the road.

(4.110) " Now , " says Joseph Napolitan , a pioneer in political television , " the idea is to attack first , last and *always*.

(4.111) It 's a shame their meeting *never* took place.

(4.112) Until last week , the IRS *rarely* acted on the incomplete forms.

(4.113) The six-story hotel will be on Gorky Street and *initially* will cater mostly to business travelers.

[20]These examples are from recipes circulated in the Internet.

4.9 Verbs

4.9.1 Aspectual Classes of Verbs

The texts reported in the previous sections include verbs of all aspectual classes: accomplishments (such as *took a trip* in (4.114)), achievements (4.115), statives (4.116), and activities (4.117).

(4.114) After Dave Fenimore of Washington , D.C. , graduated from law school this spring , he *took a trip* around the world , hashing nearly every place he went , including Katmandu .

(4.115) A car-bomb *exploded* in front of the PRC embassy.

(4.116) Undergraduates *were* the best tic-tac-toe players.

(4.117) Until last week, the IRS rarely *acted on the incomplete forms.*

4.9.2 Copula - Light Verbs

Examples of copular constructions and light verbs from the texts reported above include:

(4.63) The average Visa card also carries a $15 annual fee, but it *has* a stiffer 17.5% rate, and several big banks charge even more.

(4.21) The asbestos fiber , crocidolite , *is* unusually resilient once it enters the lungs ...

(4.32) Fed funds *is* the rate banks charge each other on overnight loans;

4.9.3 Modals

The Brown corpus includes a total of 14002 modals, 1,4% of the total of word tokens in the corpus [Francis and Kucera, 1982]. Modals are very frequent in scheduling conversations; the 16 TRAINS transcripts collected in 1991 contain 62 uses of *would*, 51 uses of *need*, 39 uses of *could*, 17 uses of *should*, out of a total of 16 conversations. The following examples are from the transcript in (4.36).

(4.118) we *need* to get a boxcar to Corning where there are oranges.

(4.119) we *should* move the engine at Avon ...

(4.120) we *could* actually move it to Dansville to pick up the boxcar there

4.10 Attitudes

The Brown corpus includes 2765 instances of *say*, 982 instances of *think*, 631 instances of *want*, 472 instances of *try*, 336 instances of *believe*, 179 instances of *seek*, 164 instances of *hope*, 109 instances of *deny* and 53 instances of *fear*. The texts searched to find the examples in this section include the GNN Directory on WWW (`http://192.190.21.10/gnn/GNNhome.html`) and the Vogon News Service on WWW (`http://www.cm.cf.ac.uk/htbin/RobH/Vogon`).

4.10.1 Epistemic attitudes

From The GNN Journal, 13 april 1994 (http://192.190.21.10/news/journal_0413.html)

(4.121) WSJ *believes* the administration is "afraid that somewhere, somehow consumers could be 'hurt' when the corporate giants start competing hard for the information market."

(4.122) White House officials *believe* that by enforcing antitrust laws they are promoting competition and "new rules on cable rates merely prevent the extortion of monopoly profits."

4.10.2 Intentional attitudes

From the GNN directory: " The Benefits of Adding "Inc." to Your Company Name," http://192.190.21.10/meta/internet/mkt/cocorp/whyinc.html

(4.123) This structure is used for corporations that have or *intend* to have more than 30 shareholders, or who plan to make large public stock offerings.

4.10.3 Reportive attitudes

From *The Vogon News Service*, http://www.cm.cf.ac.uk/SEARCH/#3075_Friday_6-May-1994.html-1

(4.124) Richard Miller, vice president of research and development at Atari, *said* that the new Jaguar PC card, essentially a graphics acceleration card, will let consumers play Atari's Jaguar games on a PC equipped with a double-speed CD-ROM drive.

4.10.4 Perceptive attitudes

From the GNN directory, " Free-nets and communities", http://192.190.21.10/mag/10_93/articles/lmui/lmui.html

(4.125) If the Free-Net provides guest access, then you don't have to register just to browse through the Free-Net and *see* what it has to offer.

4.10.5 Iteration of attitudes

From *The Vogon News Service*, http://www.cm.cf.ac.uk/SEARCH/#3040_Wednesday_16-Mar-1994.html-1

(4.126) The last I *heard*, this *was suspected* to have been there for up to three months since the IRA were last planting bombs along the railway lines, and was found by a BR worker during a routine track inspection.

4.11 Questions

Questions are very frequent in conversations. The examples (4.127)-(4.132) are all from the TRAINS dialogues:

(4.127) is that going to get to Avon at time?

(4.128) did you say Corning or Elmira?

(4.129) which route do you wanna take?

(4.130) what time do we get to Dansville?

(4.131) when do we when do we have orange f orange juice at Elmira?

(4.132) how long does it take from Elmira to Corning?

As far as embedded questions are concerned, an indication about their frequency is given by the count of 286 instances of *whether* in the Brown corpus, 612 instances of *ask*, and 119 instances of *wonder*. Some of the examples we found in Reuter press releases are shown below:

(4.133) President Kennedy at his Washington Press conference admitted he did not know whether America was lagging behind Russia in missile power.

(4.134) How many of our leading actors are anxiously waiting for April 17 to find out whether they will be able to continue their forward strip?

(4.135) But when I asked Hill today whether, in his capacity as chairman of the Professional Footballers' Association, he was prepared to say anything about captains who gesticulate, show their displeasure and sometimes disgust when passes go astray, he refused.

4.12 Conclusions

The set of core semantic phenomena does illustrate semantic problems that occur in naturally occurring text. Furthermore, essentially every application will have to deal with at least some of the semantic phenomena illustrated by the fragment: the interpretation of anaphoric expressions, of plurals, of definite and indefinite NPs, of tense, and of modal expressions such as adverbs of quantification and modals. The frequency with which these phenomena are observed suggests that a rigorous treatment of these phenomena may be more useful than *ad-hoc* solutions.

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