ASPECTS OF QUANTIFICATION IN NATURAL LANGUAGE

Rijksuniversiteit te Groningen

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voor mijn ouders
en voor Liet

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PREFACE

The initial motivation for engaging in the research for this thesis has been a wish to investigate the possibilities for bridging the gap between theories of natural language in the spirit of Transformational Generative grammar on one hand and current theories of natural language in the logico-semantic tradition on the other. As this subject is hopelessly broad, I decided to restrict attention to the topic of quantification in the context of noun phrases. More specifically, the subject matter of this book is a study of the framework necessary for the description of scope-ambiguities and constraints on anaphoric possibilities for noun phrases. My central question is whether in this area a synthesis is possible between proposals from TGG-theorists and proposals in the spirit of Montague-grammar and Discourse Representation Theory, an alternative to Montague grammar developed by Hans Kamp.

Focussing on the topics of NP-scopes and NP-anaphora, I will argue that in spite of the apparently vast differences between the various theories, there are enough points of contact and concurrence for a synthesis to be possible. A synthesis between TGG-theories about NP-quantification and Montague grammar will be presented in chapter IV. In this synthesis the notion of 'Logical Form' will turn out to be a key concept. In chapter V it will be argued that Kamp's theory of discourse representation provides structures suitable to play the rôle of 'logical forms' at the text level.

The intended public of this dissertation is twofold. In the first place I hope that what follows will be of interest to readers with a concern for the application of logical methods in the study of natural language (including Montague-grammarians). In the second place I intend to convince linguists in the TGG tradition that the logico-semantic viewpoint has something of interest to offer them.

Because of the fact that this book is intended for readers with various backgrounds, I sometimes had to include rather familiar material, given a certain background. I have assumed little knowledge of either logic or linguistics. As a result, the logician may safely skip most of chapter I, while most workers in the TGG tradition will find much of the contents of chapter II familiar. They should read section II.2.2, though. Similarly, the Montague grammarian may skip III.0-2, but should read the rest of chapter III.

Chapter I starts with a survey of logical contributions to the toolbox of instruments for the analysis of quantification in natural language, beginning with Frege. Then a sketch is provided of ideas from the logical and philosophical folk-lore concerning the connection between quantification, description, naming, binding and anaphora. The chapter ends with a short account of the Misleading Form controversy.

In chapter II several TGG-proposals for the treatment of scope ambiguities and anaphoric constraints are discussed, criticized and sometimes amended. Also, a proposal is made for a categorial treatment of the NP-specifier system, including the singular/plural distinction. The proposal is put forward as an alternative for a TGG-treatment in terms of X-bar-syntax, and it uses a version of categorial grammar in which certain category-shifts are allowed.

In chapter III, I address myself to the Montague account of quantification in natural language. After a brief survey of the Montague framework, some cosmetic surgery on it is performed, by the introduction of a format for the syntactic component of Montague grammar that, unlike Montague's, is explicit about allowed syntactic operations. Next, a compositional semantics is presented for the NP-specifier system of the previous chapter. Chapter III concludes with a recipe for avoiding certain kinds of the meaning postulates that play such an important rôle in Montague grammar.

Chapter IV is devoted to the relation between the TGG-proposals from chapter II and Montague grammar. First an earlier attempt at a synthesis between the two traditions is discussed: Cooper's NP-storage technique, in which wide-scope readings of NPs are accounted for by storing and quantifying-in of NP-translations. Next, it is pointed out that a more elegant synthesis becomes possible, provided that one is willing to view the TGG-level of 'Logical Form' as part of the description of syntactic structure, or as an extension of syntax. It is argued that Logical Form is not - as some TGG-theorists have it - an alternative for a level of modeltheoretic interpretation, nor - as some Montague-grammarians seem to think - a level that fulfils the rôle played by logical translations in Montague grammar.

A framework and a fragment are presented in which the quantifying-in rules of Montague grammar are replaced by extraction rules. In this version of Montague grammar syntactic structures are gradually desambiguated by transforming them into Logical Forms which can be compositionally interpreted. Montague's quantifying-in of NPs may be considered as the inverse operation of the transformation of quantifier-extraction in TGG-theories of Logical Form. Quantifying-in operates outside-in and hides structure, whereas quantifier-extraction operates inside-out and adds structure. This difference is connected with the fact that Montague's syntactic structures are compositional in terms of the nature of their components and the manner of composition, while Logical Form structures are compositional in terms of the nature of their components alone.

In chapter V the perspective is shifted to an alternative for the Montague framework, proposed by Hans Kamp: discourse representation theory. In this theory, representations are constructed for sequences of sentences. Like the logical forms from the previous chapter, these representations may be considered as extensions of sentence syntax. The setting of the theory is sketched, and proposals for reformulation and extension are made. It is argued that discourse representation structures are eminently suited to play the rôle of logical forms at the text level. As a demonstration, an outline for a theory of VP- and S-anaphora - a topic for which TGG invokes logical forms - in terms of discourse representation structures is provided.

Finally, in VI, the concluding chapter, some loose ends are exposed, some possible connections of DR-theory with possible world semantics and situation semantics are explored, some promising directions for further research are pointed out, some pious intentions are voiced, and some conclusions are drawn.

CHAPTER I

HISTORICAL SURVEY

I.0 Introduction

In this first chapter I will sketch the development of the tools that are now being used by linguists and logicians in the logico-semantic analysis of quantified (noun-) phrases in natural language.

The history of the study of quantification in natural language is mainly a history of logical contributions. The issue of quantification has been first and foremost in the minds of logicians and philosophers of logic for quite a while, whereas the linguistic interest in it is relatively recent. Many important contributions to the understanding of quantification in natural language have been made by people with a background in logic who got sufficiently interested in natural language to venture beyond their own special field. Their example has increasingly inspired linguists to employ logical tools in the study of natural language. Still, it is not surprising that logicians and philosophers of logic figure more prominently in this historic chapter than linguists.

A study of the history of the theory of quantification in natural language might follow the trail back to any of the heroes of philosophical logic. Aristotle's logic would be a particularly good place to start: his system of syllogistics is in fact a theory of the inference patterns that can be formed with expressions that contain a combination of a 'typical' quantified NP-subject with a simple predicate.

Rather than plough through 23 centuries of history of logic, however, I prefer to let the historic chain of contributions start some 22 centuries later, with Gottlob Frege. After Frege, important contributions to our understanding of quantification with relevance to natural language have been made by the logicians Peirce, Skolem, Tarski, Mostowski, and Montague. There are others besides, but those others made less important contributions, or they did not fit as nicely into my tale. The historical overview ends with a sketch of the so-called Generalized Quantifiers perspective that has recently emerged.

After this seven-league boots' stroll through the history of logic after Frege I turn to a discussion of topics in the theory of quantification that are directly relevant to linguistics. In section I.2, I sketch different theories of the relation between quantification, definite and indefinite description, and naming, I list some problems of the application of the logical notion of variable-binding to natural language, and I give a sketch of a theory that uses an indefinite-description operator proposed by Hilbert & Bernays for an account of anaphoric links.

Finally, in section I.3, some episodes from the history of the Misleading Form Thesis are commented upon, and ideas about 'Logical Form', from Misleading Form Theorists and from others, are outlined and briefly discussed.

I.1 The Nature of Quantification

I.1.1 Frege's Theory of Quantification

The systematic introduction of quantifiers in Frege's *Begriffsschrift* (1879) can be considered as the first comprehensive logical account of matters of quantification. In the introduction to this epoch-making work the author states his reasons for developing the formal language he is about to present. He makes it clear that this calculus is not meant as a tool for the analysis of natural language, but as a *substitute* for it, a tool that is much better fitted for precise scientific discourse than natural language.

In the *Begriffsschrift* variables and quantifiers that bind them are introduced in a systematic way and a general theory of relations is presented. Frege wants to develop a universal scientific language of which the system of the *Begriffsschrift* is to be the kernel. The system represents the content of assertions or judgements in such a way that everything that is relevant for correct reasoning is expressed in full, and everything else is left out. The traditional distinction of subject and object, e.g., is disregarded, as it does not influence the process of drawing consequences. According to Frege, such distinctions have 'nur grammatische Bedeutung', and should be disregarded in an artificial language set up exclusively for scientific purposes.

In the language of the *Begriffsschrift* (Greek capital) letters are used as abbreviations for declarative sentences. 'Γ' could stand, e.g., for "grass is green". Frege introduces the sign '$\vdash$' to express the *assertion* that can be made with a declarative sentence: '$\vdash \Gamma$' could stand for the assertion that grass is green. Actually, Frege viewed the sign '$\vdash$' as a composition of '$|$' (the "judgement-stroke") and '$-$' (the "content-stroke"). (Later, the sign has evolved into a sign of theoremhood within formal systems, with '$\vdash B$' standing for 'B is a theorem', and '$A_1, .. A_n \vdash B$' for 'B is deducible from $A_1, .. A_n$'.)

Out of simple expressions complex ones may be formed. Frege takes the operator that later became known as the operator for material implication as basic. If 'Γ' and 'Δ' are abbreviations for declarative sentences then '$\Gamma \rightarrow \Delta$' is a declarative sentence that expresses that the affirmation of 'Γ' together with the denial of 'Δ' is ruled out. (Actually, Frege uses a rather cumbersome notation that I will not follow.) Next, a sign for negation is introduced. Frege shows how all truth-functional operators can be expressed with the signs for material implication and negation.

Frege recognizes that the material conditional is weaker than the 'if.. then..' of natural language: 'if A then B' expresses a "lawlike" connection between A and B, '$A \rightarrow B$' does not. Nevertheless, Frege take negation and material implication as basic, rather than negation and conjunction, despite the fact that the latter operator corresponds closely to the 'and' of natural language. The reason is the rôle that material implication plays in connection with Modus Ponens, Frege's only rule of inference besides the rule of substitution.

Next, Frege introduces the sign for identity. Then the notion of function-argument structure is explained. We can regard certain expressions as containing a symbol that is *replaceable* by another symbol at one or more of its occurrences. In these cases the part of the original expression that is invariant under the replacement can be said to denote a *function*, the replaceable part an *argument* of this function.

One could think of the word 'gold' in the expression 'Gold is heavier than lead' as replaceable by the word 'platinum': the result of the replacement is an expression of the same kind as the first. If one makes such a replacement, one considers the word 'gold' as an argument-symbol that fits in the slot marked by '---' in the functional expression '--- is heavier than lead'. Alternatively, one might look at the original expression in a different way, considering 'lead' as an argument-symbol that combines with 'Gold is heavier than ...'. Or one might consider 'gold' and 'lead' as occupying the two argument places indicated respectively by '---' and '...' in '--- is heavier than ...'. Examination of other examples leads to the recognition of functions with more than two arguments.

Actually, there are many passages in the Begriffsschrift where Frege seems to confuse symbols with what they symbolize. Notably, no clear distinction is drawn between functional symbols and functions. Apparently, Frege deems it unimportant to be careful here because he considers his language to be without ambiguities of intended application. Every functional symbol symbolizes one and only one function in the real world, so no mistakes are possible.

Indeed, the thought of different intended applications for his new symbolic language did not occur to Frege. For him, and for his logicist followers, logic has only one application. The subject matter of the language of logic is simply everything there is, the whole universe. (This perpective on logic is particularly striking in Wittgenstein's Tractatus and in Russell's lectures on the philosophy of logical atomism; cf. Russell (1918).)

Thus, Frege's view of logic differs from our modern view. For us, logic is general in the sense that we recognize that a formal system with appropriate axioms can be applied to any subject-matter we wish to investigate with it. For Frege and the logicists, logic is universal in the sense that it is a conceptual system developed expressly in order to formulate the most general truths that can be stated about the universe. This explains why neither Frege nor Russell raised any metasystematical questions of the kind studied in model-theory nowadays (cf. Goldfarb (1979)).

According to Frege, the universe consists of two kinds of entities: objects and functions. Objects are not only the perceivable things in the world, but also numbers, periods of times, etc., in short: all things that have objective existence and are not functions. What functions are is difficult to express, for in talking about them, one necessarily treats them as objects, which they are not. Note that Frege does not consider the possibility of describing the relation between functional symbol and symbol 'from the outside', by means of a different language that can treat the function differently, so that no contradiction is involved in calling the function an object at this new level. The essence of a function, according to Frege, is a connection between objects or functions which are its arguments, and objects or functions which are its values.

We have seen that in Frege's *Begriffsschrift* expressions are built up out of simpler expressions in a systematic way. Frege's theory of quantification fits into this enterprise. Expressions of generality are introduced by means of a construction step that forms a universal expression out of a simpler expression. The construction step of universal generalization can be applied to expressions containing a (capital Greek) letter that has one or several occurrences in argument position. The operation of universal generalization places a Gothic letter in front of the expression and replaces all occurrences of some letter in argument positions by the same Gothic letter that was placed in front to indicate which argument positions the quantification applies to.

Thus, '$\Gamma(\Delta)$' is an expression in which 'Δ' occupies an argument position. The expression can be paraphrased as 'Δ has property Γ'. Now '$(\mathfrak{a})\ \Gamma(\mathfrak{a})$' is the result of applying universal generalization to the argument position occupied by 'Δ', and it expresses that everything has property Γ. Existential quantification is covered by a combination of negation and universal quantification.

The notation for universal quantification serves two different purposes. The Gothic letter that is placed in front serves to indicate the *scope* of the quantification, and the places where the same Gothic letter appears in the expression that the quantification is applied to serve to indicate the argument slots that are quantified over.

Frege's theory of quantification is a very important historical step. In Aristotelian logic, the only inferences that are studied are those that use sentences with at most one expression of generality. In Medieval logic attempts had been made to extend the theory to make it cover types of reasoning with sentences containing several expressions of generality. The proposals of this so-called *suppositio*-theory, although subtle, were completely *ad hoc*. The concern was with the manner in which the application of a quantified expression to an object is influenced by other quantified expressions in the same sentence. This resulted in descriptions of staggering complexity for the case of as little as three interacting quantified expressions.

Frege had the striking insight that it is enough to give a general description of how the introduction of a universal quantifier in an expression A affects the meaning of A. Now the problems of the interaction of quantifiers take care of themselves: if the expression A already contains quantified phrases, then A in its turn has been construed from simpler expressions by means of steps that have involved universal quantifications. Of course, Frege's insight has become such an integral part of our logical heritage that we have trouble to apprehend the magnitude of this discovery. A vivid evocation of the context in which the discovery was made is offered in Dummett (1973).

It is not quite clear to what extent Frege's view of variables differs from our modern view. Frege does not use the term 'variable' at all. One commentator remarks that Frege disliked the term for historical reasons (Geach (1962:139)). In section 11 of the Begriffsschrift Frege draws attention to the fact that the uniform substitution of bound Gothic letters in quantified expressions can cause trouble in case the Gothic letter that the substitution is made for occurs in the scope of another quantifier. In this case wrong bindings may result. This danger does not exist if the Gothic letter is bound by a universal quantifier that has maximal scope. For this reason Frege can introduce a special abbreviation in this case: an expression in which a small Roman letter occurs in one or more argument places abbreviates an expression in which a Gothic letter at these argument places is bound by a universal quantifier with maximal scope.

When Frege uses two small Roman letters and writes:

f(a),

(this is his notation) it is tempting to interpret this as an expression in which the function sign f is used as a free predicate variable and the argument sign a as a free object variable. Talk of free variables hinges on the possibility to evaluate a formula in models with different interpretation functions for the predicate letters, and on the use of different *assignments* for the object variables (cf. section I.1.4). The perspective that distinguishes between different intended models is alien to Frege, however. Switching to the modern notation in which upper case letters may stand for predicate variables, lower case letters for individual variables, we may say that Frege's expression is just a syntactic abbreviation for

/\P/\x P(x),

an expression in which no free variables occur. Likewise, Frege's axiom

(c=d) -> (f(c) -> f(d))

should be read as

/\P/\x/\y((x=y) -> (P(x) -> P(y))).

Frege never hints at the similarities between deictic third person personal pronouns in natural language and the small Roman letters in the *Begriffsschrift*, although he saw the general parallel between pronouns and the Gothic letters that appear in argument places in his notation. This also indicates that his view on variables differs more from ours than appears at first sight.

Frege remarks that natural language can play tricks in connection with different phrases that can occur as grammatical subject of a sentence. It is tempting to assign the same logical structure to the following sentences:

(a) The number 20 can be written as a sum of four square numbers.

(b) Every positive whole number can be written as a sum of four square numbers.

What is wrong with this, according to Frege, is that the expressions 'the number 20' and 'every positive whole number' have different *rank*. The second one, in contradistinction to the first, does not by itself give rise to 'eine selbstandige Vorstellung', but can only be interpreted in the context of the whole expression. It is indeed the case that in the sign language translation of the second sentence no single expression corresponds to 'every positive whole number'. Note, however, that this is not in general the case for universal NPs, if we take the abbreviation that was mentioned above into account:

(c) Everything is a number

can be rendered in the *Begriffsschrift* as

(d) Γ(a),

if one takes 'Γ' to be a functional sign for being a number. This again suggests that the small Roman letters are not to be viewed as free variables, but as a means to abbreviate the expression that reveals the *real* logical form of a judgement.

Two principles are central in Frege's account of quantification: the principle of *compositionality* and the closely connected principle of *contextuality*. The *compositionality*-principle says that the meaning of a complex expression depends in a systematic way on the meanings of the components from which the expression is construed in a step by step process. Frege does not often state this principle *explicitly* in his writings, but nevertheless it always looms large in the background (cf. Janssen (1983), chapter 1 for more details). According to the principle of *contextuality* the meaning of a phrase cannot be studied in isolation, but must always be viewed as related to the context in which the phrase appears. In Frege's view, particularly the meanings of function-denoting expressions must always be studied in context.

I.1.2 Peirce's Theory of Quantification

Independently of Frege an account of quantification was developed by logicians inspired by the approach of G. Boole: A. De Morgan, C.S. Peirce and E. Schröder attempted to extend the theory of Boolean algebra to include a theory of relations.

In a paper of 1883, C.S. Peirce introduces relational signs with subscript indices, where the indices show what individual things and what number of them were connected by a certain relation in what order. (Cf. Peirce (1931-58, III, Sections 328-58).) Moreover, these indices are combined with the symbols $\sum$ and $\prod$, both with an adjacent index, that Peirce also introduces in this article. Peirce calls these operators 'quantifiers', and interprets them as 'some' and 'every'. If a finite universe is considered, the quantifiers can be used to abbreviate logical additions and multiplications. In an infinite universe, the quantifiers stand for the same operations in an extended sense.

In this symbolism, 'everything loves something' will look like this (I repeat some examples that Peirce himself gives):

$$\prod_i \sum_j L_{ij} = (L_{11} + L_{12} + L_{13} + \text{etc}) \cdot (L_{21} + L_{22} + L_{23} + \text{etc}) \cdot \text{etc}$$

'Something is loved by all things' is expressed thus:

$$\sum_j \prod_i L_{ij} = (L_{11} \cdot L_{21} \cdot L_{31} \cdot \text{etc}) + (L_{12} \cdot L_{22} \cdot L_{32} \cdot \text{etc}) + \text{etc}$$

Peirce remarks that his theory of relations may be used to rephrase the subject-predicate distinction of olden times: he proposes to regard the designations of the indices of the relation signs as *logical subjects* and the relation as the *predicate*, or, alternatively, to take the entire set of logical subjects as a *collective subject*, of which the relation sign predicates something.

Next it is shown that the symbolism can be used to express what we now call second-order properties. 'If i and j are identical, then they have the same properties' can be written with the help of "the general index of a token X" (i.e., 'X' is a sign that functions as a free property variable) as follows:

$$\Pi_i \Pi_j (I_{ij} + \overline{X}_i + X_j)$$

(bars are used for negation, 'I' designates the identity relation). In the reverse statement the universal quantification over properties does not have maximal scope, so to express this statement a free property variable will not do. Still unaware - of course - of the paradoxes of naive set theory, Peirce proposes to use a relation sign 'q' that signifies the relation that holds between a quality and its subject (or a class and its members). With this sign the statement can be expressed without further ado. It is not necessary, however, to make use of the relation q. As Peirce himself puts it, we can proceed "by using the index of a token and by referring to this in the Quantifier just as subjacent indices are referred to". Thus the definition of identity can be given by means of a formula that quantifies over properties:

$$I_{ij} = \Pi_X (X_i X_j + \overline{X}_i \overline{X}_j)$$

These remarks about the identity relation make it clear that in Peirce's theory, as in Frege's, no distinction between first- and higher-order logic is drawn.

Thus, Peirce, like Frege, has presented a general theory of quantification, but here as well there is still a long way to go before one arrives at the first-order predicate calculus and the model-theoretic perspective (the insight that logical languages can be systematically studied by considering their interpretation in appropriate set-theoretic structures called models; cf. I.1.4). Things are more diffuse here than in Frege's work: Frege never treats classes or qualities as objects.

On the other hand, the theory of Peirce, as developed by Schröder, did proceed in the direction of model-theoretic considerations. Schröder considers various domains and asks questions like "Given an equation between two expressions of the relational algebra, are there relations in the domain that satisfy the equation ?" (Cf. Goldfarb (1979) p. 354.)

I.1.3 Skolem on Functional Quantification

Thoralf Skolem was the first logician to speak of first-order propositions (German: *Zahlaussagen*) and to treat them not only in the context of equations, as was the use and wont in the 'algebraist' school of Boole, Peirce and Schröder (Löwenheim, who belonged to this tradition, still talked only of *Zahlausdrücke* for propositional equations, in the proof of his theorem, published in 1915), but *by themselves*. A proposition by itself must be read as an assertion that certain relations do or do not hold between individuals.

In Skolem's extension of the Löwenheim theorem (Skolem (1920)) where it is proved that any model for a countable set of first-order propositions contains a denumerable submodel for these propositions, use is made of *Skolem functions*. First it is shown that any first-order proposition can be expressed in prenex form (i.e. as a sequence of quantifiers Q followed by a quantifier-free part *a*). Given the Axiom of Choice, if a proposition *p* (without loss of generality we may suppose that *p* is in prenex form) is satisfied in a model, there exists, for every existential quantifier Q in *p*, a function that takes, as arguments, values for all variables bound by a universal quantifier that governs Q, and that yields values for the variables bound by Q such that *p* is made true. Any countable set of propositions gives rise to at most countably many Skolem functions, and therefore the quantification involved in the formulas under consideration does not lead us out of the domain of the countable.

As an example, consider the first-order proposition (a). *a* is a quantifier-free part, so (a) is in prenex form. Now (b) is an equivalent for (a) (given the Axiom of Choice) in Skolem Normal Form.

(a) $/\backslash x_1 \ldots x_n \backslash/ y \ \underline{a}$

(b) $\backslash/ f /\backslash x_1 \ldots x_n \ \underline{a}\ [f(x_1, \ldots, x_n)/y]$

The notation "a $[f(x_1,...,x_n)/y]$" means that in a the variable 'y' is replaced, everywhere it occurs, by the expression '$f(x_1,...,x_n)$'. Thus in (b) the variable 'y' that is existentially quantified over is replaced by a term that uses the Skolem function 'f' to express the dependence of the existential quantification on the universal quantifiers $/\backslash x_1, \ldots, /\backslash x_n$.

Skolem presents his analysis of quantification by means of Skolem functions as an exploration of the 'maximal effect' a quantifier can have. Skolem functions play a rôle in Hintikka's game-theoretical semantics (cf. chapter V and the references given there) and in proposals for the analysis of 'branching' quantification in natural language (cf. Hintikka (1979) and Barwise (1979)).

The clear separation of syntax and semantic notions, the delineation of the realm of first order quantification theory, the elucidation of the notion of satisfiability, all were accomplished in Gödel (1930), Gödel's dissertation, which contains the proof of the completeness of first order predicate logic. The completely formal definition of the notions of satisfiability and truth that made it into the textbooks first appeared in Tarski (1933).

I.1.4 Tarski on Quantification, Satisfaction and Truth

Tarski (1933) (the English translation of which appeared in Tarski (1956)) offers the first crystal-clear discussion of the discipline of semantics, the study of the relations between expressions of a logical language and the objects that are denoted by these expressions. The aim of the paper is to give a precise definition of what it means for the sentences of a given logical language to be true. Tarski's theory of truth is classified in philosophical circles as a version of the so-called correspondence theory of truth.

In the first section of his paper Tarski briefly considers the problem of defining a notion of truth for natural languages. He puts this aside as a hopeless task, because of the Paradox of the Liar. Let 'c' be an abbreviation for "the sentence that occurs on line 19 of this page". Then the sentence

c is not a true sentence

is paradoxical. We derive a contradiction as follows. First we note that it is an empirical fact (in view of what 'c' stands for) that

(a) 'c is not a true sentence' is identical with c.

An explication of truth for a sentence 'x' will have the form:

(b) x is a true sentence if and only if p

where 'x' can be replaced by any name for the sentence, and 'p' expresses its content. But any explication of truth for 'c' that is of type (b) will result in:

(c) 'c is not a true sentence' is a true sentence if and only if c is not a true sentence.

Combining (a) and (c) we get the contradiction:

(d) c is a true sentence if and only if c is not a true sentence.

In natural language the concept of truth is expressible, and the attempt to provide a definition of truth for sentences that themselves talk about truth, directly leads to the Paradox of the Liar. Tarski concludes that it is impossible to define truth for natural language. (This conclusion might be circumvented by defining truth for fragments of natural language that do not admit self-reference, or by modifying the concept of truth (cf. Kripke (1975).)

In the context of formal languages the Liar Paradox can be avoided by drawing a distinction between the language that is the object of study (the 'object-language'), and the language that is used for talking about the object-language and for formulating the concept of truth for the object-language (the 'meta-language'). As long as we suppose that the concept of truth-for-the-object-language is not expressible in the object-language itself, we are invulnerable to the Liar.

Let L be a first order language in which k predicate constants occur with $r_1, \ldots, r_k$ arguments, respectively. A model M for L is a k+1-tuple $\langle E, R_1, \ldots, R_k \rangle$, where E is a non-empty set, each R_i is a relation with r_i arguments ranging over E $(i = 1, .., k)$. E is the domain of the model, the R_i are relations of the right polyadicity (number of arguments) to serve as the interpretations of the predicate constants. (If L also contains individual constants and function symbols, then the model must provide appropriate interpretations for these too. For the sake of simplicity, individual constants and function symbols will be disregarded here.) An interpretation for L in M is a function F that maps the predicate-symbols of L to relations of the domain of the right polyadicity. It is convenient to redefine a model M for L as a pair $\langle E,F \rangle$, where E is the domain and F is an appropriate interpretation function for L in E.

Tarski gives a recursive definition of truth in M for sentences of L. A problem is that sentences that involve quantification generally do not have sentences as parts, but open formulas. An open formula of L is a well-formed formula of L in which there are one or more occurrences of free variables (variables not in the scope of a quantifier); a sentence of L is a well-formed formula of L in which all variables are bound. It is impossible to define truth for open formulas without taking a decision on the interpretation of the free variables that occur in them. Here Tarski employs the device of an <u>assignment</u> of values to the variables of the language. Let U be the set of free variables of L. A value-assignment to the variables of L in M is a function with domain U and range $\subseteq$ E.

With the help of this notion we can recursively define what it means that an arbitrary well-formed formula ϕ of L is true in M relative to an assignment b, or, in other words, that b satisfies ϕ in M. Notation: $M \models \phi\ [b]$. Here '$M \models$' stands for 'truth in model M'.

I will present Tarski's truth definition by using a function $[\![\ ]\!]$ that maps any well-formed formula of L to a set of assignments. This presentation has the advantage that it emphasizes Tarski's use of Frege's compositionality principle. The definition of $[\![\phi]\!]$ proceeds by recursion on the complexity of ϕ. Let U be the set of free variables of L. Let E be the domain of the model M. Let G be the set of all assignments with domain U and range $\subseteq$ E.

If ϕ is an atomic formula, then ϕ is of the form $Pv_1..v_n$, where P is an n-ary predicate symbol, and $v_1, .., v_n$ are individual variables. Now we define: $b \in [\![\phi]\!]$ iff the elements of E that b assigns to $v_1, .., v_n$ stand in the n-ary relation R that interprets the predicate constant P (i.e. the relation R such that R = F(P)).

For complex formulas we make use of semantic operations that correspond to the syntactical operations for formula-construction. To the syntactic negation-operation corresponds the semantic operation of taking complements, to conjunction corresponds the operation of taking intersections, to disjunction corresponds the operation of taking unions. We stipulate:

If ϕ has the form $\neg\psi$, then $[\![\phi]\!] = G - [\![\psi]\!]$

If ϕ has the form $(\psi \& \chi)$, then $[\![\phi]\!] = [\![\psi]\!] \cap [\![\chi]\!]$.

If ϕ has the form $(\psi \text{ v } \zeta)$, then $\llbracket\phi\rrbracket = \llbracket\psi\rrbracket \cup \llbracket\zeta\rrbracket$.

If ϕ has the form $(\psi \text{ -> } \zeta)$, then $\llbracket\phi\rrbracket = (G - \llbracket\psi\rrbracket) \cup \llbracket\zeta\rrbracket$.

In the steps that treat the quantifiers we need a new piece of notation. Here we use 'b [y/d]' for: the assignment that is like b but with the possible difference that variable y is mapped to object d. Assignments for a universal formula (/\x ψ) can be formed out of assignments for the subformula ψ by taking those assignments that work for ψ for *all* values that the assignment could possibly take for the argument x. Similarly for existential formulas \/x ψ (take the assignments that work for for ψ for *some* value that the assignment could possibly take for the argument x). More formally, we stipulate:

If ϕ has the form (/\x ψ), then $\llbracket\phi\rrbracket =$

$$\{\ b \mid b\,[x/d] \in \llbracket\psi\rrbracket, \text{ for } \underline{\text{every}}\ d \in E\ \}.$$

If ϕ has the form (\/x ψ), then $\llbracket\phi\rrbracket =$

$$\{\ b \mid b\,[x/d] \in \llbracket\psi\rrbracket, \text{ for } \underline{\text{some}}\ d \in E\ \}.$$

This completes the definition of '$\llbracket\phi\rrbracket$', for arbitrary formulas ϕ of the language L. Now we simply define: $M \models \phi\,[b]$ if $b \in \llbracket\phi\rrbracket$.

The following is easy to prove by formula-induction: If b_1 and b_2 are assigments such that for every variable y that is free in ϕ, $b_1(y) = b_2(y)$, then: $M \models \phi\,[b_1] \iff M \models \phi\,[b_2]$. This means that only the (finite) part of the assignments that provides values for the free variables in a formula is relevant. In other words: in the definition above we could have used *finite* assignments instead of infinite ones.

A direct corollary is: if ϕ is a sentence, then we have for all pairs of assignments b_1, b_2:

$$M \models \phi\,[b_1] \iff M \models \phi\,[b_2].$$

Because of this we can now define truth for sentences as follows:

$M \models \phi$, ϕ is true in M, if, for some assignment b, $M \models \phi\,[b]$.

I.1.5 The Generalized Quantifier Perspective

In the nineteen-seventies the American philosopher and logician Richard Montague inaugurated a new kind of logico-semantic analysis of natural language that started the tradition of Montague-grammar. The framework of Montague Grammar plays an important part in this dissertation (cf. chapters III and IV below). In this section I will be concerned with the history of Montague's ideas about quantification in natural language.

One of Richard Montague's innovations in the logico-semantic analysis of natural language is his 'Proper Treatment' of quantification (cf. Montague (1973), henceforth 'PTQ'). According to Montague the proper way to treat Noun Phrases in natural language is a uniform way. Montague proposes to treat all NPs as predicables of predicables. Barring the technicalities of Montague's intensional treatment (see chapter III), an NP is interpreted as a set of sets of entities. The NP 'every man' is interpreted as the set of all sets that include the set of men; the interpretation of the NP 'a man' is the set of all sets that contain at least one man; the interpretation of 'the man' is the set of all sets that contain the one and only man that is in the domain, in case there is a unique man in the domain, the empty set otherwise. For reasons of structural uniformity this treatment is extended to cover proper names as well: the interpretation of the NP 'John' is the set of all sets that have the individual John as a member.

It follows from this treatment that the determiner in NPs of the form $[_{NP}$ Det CN $]$ is interpreted as a relation between sets. Consider a sentence of the form $[_{S}$ $[_{NP}$ Det CN $]$ VP $]$, e.g. the sentence 'every man walks'. The determiner 'every' denotes a relation between the set of men and the set of walkers, vid. the relation of inclusion: 'every man walks' is true iff the set of men is included in the set of walkers. In the case of 'a man walks' the relation is that of having a non-empty intersection: 'a man walks' is true iff the intersection of the set of men and the set of walkers is non-empty.

The logical foundations of the Generalized Quantifier perspective on NPs in natural language, a perspective in which noun phrases are interpreted as sets of sets, and NP-determiners as relations between sets, have already been laid in an article by Andrzej Mostowski (Mostowski (1957)). This historical connection has never been emphasized in print, however, until Barwise & Cooper (1981) appeared. (J.E. Fenstad has made the link to Mostowski before, though, in several talks; cf. the introduction in Fenstad (1984).)

Mostowski defines a quantifier limited to domain A (a limited quantifier) as a function from one-place predicates B on A to {0,1} that respects permutations of A. Thus:

Q(A) is a <u>quantifier limited to A</u> iff

(i) Q(A) is a function $Q(A) : C \rightarrow \{0,1\}$, where C is the set of one-place predicates on A. (Note that in the finite case C = P(A). In the infinite case it may be that there are more sets than predicates, for presumably the number of predicates is denumerable.)

(ii) $Q(A)(B) = Q(A)(F[B])$ for all $B \in C$ and all permutations F on A.

Condition (ii) expresses the requirement that a limited quantifier should be indifferent to anything but the <u>amount</u> of the elements that satisfy a one-place predicate which is argument to the quantifier.

Any quantifier limited to a set A can be fully characterized by a function T from pairs of cardinal numbers (m,n) that satisfy the equation $m+n = |A|$, to {1,0}. Given a set A, let T be such a function. Then the quantifier $Q_T(A)$ limited to A (I will call A the 'limit set') that is determined by T is defined thus:

For any one-place predicate B on A, $Q_T(A)(B) = T(|A-B|,|B|)$.

Note: for ease of comparison with the modern literature on generalized quantifiers I have interchanged the two argument places of the function T.

To see that $Q_T(A)$ is a limited quantifier, observe that it fulfils (i) and (ii) of the above definition. For (ii), notice that, for any permutation F of A:

$$\begin{aligned} & Q_T(A)(F[B]) = Q_T(F[A])(F[B]) \\ & = T(|A-F[B]|,|F[B]|) = T(|F[A]-F[B]|,|F[B]|) \\ & = T(|F[A-B]|,|F[B]|) = T(|A-B|,|B|) = Q_T(A)(B). \end{aligned}$$

Next, an *unlimited* quantifier is defined as a function Q that assigns to every set A a quantifier Q(A) limited to A satisfying condition (*).

* For any one-one mapping G with domain(G) = A it holds that $Q(A)(B) = Q(G[A])(G[B])$. (Remember that $B \subseteq A$ for all predicates B on which Q(A) is defined.)

It is easy to see that condition (*) entails condition (ii) in the definition of a limited quantifier (take G in (*) to be a permutation of A and observe that now $G[A] = A$).

Every function T from pairs of cardinal numbers (m.n) to {1,0} determines an unlimited generalized quantifier Q_T:

For any limit set A and one place predicate B on A,
$Q_T(A)(B) = T(|A-B|,|B|)$.

If the unlimited quantifier Q is determined by T, then for any limit set A, Q(A) is determined by $T \upharpoonright \{(m,n) \mid m+n = |A|\}$. If one limits attention to the finite case the arguments m, n in the characterizing function T can be viewed as natural numbers, and we can employ ordinary arithmetic.

Some examples of generalized quantifiers given by Mostowski are: If Q is determined by T such that $T(m,n)=1 \Leftrightarrow m = \underline{k}$, then Q(A)(B) means: 'exactly $\underline{k}$ A's are B's'. If Q is determined by T such that $T(m,n)=1 \Leftrightarrow n = \underline{k}$, then Q(A)(B) means: 'exactly $\underline{k}$ A's are not B's'. Similarly, 'exactly $\underline{k}$ or exactly $\underline{q}$ A's are B's', 'at most finitely many A's are B's', 'infinitely many A's are B's or infinitely many A's are not B's' can be defined. Note that m,n,k do not range over natural numbers only, but over all cardinalities.

The article of Barwise & Cooper has given rise to a renewed interest in generalized quantifiers, and to a series of articles in which noun phrases in natural language are studied in this perspective (cf. Van Benthem (1983b,1984), Westerståhl (1982,1984) and Zwarts (1983,1985)). For a study of traditional logic in the generalized quantifiers perspective, cf. Van Eijck (1984b). In the rest of this section the interpretations of determiners will, by a small sleight of hand, be referred to as 'determiners', and 'D_E' will be used to refer to determiner D on domain E.

The relational perspective on determiners suggests a very natural way of distinguishing, inside of the set of determiners, between determiners that are expressions of quantity (like 'every', 'all', 'some', 'most'), and determiners that are not (like 'my', 'the', 'John's'). Determiners that form quantifiers satisfy the following intuition (given a domain of discourse E):

QUANTITY For all permutations F of E, for all $A,B \subseteq E$,
D_EAB iff $D_EF[A]F[B]$

The intuition expresses that only the <u>cardinalities</u> of the sets A and B matter.

Another intuition that is satisfied by many determiners is the following:

CONSERVATIVITY For all $A, B \subseteq E$, ($D_EAB \iff D_EA(A \cap B)$)

The property of conservativity holds for all 'ordinary' determiners. An exception is 'only', but it is questionable whether this expression is syntactically in the same class with 'all', 'some', 'no', etc. Conservativity plays an important rôle in Barwise & Cooper (1981) (they call it the <u>live-on property</u>).

A third intuition about determiners is:

EXTENSION For all $A, B \subseteq E \subseteq E'$ ($D_EAB \iff D_{E'}AB$)

Determiners that observe EXTENSION are stable under growth of the universe. EXTENSION plus CONSERVATIVITY is equivalent to the following property (cf. Westerståhl (1984)):

STRONG CONSERVATIVITY For all A, B $\subseteq$ E ($D_E AB \Leftrightarrow D_A A(A \cap B)$)

Thus, conservativity plus extension permit us to suppress the parameter E. Conservativity plus extension ensure that the truth of DAB depends only on A and $A \cap B$. If D also observes quantity the truth of DAB depends only on the cardinal numbers $|A|$ and $|A \cap B|$ (or, equivalently, on $|A-B|$ and $|A \cap B|$).

In the modern literature on generalized quantifiers, a quantifier-forming determiner is a relation between sets of individuals A and B, that fulfils the requirements of QUANTITY, CONSERVATIVITY, and EXTENSION. The denotation of an NP that has a quantifier-forming determiner is a (modern-style) quantifier.

Mostowski's unlimited quantifiers correspond to modern-style forming determiners, and his limited quantifiers to modern-style quantifiers. More concretely: (i) Mostowski unlimited quantifiers observe QUANTITY, CONSERVATIVITY and EXTENSION; (ii) if Q is a Mostowski unlimited quantifier, then the relation

$$Q+ = \{\langle A,B\rangle \mid QA(A \cap B)\}$$

is a modern-style quantifier-forming determiner, and if Q is a modern-style quantifier-forming determiner, then

$$Q- = \{\langle A,B\rangle \in Q \mid B \subseteq A\}$$

is a Mostowski unlimited quantifier. The 'blow-up' function '+' is the inverse of the 'cut-off' function '-'.

In Van Benthem (1984) and Westerståhl (1984), where attention is restricted to finite domains, numerical relations on $\omega \times \omega$ are used to characterize quantifier-forming determiners. Each quantifier-forming determiner Q is characterized by a relation R_Q on $\omega \times \omega$. The connection is:

$$QAB \Leftrightarrow R_Q(|A-B|, |A \cap B|).$$

Observe that in the finite case, Mostowski's T-function for the Mostowski quantifier Q is the characteristic function of R_{Q+}.

I.2 Natural Language Quantification and Specific Issues

I.2.1 Quantification and Definite Descriptions

It is surprising that Frege's theory of descriptions is much less known in linguistic circles than Russell's. One of the reasons for this may be the circumstance that the theory is not recognized as a theory of descriptions at all, because Frege sometimes uses the term *Eigenname* (proper name) in a very wide sense, to include all designations for objects whatsoever. In *Ueber Sinn und Bedeutung* (Frege (1892)), the author introduces the example 'Die negatieve Quadratwurzel aus 4' as follows:

> Wir haben hier den Fall, das aus einem Begriffsausdrucke ein zusammengesetzter Eigenname mit hilfe des bestimmten Artikels im Singular gebildet wird, was jedenfalls dann erlaubt ist, wenn ein Gegenstand und nur ein einziger unter den Begriff fällt. (Frege (1892) pp. 41-42)

In Frege (1891) a different terminology is used: here the author distinguishes between proper names in the narrow sense and expressions formed with the help of a definite article that 'take the place of a proper name'.

Frege makes it clear that the use of a proper name in his wide sense must always rest on the presupposition that the object-designating expression indeed designates one and only one object. That the presupposition does not figure in the *sense* of the sentence in which such a proper name occurs, can be seen from the fact that if one negates the sentence, the same presupposition remains in force.

As can be gathered from the above quotation, Frege considers it a defect of natural language that cases where the presupposition annex to an object-designating expression is not fulfilled, do occur. In a formal language this defect must be remedied. In Frege (1893: section 11) the use is proposed of a special function $\backslash F$ for certain object-denoting expressions for which natural language uses the definite article. (Again in what follows I do not adopt Frege's notation in full.)

Frege calls a functional expression 'F' that denotes a one-place function from objects to truth-values a *concept*. Suppose 'F' is a concept. Then $\overset{,}{x}F(x)$ denotes $\{x|F(x) = 1\}$. Frege calls $\overset{,}{x}F(x)$ the *Wertverlauf* of 'F'. Now a function \ can be defined as follows: (i) for all F such that $\overset{,}{x}F(x) = \overset{,}{y}(y = a)$, for some specific object a, $\backslash F = a$; (ii) for all other F, $\backslash F = \overset{,}{x}F(x)$. It will be clear that \ fulfils the role of the definite article in descriptions that designate one and only one object. Consider e.g. the description 'the man who discovered the elliptic form of the planetary orbits'. Here 'man who discovered the elliptic form of the planetary orbits' or, to rephrase this expression in a logically more perspicuous way, 'man _ and _ discovered the elliptic form of the planetary orbits', is a functional symbol with a concept as its sense. We are here in case (i), for as a matter of fact:

> $\overset{,}{x}$[man (x) and (x) discovered the elliptic form of the planetary orbits] = $\overset{,}{y}$(y = Johannes Kepler).

So '\ man who discovered the elliptic form of the planetary orbits' designates Kepler. For an example of the other case, consider Russell's famous example 'the present king of France'. The sense of 'present king of France' is again a concept, but now, due to historical circumstances, there is no a such that $\overset{,}{x}$[present king of France (x)] = $\overset{,}{y}(y = a)$, According to clause (ii) of the above definition, '\present king of France' designates the empty set. This same clause tells us that '\present inhabitant of Holland' designates the set of all inhabitants of Holland at the moment.

The second clause of the definition of '\' has the purpose of removing the 'defect' of natural language that in some cases expressions that are used to denote objects by description do in fact describe nothing at all or too many things. This defect is remedied by an arbitrary stipulation that has for its sole purpose that sentences in which object-denoting expressions are used infelicitously will turn out false. To see how this works one must keep in mind that Frege conceives of functions that take objects as arguments as being defined for any object. Thus, the sentence '3 is a woman' has a sense and a reference, but of course the reference is the falsum (but note that as a result of this 'it is not the case that 3 is a woman' will turn out true). '\ present inhabitant of Holland is happy' has the same sense as 'the class of present inhabitants of Holland is happy', but as no class can be happy, both sentences designate the falsum.

Frege recognizes that natural languages contain expressions that in certain circumstances can cause sentences involving them to lack a truth value. By means of the introduction of the functional sign '\' he undertakes a reform of language that has as a result that the formal language equivalents of such sentences designate the falsum. This reform is rather drastic, for it has the result that the negations of such 'artificially false' sentences become true. In a footnote to Frege (1892), the author considers a different solution of the problem of object-designating expressions that fail to designate a unique referent:

> Nach dem oben Bemerkten müste einem solchen Ausdrucke eigentlich durch besondere Festsetzung immer eine Bedeutung gesichert werden, z. B. durch die Bestimmung, dass als seine Bedeutung die Zahl 0 zu gelten habe, wenn kein Gegenstand oder mehr als einer unter den Begriff fällt. (O.c., footnote to page 42.)

It seems that the exact manner in which the truth value gap caused by a failure of presupposition is closed, is immaterial to Frege.

Bertrand Russell is famous in philosophical as well as linguistic circles for his theory of descriptions. Russell's theory of descriptions is technically not very remote from Frege's. Let us technically compare the two proposals. About the definite article 'the' Russell says in 1903: "The word the, in the singular, is correctly employed only in relation to a class-concept of which there is only one instance." (Russell (1903), section 63.) This is close to Frege: in cases where the description fails to denote a single object, its use is incorrect.

Unlike Frege, however, Russell does not supplement this verdict with a proposal for language reform.

In the famous article 'On Denoting' (1905), Russell expounds a different view. Here he states that definite descriptions are not genuine constituents of the expressions in which they occur, and he suggests the following way to eliminate a definite description 'the x F(x)' from a sentence 'G[the x F(x)]', where G is a one-place predicate: rewrite the sentence as

(a) \/x (F(x) & /\y (F(y) -> y = x) & G(x))

It is clear from this example that what Frege regarded as a presupposition of the use of a definite description is treated by Russell as part of the assertion. Moreover, the rephrasing according to this recipe is presented as expressing the *real* logical form of a sentence that contains a definite description.

Russell stresses the importance of the fact that the elimination mechanism for definite descriptions is contextual: what the paraphrase will look like depends on what is taken as the sentence from which the description is to be eliminated. If a description occurs as a constituent of an embedded sentence or as a subject of a complex predicate, there are several non-equivalent ways to proceed. There are, e.g., two ways to eliminate the description from

(b) A said that G[the x F(x)]

The resulting paraphrases are (c) and (d).

(c) \/x (F(x) & /\y (F(y) -> y = x) & A said that G(x))

(d) A said that \/x (F(x) & /\y (F(y) -> y = x) & G(x))

Similarly for '¬G[the x F(x)]'. In (c) the description is eliminated from the whole expression; in (d) the embedded expression is taken as the context of elimination. Descriptions that are to be eliminated in the first way are said in 'On Denoting' to have *primary*, the others are said to have *secondary* occurrence. This terminology is unfortunate, as the number of possibilities depends on the complexity of the whole expression, and in later publications Russell drops it.

In 'On Denoting' Russell mentions three puzzles that can serve as touchstones for theories of description. One is used to dismiss Meinong's theory, the other two are relevant for the comparison with Frege's view. The first problem is that of the substitution of terms with the same referent within the scope of a propositional attitude verb. Russell's example is (e):

(e) George IV. wished to know whether Scott was the author of *Waverley*.

The second problem is that the law of excluded middle does not seem to hold for certain sentences that involve definite descriptions. Russell's examples are (f) and (g):

(f) The present King of France is bald.

(g) The present King of France is not bald.

Neither (f) nor (g) seems to be true.

Russell solves both problems by means of his scope-distinction: (g) can be seen to be true in the paraphrase that gives the description 'the present King of France' secondary occurrence (or: narrow scope with respect to the negation-operator), so the law of excluded middle is not violated, after all; likewise, the description in (e) has for its scope the embedded sentence. The substitution of the name 'Scott' for the description is not allowed, for in the paraphrase the description has disappeared as a phrase that occupies an argument-slot.

Technically, both the proposal of Frege and the theory of Russell can be seen as means of preserving the law of excluded middle. In this respect both theories are equally successful. In sentences of the form 'G(the x F(x))', where G is a predicate that may be complex but that does not involve a propositional attitude verb, Frege's translation 'G(\F)' has the same truth conditions as '\/x (F(x) & /\y (F(y) -> y = x) & G(x))', the result of Russellian wide-scope elimination. With respect to the other readings that Russell gets in case G is complex, Frege flatly denies that these are feasible readings for the sentence under consideration: "Wenn man etwas behauptet, so ist immer die Voraussetzung selbstverständlich, dass die gebrauchten einfachen oder zusammengesetzten Eigennamen eine Bedeutung haben." (Frege 1892), p. 40.) (Of course the extra readings Russell gets can be expressed in Frege's symbolism; Frege's symbolism is as rich as Russell's.)

Most linguists would side with Frege rather than Russell on this issue of presuppositions, I suppose. Frege is also linguistically more careful than Russell in that he presents his theory of descriptions as a proposal for language <u>reform</u>, useful - or indeed necessary - in scientific contexts, whereas Russell seems to claim that his theory can serve as an <u>analysis</u> of the way descriptions function in natural language.

The wide philosophical cleft that yawns between the two theories becomes evident if one compares the treatments of descriptions in embedded sentences. According to Frege sentences embedded under an attitude verb denote what in ordinary contexts are their senses. The proper names and descriptions that occur in them likewise refer to their ordinary senses, and this explains the failure of substitutivity of denoting expressions that <u>ordinarily</u> have the same referents. Russell suggests that the scope distinctions that he is able to draw by means of the different paraphrases for sentences that involve subordinate sentences in which a definite description occurs, are sufficient in itself to explain the failure of substitutivity in these contexts. He therefore drops as unnecessary and confusing Frege's distinction between sense and reference and the hypothesis that phrases in embedded sentences have as reference what in ordinary contexts are their senses.

Russell's bold claim is not justified without further ado. His theory explains why substitution of 'Scott' for 'the author of <u>Waverley</u>' is not permitted if the description is taken to have narrow scope. It incorrectly predicts, however, that such a substitution is allowed in the other case. According to Russell, the wide scope reading for the description in the George IV example "might be expressed by 'George IV. wished to know, concerning the man who in fact wrote *Waverley*, whether he was Scott'. This would be true, for example, if George IV. had seen Scott at a distance, and had asked 'Is that Scott?'." (Russell (1905), p. 489.)

In the situation that Russell mentions here, George IV is again not interested in the law of identity. This fact does not square with his theory, however. A formal rendering of the paraphrase for the sentence would be:

(h) \/x (A(x) & /\y (A(y) -> y = x) & G(x)),

where 'G(x)' is an abbreviation for 'George IV. asked whether x = Scott'. The following sentence is true as a matter of fact:

(i) The author of Waverley is identical to Scott.

There is only one way to eliminate the description from (i), and the formal result of this elimination is (j):

(j) \/x (A(x) & /\y (A(y) -> y = x) & x = Scott).

By elementary predicate-logical reasoning we can deduce from the conjunction of (h) and (j):

(k) G(Scott).

(k) is an abbreviation for 'George IV. asked of Scott whether he was Scott', so the king of England turns out to have been interested in the law of identity after all.

One way to avoid this unfortunate conclusion and hold on to the theory is to deny that (i), (j) and (k) are proper logical forms, for the reason that 'Scott' is not a *proper* proper name but a definite description in disguise. If one supposes that this description has secondary occurrence in (h), the inference is blocked. Thus Russell's theory of descriptions leads directly to the philosophy of logical atomism, according to which the only real proper names are expressions that necessarily involve existence of a unique referent, like 'this' and 'that' as names for sense data the speaker is immediately aware of. Apart from the fact that this view involves all kinds of serious metaphysical and epistemological difficulties, we must note as a point of methodology that <u>ceteris paribus</u> a philosophy of language that does not prejudge about matters of epistemology and metaphysics is to be preferred to one that does.

A third proposal for the treatment of definite descriptions (be it in mathematical contexts, not in ordinary usage) that must briefly be mentioned is the one to be found in Hilbert & Bernays (1939). Hilbert and Bernays get around the problem of descriptions that fail to denote uniquely by refusing to admit any definite descriptions as terms in their system until the stage where the two propositions that state (i) that there is a referent, and (ii) that the referent is unique have been proved as theorems. (Cf. Hilbert & Bernays (1939), Vol. I, Section 8.) Thus we may regard the following schema as valid:

$$\text{(l)}\quad \begin{array}{l} \bigvee x\ F(x) \\ \bigwedge x \bigwedge y\ ((F(x)\ \&\ F(y)) \rightarrow x = y) \\ \hline F(\iota x{:}F(x)). \end{array}$$

Note that in this approach definite descriptions are not involved in scope-ambiguities (at least in extensional contexts); '$\neg G(\iota x{:}F(x))$' is not ambiguous, for we have as a valid sentence of predicate logic:

$$\text{(m)}\quad (\bigvee x Fx\ \&\ \bigwedge y(Fy \rightarrow y = x)) \\ \rightarrow (\neg \bigvee x(Fx\ \&\ Gx) \leftrightarrow \bigvee x(Fx\ \&\ \neg Gx)).$$

Hilbert & Bernays' analysis is relevant for linguistics, for it is a fairly close approximation to the use of definite descriptions in natural language, as <u>intended</u> by the language user. If a speaker uses a definite description, he <u>intends</u> the description to refer uniquely (in a given context).

I.2.2 Quantification and Indefinite Descriptions

An interesting feature of Hilbert & Bernays' <u>Grundlagen</u> is their introduction of a notation for indefinite descriptions. They use '$(\eta x{:}F(x))$' for an arbitrary member from the set of F's. This piece of symbolism is introduced by means of the following schema:

(a) $$\frac{\backslash/x\ F(x)}{F(\eta x{:}F(x))}$$

Indefinite descriptions are more difficult to handle in the Hilbert-Bernays approach than definite descriptions, for they are - just like indefinites in natural language - <u>not</u> immune to scope-ambiguities: "The number called 'zero' precedes all natural numbers" is not ambiguous, but "A number precedes all numbers" is.

This ambiguity can be removed by the stipulation that the η-operator always has the narrowest possible scope. Such a stipulation is necessary in formal languages that employ the η-operator, but not appropriate for indefinites in natural language.

The fact that the introduction of the η-operator is contingent on the assertion that there are objects that satisfy a certain predicate is awkward. Hilbert and Bernays define a new operator 'ε' that does not have this defect:

(b) $\vdash \neg\backslash/xFx \ \mathrm{v}\ \backslash/xFx$

$\Rightarrow \quad \vdash \backslash/x(\backslash/yFy \rightarrow Fx)$

$\Rightarrow \quad \vdash \backslash/yFy \rightarrow F(\eta y{:}(\backslash/yFy \rightarrow Fx))$

In the last step (a) is used to introduce $\eta x{:}(\backslash/yFy \rightarrow Fx)$; take for $F(x)$ in (a): '$\backslash/yFy \rightarrow Fx$'.

Now define $\varepsilon x{:}Fx$ by means of:

(c) $\varepsilon x{:}Fx = \eta x{:}(\backslash/yFy \rightarrow Fx)$, and the following formula can be deduced as a theorem:

(d) ⊢ \/xFx -> F(εx:Fx).

It is clear from the definition that in case there are F's, 'εx:Fx' denotes an arbitrary F; in the other case an arbitrary non-F, i.e. an arbitrary member of the domain (on the assumption that the universe of discourse is non-empty). It follows from the definition of the ε-operator that the ε-indefinite in 'G(εx:Fx)' can be eliminated by the paraphrase:

(e) \/x ((\/y Fy -> Fx) & Gx).

Now there are two possible paraphrases for '¬G(εx:Fx)':

(f) \/x ((\/y Fy -> Fx) & ¬Gx) , and

(g) ¬ \/x ((\/y Fy -> Fx) & Gx).

(f) and (g) are not equivalent, for (g) is true on the empty domain, but (f) is not. Thus, like the η-operator, the ε-operator is prone to scope ambiguities. Again the danger of equivocation can be staved off by a stipulation that the ε-operator always has narrowest possible scope.

The ε-operator creates the interesting possibility of replacing the predicate logical axiom schemata by one alternative scheme:

(h) A(c) -> A(εx:Ax).

(h) produces (d), with the help of the inference-pattern (i):

(i)
$$\frac{\vdash B(c) \;\text{->}\; A}{\vdash \backslash/x\; B(x) \;\text{->}\; A\ .}$$

Now define '\/' and '/\' by means of (j) and (k):

(j) $\backslash/x\ Ax = A(\varepsilon x{:}Ax)$

(k) $/\backslash x\ Ax = A(\varepsilon x{:}\ \neg Ax)$.

The central role of the ε-operator makes the use of definite descriptions superfluous in renderings of mathematical reasoning: ε-indefinites can simply replace definites everywhere. Moreover, an explicit definition of Skolem functions becomes possible: the value $f(x_1,\ldots,x_n)$ of a Skolem function f that is used to paraphrase the formula

(l) $/\backslash x_1\ldots x_n\ \backslash/y\ A(x_1,\ldots,x_n,y)$

can explicitly be defined as:

(m) $f(x_1,\ldots,x_n) = \varepsilon y{:}A(x_1,\ldots x_n,y)$.

It is clear that the above definitions of indefinite descriptions are intended to serve in an account of mathematical reasoning, not as an analysis of descriptions in natural language. (The same holds of Hilbert & Bernays' theory of definite descriptions.) Nevertheless, Hilbert and Bernays compare their theory of definite descriptions to Russell's theory (as stated in *Principia Mathematica*), where Russell and Whitehead use the method of wide scope contextual elimination proposed in 'On Denoting'), and mention the affiliation with natural language use as an advantage of their treatment. Still, the case where a failure of presupposition occurs is not covered.

In section I.2.5 below I will show that Hilbert & Bernays' theory of indefinite description is relevant for linguistics, by employing the ε-operator in a proposal for a theory of anaphora.

I.2.3 Quantification and Proper Names

In *Ueber Sinn und Bedeutung* Frege mentions the fact that an utterance of the sentence 'Kepler died in misery' has as a presupposition that the name 'Kepler' has unique reference. From this example it can be gathered that he intends his reform of language to fill up 'presupposition-gaps' (cf. section I.2.1) to apply to proper names as well as to definite descriptions. Another indication for this is Frege's view that every proper name has a sense. In another passage in the same article he remarks:

> Der Sinn eines Eigennamens wird von jedem erfasst, der die Sprache oder das Ganze von Bezeichnungen hinreichend kennt, der er angehört; damit ist die Bedeutung aber, falls sie vorhanden ist, doch immer nur einseitig beleuchtet. Zu einer allseitigen Erkenntnis der Bedeutung würde gehören, dass wir von jedem gegebenen Sinne sogleich angeben könnten, ob er zu ihr gehöre. Dahin gelangen wir nie.

A footnote to this paragraph runs:

> Bei einem eigentlichen Eigenname [i.e. a proper name in the narrow sense - JvE] wie 'Aristoteles' konnen freilich die Meinungen uber den Sinn auseinandergehen. [...] Solange nur die Bedeutung dieselbe bleibt, lassen sich diese Schwankungen des Sinnes ertragen, wiewohl auch sie in dem Lehrgebäude einer beweisenden Wissenschaft zu vermeiden sind und in einer vollkommenen Sprache nicht vorkommen dürften.
>
> (O.c., p. 27)

It seems that there can be no *guarantee* that a proper name in a natural language (or indeed in a formal language) has unique reference, as long as one adheres to the view that all proper names have senses. Consider again the phrasing of the definition of '\' in I.2.1, where a distinction is drawn between function F such that $\overset{,}{x}F(x) = \overset{,}{y}(y = a)$, for some object a, and functions that do not fulfil this condition. In the definiens the proper name 'a' occurs. Either this proper name is an exception to the rule that proper names do have a sense, or we end up in a regress: if 'a' has a sense, then this sense - or better: the sense the name has for some particular language-user - can presumably also be expressed by means of a description 'the x G(x)'. Now we have to ask ourselves whether this new description has unique reference...

If one wants to retain the doctrine that all proper names have senses, then an infinite regress can be avoided only if one, unrealistically, assumes that language users can have complete knowledge of the intended referents of certain object-designating expressions, so that they can use this knowledge to deduce from the sense that the expression does indeed denote the intended object.

As was mentioned already in section I.2.1, Russell's theory of proper names is closely linked to his philosophy of logical atomism. Only sense data can be referred to by proper names in his narrow sense. All ordinary proper names are treated as definite descriptions in disguise.

W.V.O. Quine, like Bertrand Russell, treats proper names as disguised definite descriptions. He goes one step further than Russell: in cases where, for a given name a, no description that can replace the name seems to be at hand, such a description can be faked by using the attribute of being (named) a. (Cf. Quine (1952a).)

A next contribution to the theory of naming is made in Reichenbach (1947). Reichenbach disposes of the problem of proper names that fail to denote a single referent by drawing a distinction between proper names and names: a proper name is a symbol coordinated by definition to a single individual thing; a name is a symbol that is used like a proper name (as argument-sign to functional signs), but that fails to denote a single individual. (Presumably, all sentences in which names - in Reichenbach's sense - that are not in the scope of a propositional attitude verb have a positive occurrence, must be considered false, except in cases where it is possible to replace the name by the description of a fictitious personality, a person described in the - physically existent - sentences of some work of literature. Reichenbach's solution for these 'fictitious names' will not concern us here.)

The distinction between proper names and names *simpliciter* seems an easy and obvious move to keep clear of philosophical difficulties, but it should be noted that the *extensions* of the two terms will be partly unknown to users of the language. It remains undecided whether I can conclude from the truth of '¬F(a)' that '\/x (x=a & ¬Fx)' is also true, as long as I do not *know* whether 'a' is a proper name or just a name.

Finally, let us - by way of a brief digression - look at the theory of naming proposed by P.T. Geach. Geach does not agree with the Russellian view (also adopted by Quine) that ordinary proper names are disguised definite descriptions. According to him this view is false as a matter of psychology: we often use a proper name to refer to a person without thinking of that person in terms of a definite description, or being able to supply a *unique* description on demand.

Another view is that proper names do not have sense. They do not tell us anything about the *essence* of the bearer of the name: in still other words, they are not shorthand for a description that makes use of general terms, and therefore they do tell nothing about the attributes of the things named. Again Geach does not agree. Proper names do have sense (in Frege's sense). This sense does not involve anything about the peculiarities of the individual referred to by the name, but it is something else:

> In general, if an individual is presented to me by a proper name, I cannot learn the use of the proper name without being able to apply some *criterion* of identity; and since the identity of a thing always consists in its being the same X, e.g. the same *man*, and there is no such thing as being just 'the same', my application of the proper name is justified if (e.g.) its meaning includes its being applicable to a *man* and I keep on applying it to one and the same *man*.
>
> On this account of proper names, there *can* be a right and wrong about the use of proper names. Suppose that an

> astronomer observes two different fixed stars at two different times, erroneously believes that one and the same planet has been observed on both occasions, and christen this supposed planet "Vulcan". His use of the word would be justified if he had succeeded in identifying an astronomical object as one and the same planet on different occasions; and since in point of fact this identification was a mistake, his use of the term "Vulcan" was also a mistake; he has given the term no reference, no use, whatsoever, and there is nothing he can do except to drop it.
>
> (Geach (1957), pp. 69-70.)

Thus Geach holds that for any proper name that is used properly there exists a common noun 'X' such that it is part of the sense of the name a that it be always applied to the same X. From this it follows that we can always replace repeated occurrences of a proper name a in a story by occurrences of the noun phrase 'the same X', for some common noun 'X'.

How is it possible that a name a can be used to talk about one particular object, although there may be many things that bear that same name, and although the 'mental image' connected with the name (if there is one) may be vague? Here the real life context in which the name is uttered comes to the rescue. "Although lots of people are called "Smith", the summons "Smith!" may be quite effective to fetch the Smith I want if he is the only man of that name within earshot; and similarly, a judgment that might in principle relate to many men may yet in a particular real-life context be relatable to just one." (Geach (1957), p. 73.)

Geach stresses the point that logically speaking it is immaterial just how we are able to continue to refer to a man as the same man. That we are able of such identifications is presupposed in our use of names, but the study of this ability is a matter for psychologists. It may occur that one's identifications in using a name are mistaken, but typically as soon as this becomes evident one has to recant.

Geach draws an absolute distinction between names and predicables, a predicable being what is left when a proper name is removed from a proposition. Predicables are true of objects, but they never name an object they are true of. That names and predicables should be distinguished can also be seen from the fact that negation never goes with a name: names do not come in contradictory pairs, whereas predicables do. 'Not John' is not a name, for it does not make sense to ask whether a certain person is the same not-John. Likewise, tenses attach to predicables, not to names: names are tenseless. (Cf. Geach (1962), section 27.)

On Geach's view names are related to common nouns, or, to use his terminology, to a certain brand of general terms. Not all common nouns do qualify, however. Geach distinguishes between substantival and adjectival general terms. A substantival general term carries a criterion of identity with it, an adjectival general term does not. The distinction corresponds roughly to the grammatical distinction between common nouns and adjectives, but Geach once again implores us to remember that the grammar of natural language can be misleading.

He gives an example that is not quite convincing, however: according to him the common noun 'sea' is not substantival, because no-one can determine how many seas there are, and therefore it does not make sense to speak of 'the same sea'. (Cf. Geach (1962), section 31.) If we reflect on the fact that we do give names to seas, and that we can learn the name of a sea by direct or indirect ostension (by encountering a teacher who - vaguely - points at an area of water or at an area on a map) without the exact limitations of the object so named being shown to us, then it seems that Geach makes a mistake here. I can use 'the Pacific', 'the Atlantic' or 'the Aegean' (certainly not descriptions, but names) without being able to exactly mark the boundaries of the areas of water thus specified. I only know that some - more or less clear cut - boundaries must exist, and that I could find out about these if I should wish. The same applies to names of rivers, mountain ridges etc.. It seems that Geach's theory of names must be qualified. Any name does indeed involve some criterion of identity that can be expressed by means of a common noun, but it is by no means necessary that every user of the name can wield it.

If this qualification is adopted, Geach moves closer to the view that proper names do not have sense. A name need not have sense for <u>everyone</u> who uses it, although there must be (or have been) <u>someone</u> for whom it has sense.

In another passage Geach recognizes that it is enough that the ability to identify the referent of a name exists or has existed somewhere in the language community.

> People sometimes speak as if a proper name had meaning just by having a bearer. This is absurd; we certainly do not give a man the meaning of a proper name by presenting him with the object named. In using a proper name we claim the ability (or at least acquaintance, direct or indirect, with somebody else who has the ability) to identify an object [...]. (Geach (1962), section 34.)

The theory of naming proposed by Geach is by far the most sophisticated of the ones that we have examined. In the quoted passage Geach gives what is possibly the earliest formulation of the 'historical chain theory' for the reference of proper names. The reader is referred to Kripke (1972) and Schwartz (1977) for information about the later vicissitudes of this theory.

I.2.4 Quantification, Pronouns, and Binding

The logical notation for quantifiers and variables that was introduced by Frege generates a distinction between two kinds of variables that may occur in a logical formula. For each quantifier Q that occurs in a logical formula ϕ, there is some well-formed subformula ψ of ϕ such that ψ is the domain in which Q has the power to bind variables. This domain is called the scope of Q. Variable-occurrences in the scope of a quantifier that ranges over them are called bound by that quantifier. Variable-occurrences that are not in the scope of any quantifier that ranges over them are called free. A variable(-type) may have both free and bound occurrences in the same formula.

Variables like those employed in formal languages in the spirit of Frege's Begriffsschrift simply do not occur in natural language, nor does natural language use a mechanism of variable-binding as it is used in formal languages. Nevertheless, often it is tacitly assumed that in a rational reconstruction of the way pronouns behave in natural language, these pronouns play the same rôle as that of variables in formal languages. This reconstruction tries to assimilate the connection between an antecedent and its anaphor in natural language to the mechanism of a quantifier binding a variable.

This view is exhibited in the following quotation from Quine's famous ontological catechism:

> To be assumed as an entity is, purely and simply, to be reckoned as the value of a variable. In terms of the categories of traditional grammar, this amounts roughly to saying that to be is to be in the range of reference of a pronoun. Pronouns are the basic media of reference; nouns might better have been named propronouns.
>
> (Quine 1953a, p. 13)

This perspective on pronouns is quite successful for a large number of cases. Consider the following examples:

(a) Someone is nice and he is also rich

(b) Everyone is nice if he is rich

(c) No-one is nice if he is poor

The following translations in the language of first order predicate logic show that the antecedent NP gives rise to a quantifier plus a variable bound by that quantifier, while the pronoun reappears as a variable bound by the quantifier generated by its antecedent:

(d) \/x (N(x) & R(x))

(e) /\x (R(x) -> N(x))

(f) /\x (P(x) -> ¬ N(x))

Similarly, deictic pronouns can be assimilated to free variables: these pronouns are rendered as variables without a quantifier to bind them, and it is supposed that the context provides information about the objects that are to be assigned to them. Lewis (1972) invokes an 'indicated objects coordinate' for this purpose; David Kaplan and Richard Montague have proposed similar devices.

Example (g), with a deictic pronoun, might be uttered in a situation where the speaker points to a certain person.

(g) He is a fool

This example could get a translation in which the pronoun reappears as a free variable:

(h) F(x)

The variable 'x' is supposed to be mapped to an appropriate object by a partial assignment of objects to variables (the 'indicated objects coordinate').

Unfortunately, there also are cases where a theory that postulates a correspondence between pronouns and bound or free variables is less convincing. How, one might ask, are anaphoric links between proper names and pronouns established? If the proper name is rendered as a constant in the logical translation, then it lies near to replace the anaphoric pronoun by the same constant in the translation process. Such a procedure would treat the pronoun as a so-called 'pronoun of laziness', mere shorthand for the antecedent NP, repetition of which the speaker wishes to avoid for stylistic reasons. Alternatively, one might, *à la* Quine, explain away the proper name *a* by replacing it with a definite description '$(\iota x: x = a)$' that can be eliminated in favour of quantifiers in the Russellian way. Now the pronoun may be translated as a variable in the scope of the existential quantifier that is introduced by the elimination of the description. This move would preserve the correspondence between pronouns and bound variables.

Suppose one assimilates descriptions and proper names to quantifiers and one treats pronouns with a description or proper name as antecedent as variables bound by the quantifiers that replace the name or description. Does this solve all problems posed by the anaphoric behaviour of pronouns in natural language? No, it does not. There is still a well-known difference with respect to anaphoric behaviour between descriptions and names on the one hand, and 'typical' quantifier-expressions like 'everyone' and 'no-one' on the other. Antecedent-NPs of the first kind permit across-sentential anaphoric links, while antecendent-NPs of the second kind do not:

(i) John/a man/the man laughed. He was happy.

In this example an anaphoric link between the subject of the first sentence and the pronoun in the second one is possible. In the following example such a link is forbidden:

(j) No-one/everyone was happy. He was ill.

Linguists have distinghuished between 'referential' pronouns

(pronouns with a description or a proper name as antecedent) and 'variable' pronouns (pronouns with a quantified expression as antecedent). Logicians have tried to subsume the first class under the latter, e.g. by incorporating the anaphoric possibility in (i) by means of a device that admits existential quantification across sentence boundaries.

Other problems are posed by pronouns like those in examples (k) and (l).

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

(l) If a farmer owns a donkey, then he beats it.

The underlined pronouns are often referred to as 'donkey'-pronouns after the examples in Geach (1962). They were rebaptized 'E-type pronouns' in Evans (1980). Donkey-pronouns do not readily submit to a treatment as bound variables. If one tries a straightforward translation in the language of predicate logic, the variable that corresponds to the pronoun ends up outside the scope of the existential quantifier:

(m) /\x ((Fx & \/y (Dy & Oxy)) -> Bxy)

There exists a predicate-logical paraphrase of (k), of course, but this paraphrase changes the existential quantifier into a universal one:

(n) /\x /\y ((Fx & Dy & Oxy) -> Bxy)

This merely replaces one problem by a different one: how can the translation of the indefinite description as a universal quantifier be motivated?

Puzzles about binding of variables, anaphoric links, and scopes of quantifiers will pop up time and again in the following chapters. In the next section I will sketch a theory that uses Hilbert & Bernays' ε-operator to settle some of the issues that have been raised above.

I.2.5 Quantification, Descriptions, and Anaphoric Links

Note: this section may be skipped by readers who wish to avoid the technicalities of a proposal to employ Hilbert & Bernays' ε-operator in an account of anaphora. In the proposal below a typed extensional language with λ-abstraction is used. Typed languages and λ-abstraction are discussed in some detail in the context of Montague Grammar, in chapter III.

Using the Hilbert-Bernays theory of indefinite descriptions, it is possible to give an interesting account of (in)definiteness and anaphora in natural language.

Recall that in case there are F's, $(\varepsilon x: F(x))$ denotes an arbitrary F, in case there are no F's, $(\varepsilon x: F(x))$ denotes an arbitrary non-F (it is presupposed that the domain is not empty).

Now if one <u>presupposes</u> that the CN inside an indefinite description [a CN] does denote a non-empty set, the following introduction of indefinite terms in a typed logical translation language that employs λ-abstraction becomes possible:

(a) $[_{Det}$ a] translates as: $\lambda P \lambda Q [Q (\varepsilon x: Px)]$

Next we have (I use '==>' for 'translates as'):

(b) $[_{NP}$ [a] [man]] ==> $\lambda Q [Q (\varepsilon x: MAN\ x)]$

and the presupposition is made that \/x MAN x.

Now $[_S$ [a man] [walks]] translates as:

(c) WALK $(\varepsilon x: MAN\ x)$

The indefinite description in (c) can be eliminated again with principle (e) from I.2.2 above; the result is (d).

(d) \/x ((\/y MAN y -> MAN x) & WALK x)

Under the above-mentioned presupposition '\/x MAN x ', (d) entails (e):

(e) \/x (MAN x & WALK x)

This means that - as long as the presupposition is not in doubt - the alternative definition of indefinite descriptions yields the right truth values. In case there are walking men, (c) denotes the value 1, otherwise (c) denotes the value 0, just as it should be.

As we have seen in I.2.2, the ε-operator is sensitive to scope ambiguity. I therefore propose the following notation:

Df. 'G(Ex: Fx | Gx)' is short for 'G(εx: Fx)', where it is understood that '\/x Fx' is <u>presupposed</u> and where 'G' is the context of elimination for '(εx : Fx)'.

Using this definition, we can restate the translation rule for the indefinite determiner as follows:

(f) $[_{\mathrm{Det}}$ a] ==> λP λQ [Q (Ex: Px | Qx)]

It might seem that - in view of the trivial reduction of the newly defined indefinites - nothing is gained by this innovation. This is not so, however.

The interest of the new theory is in the account of intersentential anaphoric links that it engenders. Call logical formulas from which indefinites have not yet been eliminated "formulas in ANA-form". Formulas in ANA-form can be used to define the possible antecedents for the pronouns that establish intersentential anaphoric links. A pronoun PRO can pick up a reference from any indefinite description D, provided D does not contain variables bound by a quantifier Q outside D that does <u>not</u> have PRO in its range. (The examples below will make this clear.)

I propose the following translation for an intersentential pronoun that picks up a reference to an indefinite description (Ex:Fx|Gx) [we may denote such a pronoun as '$\mathrm{PRO}_{(\mathrm{Ex:\ Fx|Gx})}$']:

(g) $\mathrm{PRO}_{(Ex\ :\ Fx\ \mid\ Gx)}$ ==> λP P (Ex: Fx & Gx | Px)

Consider the following example:

(h) A man walks. He talks. He is happy ....

Suppose the first pronoun picks up a reference to the indefinite description 'a man' in the first sentence of (h). This occurrence of 'a man' is translated as: (Ex: MAN x | WALK x).

Now the first 'he' will be rendered - according to the above recipe - as: (Ex: MAN x & WALK x | TALK x). The presupposition of the use of this intersentential pronoun, with the envisaged anaphoric link, is, on this account:

(i) \/ x (MAN x & WALK x).

Intuitively, this is correct: when the second sentence of (h) is uttered, and the anaphoric link is made, the truth of the first sentence is presupposed by the speaker (and the hearer understands that the speaker makes this presupposition).

Note that, semantically, two walking men could be involved; we may assume, however, that pragmatic factors ensure that the second sentence refers to the same individual as the first. This involves the pragmatic handling of presupposition (i), which states that the story is *about* some walking man. Thus, the presupposition and the translation of the second sentence of (h) *together* establish the anaphoric link between antecedent and pronoun.

Next, the second occurrence of the pronoun 'he' in (h) may be used to pick up a reference to the first pronoun-occurrence, and thus - indirectly - to the indefinite description in the first sentence of the story. According to the recipe (g), the translation of the second pronoun becomes:

(j) (Ex : MAN x & WALK x & TALK x | HAPPY x).

The presupposition is: \/x (MAN x & WALK x & TALK x). Again, this is intuitively correct.

The same account that works for intersentential pronouns works for <u>definite</u> <u>descriptions</u> that establish anaphoric links (by picking up a reference to a previous description or pronoun).

The rule is:

(k) $[\mathrm{the}]_{(Ex:Fx|Gx)} \quad ==> \lambda P\ \lambda Q\ [Q(\mathcal{E}\ x{:}\ Fx\ \&\ Gx\ \&\ Px\ |\ Q\ x)]$

This rule is intended for examples like (l):

(l) A visitor entered the shop. <u>The</u> <u>man</u> asked for the manager...

The examples mentioned so far suggest that the account is limited to indefinite descriptions occupying subject position. To see whether this is so, let us consider an example where an indefinite occurs as direct object:

(m) A boy loves a girl.

Translation:

(n) $[\mathrm{a\ boy}] ==> \lambda Q\ [Q\ (Ex{:}\ \mathrm{BOY}\ x\ |\ Qx)]$
$[\mathrm{a\ girl}] ==> \lambda P\ [P\ (Ez{:}\ \mathrm{GIRL}\ z\ |\ Pz)]$
$[\mathrm{love}] ==> \lambda\ R\ \lambda y\ [R(\lambda x[\mathrm{LOVE}\ (x)(y)])]$
(where R has type $\langle\langle e,t\rangle,t\rangle$ and LOVE has type $\langle e,\langle e,t\rangle\rangle$; cf. III.6 below for an explanation)
$[\mathrm{love\ a\ girl}] ==> \lambda y\ \lambda P[P\ (Ez{:}\ \mathrm{GIRL}\ z|Pz)](\lambda x[\mathrm{LOVE}(x)(y)])$
which reduces to:
$\lambda y\ [\mathrm{LOVE}\ (Ez{:}\ \mathrm{GIRL}\ z|\mathrm{LOVE}(z)(y))(y)]$

The translation of the whole sentence (m):

(o) $\lambda Q\ [Q(Ex{:}\ \mathrm{BOY}\ x|Qx)](\lambda y\ [\mathrm{LOVE}(Ez{:}\ \mathrm{GIRL}\ z|\mathrm{LOVE}(z)(y))(y)])$

This reduces to:

(p) $\lambda y\ [\mathrm{LOVE}\ (Ez{:}\ \mathrm{GIRL}\ z\ |\ \mathrm{LOVE}(z)(y))(y))]$
$(Ex{:}\ \mathrm{BOY}\ x\ |\ \mathrm{LOVE}\ (Ez{:}\ \mathrm{GIRL}\ z\ |\ \mathrm{LOVE}\ (z)(x))$

and further to:

(q) $\text{LOVE (Ez: GIRL z} \mid \text{LOVE(z)(Ex: BOY x} \mid \text{LOVE (Ez: GIRL z} \mid \text{LOVE(z)(x)))) (Ex: BOY x} \mid \text{LOVE(Ez: GIRL z} \mid \text{LOVE (z))(x))))}$

Even if this does not win a prize for elegance, at least it works. Now we are ready to reap the benefits of our rather cumbersome move.

(r) Every boy who loves a girl kisses her

The type of anaphoric link exemplified in (r) cannot be handled by a theory that treats pronouns as bound individual variables (cf. III.5 for a discussion of this problem in the context of Montague grammar). We analyze the pronoun according to the recipe that was given above.

'boy who loves a girl' translates as:

(s) $\lambda x\ [\text{BOY}(x)\ \&\ \lambda y\ [\text{LOVE(Ez:GIRL(z)} \mid \text{LOVE(z)(y))(y)](x)]}$

This reduces to:

(t) $\lambda x\ [\text{BOY}(x)\ \&\ \text{LOVE (Ez:GIRL(z)} \mid \text{LOVE(z)(x))(x)]}$

'every boy who loves a girl' translates as:

(u) $\lambda Q [/\backslash x\ ((\text{BOY}(x)\ \&\ \text{LOVE(x)(Ez:GIRL(z)} \mid \text{LOVE(z)(x))(x))} \text{ -> } Q(x))]$

In this translation an entity-type expression occurs that (in a sense that can easily be made more precise) corresponds to the NP 'a girl': '(Ex:GIRL(x) | LOVE(z)(x))'. Note that this expression fulfils the condition that was referred to above: the description does contain a variable x bound by a quantifier outside the description, but the range of this quantifier extends over the pronoun that is a candidate for anaphoric linking to the description. Therefore an anaphoric link between 'a girl' and 'her' in (r) is possible.

'her$_{\text{a girl}}$' = 'her$_{(Ez:GIRL(z)\ |\ LOVE(z)(x))}$' translates as:

(v) $\lambda S\ [\ S\ (Ez:\ GIRL(z)\ \&\ LOVE(z)(x)\ |\ S(z))]$

'kisses her' translates as:

(w) $\lambda y\ [KISS(Ez:GIRL(z)\ \&\ LOVE(z)(x)\ |\ KISS(z)(y))(y)]$

The translation of (r) becomes:

(x) $/\backslash x\ ((BOY(x)\ \&\ LOVE(Ez:GIRL(z)\ |\ LOVE(z)(x))(x))\ \text{->}$
$\quad KISS\ (Ez:GIRL(z)\ \&\ LOVE(z)(x)\ |\ KISS(z)(x))(x))$

This translation is intuitively acceptable. Note that the presupposition of the description that translates 'a girl' is that there are indeed girls, and the presupposition of the description that translates 'her' is that there are girls that are loved by boys. Note also that the translation does <u>not</u> state that every boy that loves a girl kisses <u>exactly</u> <u>one</u> girl. It merely states that every girl-loving boy kisses <u>at</u> <u>least</u> <u>one</u> <u>of</u> the girls he loves. It would pose no problem to formulate a rule that generates the stronger reading along the sketched lines, but as my intuitions are very vague here, I will refrain from doing so.

Now consider (y):

(y) Every boy loves a girl. He kisses her.

There is a rather strong intuition here that the pronouns 'he' and 'her' cannot be anaphorically linked to 'every boy' and 'a girl', respectively. For 'every boy' the explanation is that universal NPs do never give rise to unbounded anaphoric links: they do simply not generate entity-type expressions. For 'a girl' the explanation is that the description '$(Ex:GIRL(x)|LOVE(x)(y))$' contains a variable y that is bound outside of the description by a quantifier that does not have the pronoun in its scope.

There is a close connection between the account of anaphoric links sketched here and recent theories that propose to resolve anaphoric ambiguities at an intersentential level (cf. V below).

I.3 Misleading Form and Logical Form

It is clear from the details of the account of Frege's theory of quantification in section I.1.1 that Frege saw a wide gap between natural language and the language of the Begriffsschrift. As Frege's well-known metaphor has it, natural language is related to formal language as the naked eye is to a microscope. This suggests that natural language, although quite a versatile tool, is inadequate in contexts where rigour of demonstration and analysis is called for.

Frege's verdict on natural language in the introduction to the Begriffsschrift sets the tone for a recurrent theme among logicians since his days. Quite a few logicians, concerned as they are with drawing correct conclusions, tend to be less than satisfied with natural language as a tool for reasoning. As a consequence, they view the replacement of natural language by an artificial alternative that somehow better reveals the formal structure of thought, at least in certain contexts ("in scientific contexts", as Frege puts it), as a goal of their professional activity. Some well-known adherents of this standpoint, that came to be called the 'Misleading Form Thesis for Natural Language' (cf. Flew (1951)) are Bertrand Russell, Ludwig Wittgenstein (in his Tractatus period), Peter Geach and Willard Van Orman Quine.

Bertrand Russell has in several publications commented upon the behaviour of phrases that he called denoting expressions. Examples of denoting expressions are 'all men', 'every man', 'any man', 'a man', 'some man' and 'the man'. The passage from The Principles of Mathematics in which Russell explains the meaning of these phrases is worth quoting in full:

> All a's, to begin with, denotes a numerical conjunction; it is definite as soon as a is given. The concept all a's is a perfectly definite single concept, which denotes the terms of a taken all together. The terms so taken have a number, which may thus be regarded, if we choose, as a property of the class-concept, since it is determinate for any given class- concept. Every a, on the contrary, though it still

> denotes all the *a*'s, denotes them in a different way, i.e. severally instead of collectively. *Any a* denotes only one *a*, but it is wholly irrelevant which it denotes, and what is said will be equally true whichever it may be. Moreover, *any a* denotes a variable *a*, that is, whatever particular *a* we may fasten upon, it is certain that *any a* does not denote that one; and yet of that one any proposition is true which is true of any *a*. *An a* denotes a variable disjunction: that is to say, a proposition which holds of *an a* may be false concerning each particular *a*, so that it is not reducible to a disjunction of propositions. For example, a point lies between any point and any other point; but it would not be true of any one particular point that that it lay between any point and any other point, since there would be many pairs of points between which it did not lie. This brings us finally to *some a*, the constant disjunction. This denotes just one term of the class *a*, but the term it denotes may be any term of the class. Thus "some moment does not follow any moment" would mean that there was a first moment in time, while "a moment precedes any moment" means the exact opposite, namely that every moment has predecessors.
>
> (Russell 1903, Section 60.)

Does Russell intend the quoted passage as an analysis of the use in ordinary English of the various denoting expressions he mentions or rather as a proposal for language reform? The quotation suggests the former interpretation, but a footnote in a previous section makes clear that Russell is aware of the fact that English does not quite conform to his rules: "I intend to distinguish between *a* and *some* in a way not warranted by language; the distinction of *all* and *every* is also a straining of usage. Both are necessary to avoid circumlocution." (O.c., footnote to section 59.)

The distinction between *every a* and *an a* is familiar enough, but the same can hardly be said for the distinction between *every a* and *any a*, and between *some a* and *an a*, by means of the dichotomy of *constant* versus *variable* conjunction and disjunction. If *a* denotes a finite set, then the constant disjunction expressed by some a gives rise to a proposition that is equivalent to a finite disjunction of propositions, and the constant conjunction expressed by every a to a proposition equivalent to a finite conjunction of propositions.

How the variable disjunction and conjunction behave is more difficult to assess. Russell gives as an example of a variable disjunction: "If it was one of Miss Smith's suitors, it must have been Brown or Jones". He remarks, rightly, that this is not equivalent to "It must have been Brown or it must have been Jones". It seems that a variable disjunction is meant to be a disjunction between terms that has narrow scope w.r.t. some other operator inside a proposition. We must conclude that in 1903 the later champion of context-dependent paraphrase for expressions that contain definite descriptions struggled in vain to provide context-independent definitions of the way in which the distinction between 'every' and 'any' and that between 'some' and 'a(n)' can be used to disambiguate scopes of operators in suitable contexts. In 'On Denoting', written in 1905, Russell again touches briefly upon the denoting expressions all men, every man, some men and a man, but no trace has remained of the distinctions that were drawn two years earlier.

We may consider the treatment of denoting expressions in Russell (1903) as an attempt to analyze denoting expressions as constituents of natural language in their own right. Two years later this approach is abandoned, and Russell endorses the Misleading Form Thesis. In Russell (1905), the method of contextual definition of denoting expressions is used to expose their form of separate constituents of the language as misleading. Russells theory of descriptions is considered by the adherents to the Misleading Form Thesis as a principal paradigm.

Interestingly, the theory of reference that Russell struggled with in Russell (1903) has also received much attention from an other adherent to the Misleading Form Thesis, P.T. Geach.

In Geach (1962) a predicable is described as an expression that gives an assertion about something if we attach it to a referring expression. A predicable that occurs with a subject, to be circumscribed below, and together with it forms a proposition, is called a predicate. A (logical) subject of a sentence is an expression that stands for something that the sentence is about. Thus, a sentence can be formed by attaching a predicable to a subject. In the sentence the predicable will be a predicate.

Proper names are the paradigms of logical subjects. (For Geach's theory of naming, cf. section I.2.3.) Take a proposition 'f(a)', where 'a' is a proper name and 'f' a predicate. Now the replacement in 'f(a)' of 'a' by 'Det CN', where 'Det' is a determiner or in Geach's terminology an applicative - an expression such as 'a', 'every', 'the', 'some', 'any', 'no', etc. - and 'CN' a common noun, results in a grammatical sentence. Can 'Det CN' be said to "stand for something that the sentence is about"?

Geach considers at length the theories of denoting expressions (or: referring phrases) that state that under certain circumstances this is indeed possible. According to these theories - of which, as we have seen, the early Russell was a proponent - 'Det CN' can be a referring phrase, but it depends on the nature of the applicative 'Det' whether and in what way the phrase refers. Not every applicative gives rise to a referring phrase.

If an applicative does give rise to a referring phrase, the applicative specifies the mode of reference of the common noun 'CN' to the things referred to by the CN. Geach states the following condition for being a referring phrase. Suppose that the proper name 'a' occurs referringly in 'f(a)' (i.e., 'a' does not occur in an oblique context). Suppose further that the identity condition for 'a' is phrased in terms of 'CN'. Then 'Det CN' is a referring phrase iff it holds for all contexts 'f' that one of the inferences 'f(a), ergo f(Det CN)' or 'f(Det CN), ergo f(a)' is valid. This stipulation declares 'every man', 'a man', 'the man' and 'some man' to be referring phrases, and excludes 'no man', 'most men', just one man', 'all but one man', etc., from this class.

The characterization of 'referring phrase' in terms of the generalized quantifier perspective (cf. section I.1.5) is as follows. Suppose $\underline{A}$ is the denotation of 'CN', $\underline{DA}$ is the denotation of 'Det CN', and $\underline{a}$ the denotation of 'a'. The requirement that the identity condition for 'a' be phrased in terms of 'a' boils down to the requirement that $\underline{a} \in \underline{A}$. 'Det CN' is a referring phrase iff $\{X \mid \underline{a} \in X\} \subseteq \underline{DA}$ or $\underline{DA} \subseteq \{X \mid \underline{a} \in X\}$.

Do referring phrases, thus defined, behave exactly like proper names? No, they do not. Let 'f' and '$f^{\sim}$' be contradictory predicables. Now 'f(a)' and '$f^{\sim}(a)$' are contradictories, but in general, for a referring phrase 'Det CN', 'f(Det CN)' and '$f^{\sim}$(Det CN)' need not be. Here lies the root of the Misleading Form Thesis, for this fact has prompted Frege to draw the conclusion that referring phrases (in the sense defined above) are not genuine constituents of the language. According to Frege, instead of connecting the applicative to the common noun, we should consider the applicative as part of the predicate. Thus, "Not every ____ walks" and "Every ____ walks" will be contradictory predicables, that form contradictories when a common noun is inserted.

Geach accepts this, but he mentions an alternative that is viable too. I quote this passage in full, for in fact Geach has hit here upon the approach to noun phrases that has been worked out by Montague in his device of 'quantifying-in' (cf. chapter III below).

> Let us use the term "first-level predicable" for the sort of predicable that can be attached to a proper name to form a proposition about what is named. On Frege's view any such first-level predicable, if well-defined, itself stands for something - for a concept (<u>Begriff</u>); and a pair of propositions "Every man is P", "Not every man is P", would be contradictory predications about the concept for which the predicable " - is P" stood. It thus seems natural to regard "every man -" and "not every man -" as being likewise predicables - a contradictory pair of <u>second</u>-level predicables, by means of which we make contradictory predications about a concept.
>
> (Geach (1962), section 41)

The conclusion Geach reaches after an elaborate study of the theory of referring phrases can be summarized as follows. The theory under consideration treats propositions that contain referring phrases as complex molecules that have places that can either be filled up with atoms (names) or with radicals (complex referring phrases). Geach notes that the analogy should not be pushed too far. Whereas in chemistry it does not make any difference which substitution is made first if more than one atom is to be replaced by a radical, in logical grammar it does make a big difference.

> [...] when we pass from "Kate / is loved by / Tom" to "Some girl / is loved by / every boy", it does make a big difference whether we first replace "Kate" by "some girl" (so as to get the predicable "Some girl is loved by -" into the proposition) and then replace "Tom" by "every boy", or rather first replace "Tom" by "every boy" (so as to get the predicable "- is loved by every boy" into the proposition) and then replace "Kate" by "some girl". Two propositions that are reached from the same starting point by the same set of logical procedures (e.g. substitutions) may nevertheless differ in import because these procedures are taken to occur in a different order.
>
> (Geach (1962), section 64)

Combining these last two quotations one arrives at the mechanism of 'quantifying in' noun phrases that has been developed by Montague.

Geach does not make the further move of regarding <u>all</u> noun phrases as second level predicables. Montague does take this further step, and in doing so he arrives at a theory of natural language that exonerates noun phrases from the blame of being misleading expressions, and reestablishes their status as genuine constituents of natural language. Montague is not an adherent of the Thesis of Misleading Form. He has reacted to the Misleading Form Thesis with a reinterpretation of the behaviour of expressions that might be classified as misleading when looked at from a different and logically less subtle perspective. Whether his reanalysis is completely successful is another matter.

Acceptance of the Misleading Form Thesis may lead to two different attitudes to natural language. A proponent of the Thesis might discard the idea of a logico-semantical analysis of natural language altogether as hopeless (this is the attitude of Alfred Tarski). But a proponent of the Thesis might also react in a more positive way. If the superficial form of natural language sentences is indeed misleading, one might still try to analyze natural language sentences by providing a translation into a more transparent medium of representation, in this manner replacing the Misleading Form by something better.

Representations of natural language sentences that want to qualify as 'representations of Logical Form', or 'Logical Forms' for short, must satisfy several conditions. In the first place they must provide a good clue to the meaning of the sentence that is represented; in other words, they must give us a fairly good idea about what exactly is the case if the sentence is true. In the second place they must provide reliable information about how the sentence behaves in logical inferences. In the third place they must be such that they can be arrived at from a (semantically misleading) grammatical form by a process that is not ad hoc.

The first two requirements are interconnected, but nevertheless they must be kept apart. It is conceivable that some medium of representation copes successfully with the first demand, but not nearly as well with the second one (e.g. because the Logical-Form structures are too cumbersome for use in systems of inference). The language of predicate logic is rather good for both the first and the second purpose.

Frege, Russell, Quine and Geach each have proposed such representations of Logical Form. In each case the medium of representation that was used was that of predicate logic. The connection between Misleading Forms (expressions of natural language plus information about their semantically misleading linguistic structure) and Logical Forms, however, was completely ad hoc.

Montague uses syntactic construction-rules that generate analysis-trees for sentences that are not misleading: these trees contain enough information about both meaning and inferential behaviour to enable direct interpretation in an appropriate model. Use of an intermediate level of translation in a logical language is possible but not essential. This has led to the standard view that the concept of 'Logical Form' is alien to

Montague grammar. I do not agree, but I will postpone discussion of this issue until chapter IV of this dissertation.

Linguists in the TGG tradition have been divided on the issue of Misleading Form. Some of them have argued that surface syntactic structures are not misleading at all and indeed provide all semantic information that one might wish for. Others have, like the adherents of the Misleading Form Thesis, been looking for a level of representation distinct from the level of surface syntactic structure, a level that provides more or better information about meaning and inferential properties. Also, these TGG-theorists saw the importance of a systematic relation between surface syntactic structure and logico-semantic structure. They have postulated a separate component of the grammatical framework which they call the Logical-Form component of the grammar. This LF-component of the grammar is connected by structure-transforming rules to the component of (surface-)syntactic structures. The LF-structures, which look rather similar to formulas of first-order predicate logic, will be studied more closely in the next chapter, where some important TGG-contributions to the analysis of quantification in natural language will be considered in detail.

CHAPTER II

THE TGG PERSPECTIVE ON QUANTIFICATION

II.0 Introduction

We now turn from a survey of logical contributions to the understanding of natural language quantification to a discussion of the results of the recent linguistic study of quantification phenomena. It is on purpose that I confine myself to recent linguistic theories in this chapter. Traditional linguistic theories dealt with matters of quantification from the vantage point of an old-fashioned, pre-Fregean logic, a fact that led the logician Hans Reichenbach to write:

> [...] the instrument of language as it has been developed in the course of human civilization is superior to the theory of the instrument developed by logicians. Traditional grammar reflects the primitive stage in which logic remained up to the beginning of logistic [i.e. modern symbolic logic - JvE]. We should not be astonished when the instruction in syntax, in grammar schools and colleges, meets with antagonism, in particular on the part of intelligent students. Our present grammar as it is taught, with its artificial classifications and gratuitous constructions, is based on obvious misunderstandings of the structure of language. We should like to hope that the results of symbolic logic will some day, in the form of a modernized grammar, find their way into elementary schools. It seems to us that the deficiencies of traditional grammar are equally visible in the science of language in its present condition. The high level of historical and psychological analysis in philology is not matched by a similar level in the understanding of the logical side of language. If philologists would try to make use of a modernized grammar for linguistic purposes

> they might discover new means of elucidating the nature of language. (Reichenbach (1947), pp. 254-255.)

These words were written at a time when most logicians shunned the analysis of natural language altogether, because of its supposedly misleading character (cf. section I.3 above), and most linguists were not familiar with post-Fregean logic.

Reichenbach's remarks apply to most linguistic theories from the years b.C. (before Chomsky), although there are notable exceptions to this (Harris' linguistic theory is a case in point). For this reason I restrict myself to the tradition of transformational grammar that was started by Chomsky. Reichenbach would have been very pleased with the new perspective on language that was adopted by Chomsky and his followers. Indeed, the theory of transformational grammar has inspired logicians with new hopes for a logical analysis of natural language.

In this chapter I will first give a brief sketch of the underlying assumptions of Transformational Generative Grammar. Then, as a starting point for the discussion of the TGG account of quantification phenomena, I will present Jackendoff's theory of the internal structure of NPs. This theory focusses on issues of quantification, and it was more or less the current standard in this area (at least until Stowell (1981) appeared). Jackendoff concentrates on syntactic issues, and it is not immediately evident how the proposed structures can be supplemented with rules for semantic (model-theoretic) interpretation (the same applies to Stowell's theory). Therefore the review of Jackendoff's theory is followed by a proposal for a categorial treatment of the NP specifier system; a set of matching semantic rules will be presented in III.4.4.

Next, I will discuss some of the most important theories about scopes and anaphora that have recently been proposed in the TGG tradition, viz. the theories of Kroch, Reinhart, May and Higginbotham. Two semantic issues that have been extensively discussed in the TGG literature, roughly within the confines of the Extended Standard Theory, are (1) the problem of the prediction of scope ambiguities exhibited in sentences that contain more than one quantified NP, and (2) the problem of the prediction of anaphoric possibilities in sentences that contain anaphoric elements like pronouns, reflexives and reciprocals. These are the issues that will concern us in sections 3 and 4 of this chapter.

An example of a problem of the first kind is the difference between the scope possibilities of the following sentences:

(a) Both of Homer's stories thrill many people

(b) Many people are thrilled by both of Homer's stories.

The scope-problem is addressed in Reinhart's and May's theories of scope ambiguity, and, from a different perspective, in Kroch's theory of scopes. These theories will be discussed in section II.3.

A problem of the second kind is the explanation of the anaphoric possibilities for sentences like the following:

(c) Achilles told Agamemnon that he had fooled himself.

This second problem is addressed in Reinhart's and Higginbotham's theories of anaphora, that will be reviewed in section II.4.

The two topics are linked by the fact that a mechanism that handles scopes of operators can also be made to handle anaphoric pronouns and reflexives by treating them as bound variables. But note that we have seen already (in section I.2.4) that not all anaphoric elements behave as bound variables.

As the review of theories in II.3 and II.4 will make clear, authors that adopt the TGG-approach to quantification tend to make a rather rigid distinction between 'quantified' and 'referring' NPs. The boundary line is not always drawn at the same place, and often it is not quite clear on what linguistic evidence the distinction is based. Also, the distinction looks suspiciously like that between quantifiers and individual constants in first order predicate logic, a logical theory that seems to have been very much in the back of the minds of TGG-theorists until quite recently.

II.1 Underlying Assumptions of TG Grammar

Linguists in the transformational tradition have gradually become more interested in the application of logical formalisms, as the lure of semantic problems became stronger. The representations that have been proposed in the TGG tradition for the semantics of natural language gradually have come to incorporate more and more 'logical' devices, most notably devices for the disambiguation of operator scopes and the binding of variables.

Still, there is no universal agreement among transformational linguists about the rôle that logical formalisms should play in their discipline. Logic becomes important for linguistics as soon as questions of semantics are addressed, but not all transformational linguists agree that semantics is a central linguistic concern.

Chomsky has repeatedly expressed the view that linguistics is a branch of empirical psychology, and that the ultimate aim of the discipline is to uncover the properties of the sector in the human mind where the ability to learn a language (i.e. *any* language) resides (cf. e.g. the first chapter of Chomsky (1965), and Chomsky (1980a)). The aim suggests the method of *Hunting After Broad Structural Generalizations*: only the study of those structural properties of languages that are general enough to be shared by any and every grammar will tell us something about the functioning of the language faculty of the human mind. This may explain why Chomsky, when in a philosophical mood, suggests that logic and linguistics are at variance. The logician is interested in relations of logical entailment between the sentences of a language and in the explication of the concept of 'meaning' for expressions of natural language, but for the TGG-linguist who shares Chomsky's views about the ultimate goal of the discipline there is no *a priori* reason to suppose that the concept of logical entailment plays an important part in the language faculty of the mind.

In matters of methodology, a student of natural language can be either a 'fragmentarian' or a 'globalist'. The fragmentarian follows the step by step approach: this explorer contents himself with the study of artificially limited systems that merely approximate the full complexity of a natural human language, in the hope of increasing his understanding step by step, by gradually taking more aspects into consideration. The globalist, out of a fear that staying within self-imposed boundaries will interfere with his search for cross-connections between widely varying aspects of natural language, rejects the method of fragments.

Linguists in the tradition of Chomsky tend to be globalists. It may be that Chomsky's view of the ultimate aim of the discipline of linguistics has influenced the methodology of his followers. The assumption that there is a wide gap between natural language and artificial languages may well lead to the fear that the study of the structural properties of artificially restricted fragments will never give rise to generalizations that reveal something about the structure of <u>real</u> natural languages.

For a logician with an interest in natural language it is natural to reflect on the issue of the choice of logical tools. This issue has been hotly debated and the answers that are given vary. W.V.O. Quine and D. Davidson favour first order predicate logic (cf. Quine (1952b) and Davidson (1967)). Richard Montague, David Lewis, and kindred spirits opt for an intensional, higher order logic (cf. Chapter III below).

Within the TGG tradition this question has hardly received the attention it deserves. In discussions of the component of TG grammar where 'semantic representation' takes place, the medium of representation that is proposed is always very close to first order predicate logic.

At the moment, the outline of a grammar for natural language in the TGG tradition looks like this:

```
                                                 -----------------------
 --------------       ------------------       /|Semantic representation|
|Deep structure|  -> | Surface structure|  /    -----------------------
 --------------       ------------------     \   -----------------------
                                               \|Phonological represent.|
                                                 -----------------------
```

Deep structures of sentences are tree structures generated by rules of a (context sensitive) phrase structure grammar. The grammatical relations inside sentences ('subject', 'direct object', etc.) are encoded in their positions in the tree structures at this level. The tree-structures also provide information about the internal structure of important sentence-constituents like Noun Phrases, Verb Phrases and Prepositional Phrases.

Surface structures of sentences are the result of applying transformation rules to a certain deep structure-tree. Surface structures of sentences provide the input for the component of Semantic Representations (or 'Logical Forms', or 'LF-structures'), that to a large extent resembles the notation of first order predicate logic, and for the component of Phonological Representations.

The above scheme, first introduced in Chomsky (1970), characterizes the so-called Extended Standard Theory, and presents a modification of the overall structure of the Standard Theory (Chomsky (1965)). In the Standard Theory it had been supposed that semantic representation of a sentence was fully determined by the deep structure of that sentence. The controversy with regard to this hypothesis has led to a schism in the TGG school. When Chomsky came back on this proposal, the school of Generative Semantics hung on to it (although there are some differences between 'Semantic Representation' in Generative Semantics and 'Deep Structure' in Chomsky (1965)).

At the moment it looks as if Generative Semantics has lost most of its original force, although occasionally new pleas for deep structure interpretation are made. As the most interesting proposals in TGG grammar concerning quantification are part and parcel of the main line of the tradition, I will restrict myself in what follows to a discussion of the Extend Standard Theory, including the refinements incorporated later.

In the Extended Standard Theory there is no absolute agreement on the exact relation between the level of surface structure and that of semantic representation. The theory that Reinhart proposes as an account for both scope-phenomena and anaphora (cf. sections II.3.3 and II.4.1, respectively) supposes that the two levels coincide, and that semantic interpretation takes surface structures as its input. The theories of May, Higginbotham and others (including Chomsky), maintain, on the other hand, that extra rules are needed to construct Logical Form structures out of surface structures.

The shift from Standard Theory to Extended Standard Theory has been motivated by examples in which transformations (like the Passive-transformation) influence interpretation:

(a) Both of Homer's stories thrill many people.

(b) Many people are thrilled by both of Homer's stories.

(c) Everyone in this room speaks two languages.

(d) Two languages are spoken by everyone in this room.

If in these examples the shift from (a) to (b) and from (c) to (d) is attributed to a transformation, then it is clear from the scope reversal for the quantifiers in the preferred readings for the sentences that this transformation does not preserve the original meaning.

The revisions of the Extended Standard Theory presented in Chomsky (1973,1976) have narrowed down the possible forms that transformations could take. Every movement-transformation is of the form 'move a'; the place to which the element a will have to be moved is not specified in the formulation of the transformation itself, but is taken care of by general restrictions on movement. Conditions on transformations proposed in Chomsky (1973) are the A-over-A principle and the subjacency condition.

The A-over-A principle forbids the application of a movement-transformation to a constituent Y of a certain category A if the transformation could also apply to a constituent Z, where Z is also of category A and Z contains Y. This condition forbids the application of the passive-transformation as in (e) -> (f):

(e) He reads only Homer and Herodotus.

(f) *Homer is read only and Herodotus by him.

The subjacency-condition forbids the direct movement of a constituent through two cyclic nodes (the cyclic nodes are S and NP). This condition forbids the direct application of WH-movement in (g) -> (h). Also, cyclic movement of the WH-element through the COMP positions is ruled out by the fact that the COMP node of the most deeply embedded sentence is occupied by 'who'. Therefore, example (h) is ruled out.

(g) You believe Herodotus knew who told what story?

(h) *What story do you believe Herodotus knew who told?

Furthermore, in order to make it possible to retain all the information necessary for semantic interpretation in surface structure, the EST has introduced the concept of 'trace'. (Actually the emergence of traces in the theory has been a gradual process - cf. Chomsky (1981), Section 2.4.5. - but then this is only a rough sketch.) Every movement-transformation leaves a trace e in the place where it removes an element. An indexing mechanism keeps track of the connection between traces and the elements they are traces of.

Here are some examples of surface structures containing traces:

(i) What$_i$ do you want to read e$_i$?

(j) Who$_i$ do you want e$_i$ to read Homer?

These surface structures are obtained by movement-transformations from (k) and (l), respectively:

(k) You want to read what?

(l) You want who to read Homer?

The traces in (i) and (j) serve to retain the deep-structure information that in (i) 'what' is the object of 'read' while in (j) 'who' is the subject of 'read'.

As can be seen from these examples, the connection between a moved element and its trace is made by assigning a common index to both. Various proposals have been made for the exact formulation of <u>indexing mechanisms</u>. Generally the mechanism performs multiple functions (one variant will be discussed below, in section II.4.2). The overall effect of the introduction of traces and indices has been a gradual enrichment of surface structures (and a corresponding weakening of the empirical force of the hypothesis that surface structure determines semantic representation, for that matter). The introduction of traces makes it possible to reformulate the subjacency-condition as a condition on the shapes that surface structures or LF-structures may take (for this perspective on conditions on transformations cf. Freidin (1978) and Koster (1978)). Surface structure (m) is forbidden by the subjacency-condition, but (n) is allowed:

(m) <u>Which</u> <u>story</u>$_i$ [do you believe [Herodotus heard $\underline{e}_i$]]?

(n) <u>Which</u> <u>story</u>$_i$ [do you believe [$\underline{e}_i$ [Herodotus heard $\underline{e}_i$]]]?

Note that (n) shows that WH-movement has applied twice; neither application violates the condition of subjacency. The condition of subjacency will concern us in connection with May's theory of quantification.

Deep structures and surface structures of the EST only faintly resemble those of the Standard Theory, which is why the practice has emerged to speak of 'D-structure' and 'S-structure' (the term 'surface structure' now being reserved for a stripped - and therefore less abstract - version of S-structure).

Before discussing the proposals made in the context of the EST concerning the handling of quantification phenomena, we will take a look at what is said about the general structure of (quantified) NPs in the deep structure component of a transformational grammar - focussing on one influential theory - and we will propose a categorial alternative for such a deep-structure theory of the syntax of NPs.

II.2 The Internal Structure of Quantified NPs

A more or less standard account of the general structure that is assigned to NPs at the level of the Phrase Structure component of a TGG (also called the 'base component') can be found in Jackendoff (1977). In section II.2.1, I will review this theory in some detail.

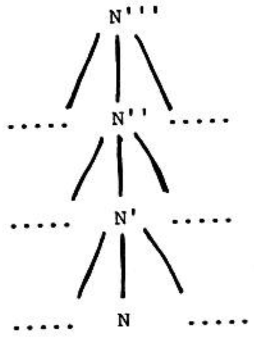
Section II.2.2 is devoted to a treatment of the syntactic structure of NPs in the framework of categorial grammar. In II.2.2.1 the basics of categorial grammar will be sketched. In II.2.2.2 I present a proposal for the categorial treatment of the NP specifier system. In my own proposal, I will keep some of Jackendoff's considerations in mind, but I will also have half an eye on a semantic elaboration in the spirit of Montague-grammar.

My categorial syntax for NP structure is meant to provide the syntactic bones needed to support the flesh of a semantics à la Montague. I will argue that, contrary to popular assumptions, semantic considerations hardly constrain the syntax of NP-structure. The semantic elaboration of the proposed categorial treatment of NPs will be postponed until chapter III.

II.2.1 Jackendoff's Theory of NP Structure

Jackendoff (1977) presents a version of an influential theory about the Phrase Structure component of a TGG, the so-called "X-bar theory", a theory that generalizes over the four 'major categories' of the base component: Adjective Phrases, Verb Phrases, Prepositional Phrases and Noun Phrases (cf. also Stowell (1981)). The connections between NPs and the other categories will hardly concern us, however.

According to the so-called three-level hypothesis of Jackendoff's version of X-bar theory, an NP has the following internal structure:



For typographical reasons I write N' instead of $\bar{N}$ (the so-called bar-notation). The picture generalizes to the other major categories, but we restrict ourselves to NPs. N''' is an abbreviation for NP. N is called the head of the NP-structure. N''', N'', and N' are called projections of N. The dots indicate places that may contain a concatenation of syntactic categories. Syntactic categories in the phrase that occur to the right of the head are called complements. Syntactic categories that occur to the left of the head are called specifiers. Pre- and post-head position provide only a rough indication of the status of lexical categories and grammatical formatives (and only in languages with constraints on word order). Adjectives, e.g., are considered as complements in NPs, "for semantic reasons, their prehead position notwithstanding" (Jackendoff, (1977), pp. 72-3).

Jackendoff distinguishes between N'-complements, N''-complements and N'''-complements. The syntactic criterion for the distinction is the fact that the tie with the head gets weaker as the number of bars increases. It turns out that N'-complements (adjectives) act semantically as functions that take their N-heads as arguments; N''-complements act as restrictive modifiers (restrictive relative clauses are N''-complements), and N'''-complements act as nonrestrictive modifiers (non-restrictive clauses are N'''-complements).

In the case of NP-specifiers matters are less clear. Jackendoff distinguishes between NP-specifiers as follows (1977:104):

> Among the demonstratives are the traditional definite articles the, this, that, these, those, the interrogatives which and what and possibly the indefinite article a and the singular some (as in Some man is at the door. Among the quantifiers are each, every, any, all, no, many, few, much, little, and other uses of some. The third class is numerals, including all the usual cardinals plus a dozen, a couple, a few, and a little. Notice already the confusion that is cropping up, for some belongs to different categories depending on its stress, and negative few and little belong to a different category from nonnegative a few and a little.

To account for certain restrictions on NP specifiers, Jackendoff proposes the following constraint.

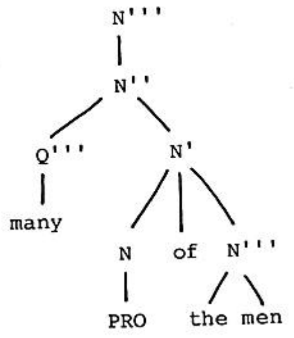
Specifier constraint:

(SC) An NP specifier may contain at most one demonstrative, one quantifier, and one numeral.

SC accounts for '*All few men', '*Which the man', etc., but not for '*Those all men', '*Which any dwarfs'. To accommodate examples like these as well, the class of quantifiers is split in two subclasses: Art-quantifiers have the feature [+det], and include each, all, no, every, some, any, Q-quantifiers have the feature [-det], and include many, few, several. Next Art-quantifiers are syntactically lumped together with demonstratives (both occupy N'''-specifier position) and Q-quantifiers with numerals (both occupy N''-specifier position). SC rules out structures with two quantifiers, one in N'''-specifier position and one in N''-specifier position.

The syntactic distinction between Art and Q is made as follows: Art-quantifiers cannot be preceded by genitive NPs and demonstratives, Q-quantifiers can. There does not seem to be a semantic reason for the division. (Jackendoff mentions the fact that his test classes little as a N''-quantifier, but its positive counterpart much as an N'''-quantifier.)

Next, Jackendoff discusses the partitive construction, as in 'many of the men'. With Selkirk (1977) he argues on syntactic grounds that *of the N''* belongs to the N'-complement. The following syntactic structure is proposed:



Semantic considerations hardly come into play in the argument for this syntactic structure.

Jackendoff follows Selkirk in denying that the structure of 'many men' is derived from the above by *of*-deletion. The following constraint is needed to filter out '*many of men':

Partitive constraint:

(PC) In a SPEC *of* SPEC CN construction interpreted as a partitive, the SPEC following *of* must have a demonstrative or genitive specifier.

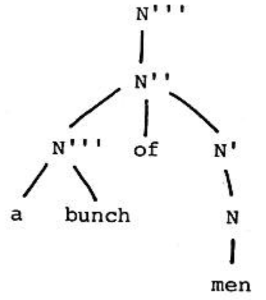
This constraint seems to be rather well motivated. It accounts for '*all of some men', '*either of two men', '*some of no men', etc.. The genitive must be *definite*, for we have: 'all of Mary's admirers' and 'all (of) the president's men' versus '*all of some girl's admirers'. Note that the constraint refers to the *semantic* property of being a partitive. 'The spokesman of many farmers' is not a partitive, and the construction does not fall under the constraint.

The distinguishing property of the specifiers that are allowed after *of* in partitives can be characterized semantically as well, by looking at the model-theoretic properties of the NP-denotation (cf. Barwise & Cooper (1981)):

Df. An NP is definite iff for all finite models $M = \langle E, F \rangle$ for which $[\![\text{NP}]\!]$ is defined, $[\![\text{NP}]\!]$ is a proper filter.

Given a model $M = \langle E, F \rangle$, a filter is a subset of $P(E)$ that is closed under the formation of intersections and of supersets. A proper filter is a filter that is neither empty nor equal to $P(E)$. On finite models, every non-empty filter is a principal filter, i.e. it has a generating element, a set A such that the filter is given by $\{X \subseteq E \mid A \subseteq X\}$. This means that the above definition says that an NP is definite iff in every model for which the NP is defined, its interpretation can be rendered in this form.

There are a number of constructions with <u>of</u>, where the <u>of</u> functions as a partitive, but the partitive constraint seems to be violated: 'a bunch of men', 'a number of people', 'a pair of shoes'. These phrases are accorded a structure that differs from the one for 'many of the men'; they are called 'pseudo-partitives'. Again Jackendoff follows Selkirk (1977), where syntactic evidence is given for the hypothesis that the structure of pseudo-partitives is parallel to the structure of 'many men':



Pseudo-partitives contain a specifier and a 'measure expression'; Jackendoff labels the measure expression as a noun. Some more examples are: 'a dozen of pencils', 'a pound of butter', 'a wagonload of cokes', 'a bottle of wine'. In languages like German and Dutch the difference between pseudo-partitives and partitives is more obvious than in English and French: we have 'eine Flasche Wein' and 'een fles wijn' versus 'a bottle of wine' and 'une bouteille de vin'. Note that the specifier in a pseudo-partitive may contain numerals, and a lot more besides: 'these five pairs of gloves', 'Michael Jackson's several hundred pairs of shoes'.

Next, the class of numerals is divided into cardinals ('three', 'fifteen') and seminumerals (numerals that require an article, like 'dozen' and 'hundred'). Numerals behave partly like quantifiers (in Jackendoff's sense), partly like (group) nouns. Jackendoff labels them as nouns, mainly on the basis of the parallel between NPs like 'a beautiful two weeks' and pseudo-partives like 'a useful couple of days'. An exception is made for the numeral one (different from the pronoun that is also spelled one): this is not a noun but a quantifier. This exception is needed to explain '*a beautiful one day'.

Cardinals are distinguished from seminumerals by the fact that a local transformation that deletes the article a ('Cardinal a-Deletion') applies to them. The transformation is obligatory, but does not apply if an adjective intervenes between the article and the numeral. Numerals are distinguished from group nouns: unlike numerals, group nouns are followed by of when they act as N''-specifiers. Again an obligatory local transformation is called in ('Numeral of-Deletion') to account for this difference.

Note that most of the distinctions that Jackendoff makes in his theory of the NP-specifier system are arrived at by purely syntactic reasoning, with a strong emphasis on co-occurrence tests. In this respect there is a lot of similarity between Jackendoff's work and the treatment of NP-structure on a purely descriptive level, as in Quirk c.s. (1972). In the following sections I will replace Jackendoff's X-bar theory by a syntactic theory that is more sensitive to semantic influence, viz. categorial grammar, in order to check the internal structure of NPs for semantic constraints.

II.2.2 A Categorial Treatment of the NP Specifier System

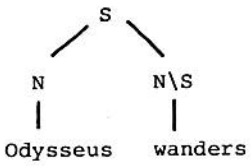
II.2.2.1 The Basics of Categorial Syntax

The theory of categorial grammar has been developed in the forties by the Polish logician K. Ajdukiewicz. The theory has been revived by logico-semanticists like Richard Montague, David Lewis, and Peter Geach. In this section I will sketch the basics of categorial grammar, with some elaborations that are known from the literature, but that have hardly been put to systematic use in theories of natural language. For a discussion of the rôle of categorial grammar in Montague grammar, cf. section III.4 of this dissertation.

In a categorial language all expressions combine as function and argument. The category assigned to an expression indicate which function-argument combinations for that expression are possible with other expressions of specified categories. In this way the category-assignments determine which strings of expressions are syntactically coherent.

Let us suppose there are two basic categories: N for proper names, and S for sentences. This already suggests a category for intransitive verbs. Intransitive verbs combine with names to their left to form sentences. We use (B\A) for the category of expressions that take expressions of type B to their left to form complex expressions of category A, and (A/B) for expressions that combine with category B expressions to their right to form category A expressions. In this notation, the category for intransitive verbs can be put on record as (N\S). In a categorial grammar that has basic expressions in the category N (i.e. names) and basic expressions in the category (N\S) (i.e. intransitive verbs), the structure tree for 'Odysseus wanders' may look as follows:

(a)



The basic 'multiplying out' rule that has been used to form this expression is (b):

(b) A (A\B) -> B

The rule says that, for any categories A and B it holds that an expression of category A combines with an expression of category (A\B) to yield a complex expression of category B.

A second multiplying out rule is needed for functor-expressions that combine with arguments to their right:

(c) (B/A) A -> B

The basic difference between a categorial grammar and a context free phrase structure grammar is that a categorial grammar provides information about functor-argument structure, whereas a context free phrase structure grammar does not. This feature makes categorial grammars particularly attractive as a foundation for theories of semantics for natural language, for in such theories function-argument structure plays an important rôle.

In general, every context free phrase structure grammar can be reformulated as a categorial grammar and vice versa. Note, however, that the result about generative capacity of categorial grammars holds for categorial grammars without category shift rules. The generative capacity of categorial grammars in which category shifting is allowed is simply not known (cf. Buszkowski (1982)). Anyway, the categorial framework is rich enough for a reformulation of Jackendoff's or Stowell's version of X-bar syntax.

A semantic counterpart for a categorial grammar can be provided by the standard procedure of associating suitable model-theoretic objects with the basic expressions of the categorial system, taking the information provided by the category assignment into account. E.g., if one decides to associate truth values with the basic category S and entities with the basic category N, then functions from entities to truth-values should be associated with the expressions of category (N\S). Intransitive verbs now get associated with (characteristic functions of) sets of entities. The semantic operation that corresponds with the syntactic operation of combining two suitable expressions in the categorial system is simply function-argument application of the associated model-theoretic objects.

Although information about function-argument structure is the key to the link between syntax and semantics in a categorial framework, there is no need to regard this function-argument structure as fixed. Suppose that names are indeed interpreted as entities, and intransitive verbs as functions from entities to truth-values. One might decide now to reinterpret names as more complex model-theoretic objects, by associating with the name, not an entity a that is named, but a characteristic function F that maps every characteristic function g from entities to truth-values to the truth value 1 if g characterizes a set that contains a, and to the truth value 0 if g characterizes a set that does not contain a. Such a function F would take an IV-interpretation as argument and would yield a truth-value. Function-argument order is reversed, but the result of the semantic evaluation remains the same. Reasoning backwards from the semantics to the syntax, we see that in this example the name has got an interpretation suitable for an expression of category (S/(N\S)).

The example suggests a set of two general rules for allowing category shifts in categorial grammar without spoiling the possibilities for a match between the categorial syntax and its envisaged semantics. Category shift rules (d) and (e) apply to arbitrary categories A and B. Let us call the applications of (d) and (e) applications of the principle of Function Argument Reversal, or FAR for short.

(FAR)

(d) A ==> (B/(A\B))

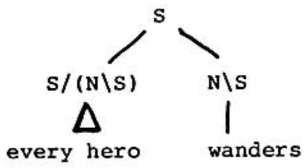
(e) A ==> ((B/A)\B)

As we will see in chapter III, the FAR principle is used implicitly in Montague grammar.

The FAR principle is not the only principle of category shift that can be added to a categorial grammar without tampering with the semantics. Peter Geach has proposed a different category shift principle (cf. Geach (1972b)). Again I will introduce the principle with an example.

We have seen in section I.1.6 above that in the Generalized Quantifier Perspective a quantified NP is interpreted as (the characteristic function of) a set of sets. The interpretation of 'every man' is the function g that maps a function h from entities to truth-values to the value 1 in case h characterizes a set containing all men, to the value 0 otherwise. This suggests that in a categorial system underlying such a semantics, quantified NPs should be in category (S/(N\S)). Thus, 'every hero wanders' would have the following structure:

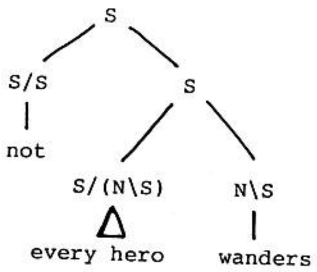
(f)



Suppose we now want to extend the grammar with a word that can be used to negate a sentence: 'not' or 'it is not the case that'. The expression 'not', put before a sentence, yields a new sentence, so an appropriate category for 'not' seems to be (S/S). The interpretation of 'not' is a function F from truth-values to truth-values that swaps 1 to 0 and vice versa.

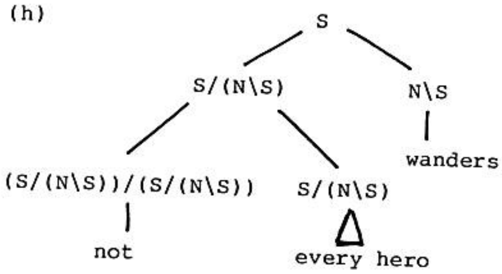
We now get the following structure for 'not every hero wanders':

(g)



Now we reinterpret 'not' as a function H that takes the characteristic function k that interprets 'every hero' and maps it into the function F(k) of the same type as k but with all truth values swapped. The suitable category for 'not' after this move would be (S/(N\S))/(S/(N\S)), and we get the following categorial alternative for (g):

(h)



'Not every hero' has now become a constituent that combines with an intransitive verb. Semantically nothing has gone wrong: the interpretation of the whole expression remains the same.

Again the example suggests the formulation of a set of rules for category shifts that do not spoil the semantics. We call these rules applications of the Geach Expansion Principle, or GEP for short (cf. Geach (1972b); but essentially the rule can already be found in Lambek (1958)). Two instances of the GEP are:

(GEP)

(i) A/B ==> (A/C)/(B/C)

(j) B\A ==> (C\B)\(C\A)

Precise formulations for the semantic counterparts of the category shift rules will be given in chapter III. The question under what circumstances category shifts do or do not give rise to changes in meaning will also be postponed to that chapter.

We now turn to the application of categorial syntax, including applications of the category shift principles that do not change meaning, to the NP-specifier system.

II.2.2.2 Application to the NP Specifier System

In the NP-structures proposed by Jackendoff, free use is made of local deletion transformations. Especially in the treatment of numerals and seminumerals, the heavy reliance on this very powerful device is rather suspect. Furthermore, one gets the impression that most of the distinctions that Jackendoff draws do not have obvious semantic correlates. To see, e.g., that the division between cardinals and seminumerals is largely syntactic, note that in other languages, e.g. Dutch, every cardinal has a corresponding seminumeral ('vijftien' vs. 'een vijftiental'). Still, there is a slight difference in meaning between 'vijftien mensen' and 'een vijftiental mensen' ('fifteen people'): the use of the seminumeral seems to imply that the count may not be precise (Henk Verkuyl suggested to me that a rounding-off to fivefolds may be involved).

Jackendoff's treatment of numerals is controversial: others have proposed a different syntax. In Bennett (1975) and Verkuyl (1981), e.g., numerals and 'few' and 'many' get the status of adjectives. Verkuyl provides syntactic arguments for this move. He shows that it is possible to consider Jackendoff's X-bar syntax as a categorial system, and he provides a sketch of a semantic treatment for it. My proposal below is in the spirit of Verkuyl & Bennett's, with some elaborations, but I will show in chapter III that for the semantics it does not matter whether we take the numeral to be part of the CN or part of the NP-specifier.

In chapter III more will be said about the semantic correlates to the syntactic intricacies of the NP-specifier system. Here I will just note that in a Montagovian framework quite a lot can be accomplished by suitable categorizations for the classes of specifiers that Jackendoff distinguishes on syntactic grounds.

I reject Jackendoff's proposals for the treatment of numerals and seminumerals. The syntactic evidence of 'a beautiful two days' is flimsy at best. This construction has no obvious parallels in languages like French, German, and Dutch (cf. '*une belle deux journees', '*eine schöne zwei Tage', '*een mooie twee dagen'); rather, it seems to be a highly idiomatic way to say 'a beautiful period of two days' in English.

In order to take care of co-occurrence restrictions, some feature information is needed. I will use a principle of feature percolation: the features on all nodes percolate to dominating nodes. A construction is ruled out by a feature clash, i.e. a situation where the construction process assigns incompatible features to the top node. (In some cases, a slightly more complicated mechanism for feature-behaviour will be needed; quite generally, there may also be cases where features must be assumed to percolate top-down.)

Let us postulate a category NUM for both numerals and Q-specifiers. NUM is a category that takes a set-expression and yields an expression that denotes sets of sets ('two' is interpreted as a function that takes the set denoted by 'men' and yields the set of all subsets of men that have two elements). If we abbreviate the category of "numbered CN's" as CNn, then NUM in its turn is an abbreviation for CNn/CN. Jackendoff's Q-specifiers are distinguished from the numerals by the fact that the Q-specifiers have feature [-det] (for '- determinate'). This feature assignment will be needed to assure that Q-specifiers do not combine with certain expressions of category SPEC (viz. the Art-specifiers). The Art-specifiers will get feature [+det]. I will suppose there exist two empty NUM nodes, one of which combines with singular CNs, the other one with plural CNs. (The account is restricted to countable CNs throughout.)

Demonstratives and Art-specifiers are lumped together in Jackendoff's system, but for a nice implementation of the partitive constraint it is better to put them in different categories. A suitable category for 'the', the demonstratives and the genitive pronouns is N/CNn, which I will abbreviate as DEM. Category N can be lifted to NP by an application of FAR.

The Art-specifiers get assigned category SPEC; expressions in this category take a numbered CN to form an NP, i.e. SPEC is an abbreviation for NP/CNn. Art-specifiers do not combine with [-det] CNs. They have feature [+det]. The empty SPEC node does not have this feature. The use of the [det] feature plus the categorizations that we have chosen render Jackendoff's Specifier Constraint superfluous. (A separate stipulation seems to be needed to prevent the combination of the SPEC dummy with a CNn that has a dummy [sg] NUM node.)

A straightforward way to treat seminumerals is to put them in a category SPECn of expressions that combine directly with a CN to form an NP. SPECn is an abbreviation for NP/CN.

[sg] and [pl] represent the number feature. [ps] represents the feature of elements of DEM, NUM, SPEC and SPECn of being pseudo-transitive, a feature that marks the expressions that can occur with a dummy CN. Cf. 'all were satisfied', 'neither was present', 'this is a warning', versus '* no were satisfied', '* every was present'. Hoeksema (1984) notes that in the partitive construction it is a necessary condition that the specifier in front be pseudo-transitive. This condition explains '*no of the assassins', '*my of the vices', '*the of the wine'. Note that the combines with superlatives to form pseudo-transitive specifiers: 'The bravest were killed in action'. This explains the acceptability of 'the last of the wine' and similar NPs. It is an open question how the necessary condition for the specifier in front of a partitive can be strenghtened to a condition that is also sufficient (cf. Hoeksema (1984) for more discussion).

I use ∅ for an empty CN-node. This dummy CN has the feature [ps\ps], indicating that it combines only with pseudotransitive specifiers.

Below, I will give some lists of lexical entries for elements of the NP specifier system. A lexical entry is a quadruple consisting of an English expression, its category, a set of features, and a logical translation (this last element will be omitted here, but cf. III.4 for a discussion of the semantics of the NP-specifier system).

<man, CN, [sg], [] >
<men, CN, [pl], [] >
<∅, CN, [ps\ps], [] >

The expressions in category NUM are:

<few, NUM, [pl, ps, -det], [] >
<many, NUM, [pl, ps, -det], [] >
<several, NUM, [pl, ps, -det], [] >
<one, NUM, [sg, ps], [] >
<two, NUM, [pl, ps], [] >
<three, NUM, [pl, ps], [] >
etc.
<∅, NUM, [sg], [] >
<∅, NUM, [pl], [] >

Note that all numerals except ∅ have the feature [ps].

A list of expressions in category DEM includes:

<the, DEM, [], [] >
<this, DEM, [sg, ps], [] >
<these, DEM, [pl, ps], [] >
<my, DEM, [], [] >
etc.

The category SPEC:

<each, SPEC, [sg, ps, +det], [] >
<every, SPEC, [sg, +det], [] >
<no, SPEC, [+det], [] >
<sm, SPEC, [ps, +det], [] >   NB: 'sm' for unstressed 'some'
<any, SPEC, [ps, +det], [] >
<∅, SPEC, [pl], [] >
<∅, SPEC, [sg], [] >

'All' is not in category SPEC for semantic reasons (cf. section III.4.3).

SPECn is an abbreviation for NP/CN. The expressions in this category do not combine with a CNn but with a CN. This accounts for the fact that they do not occur before numerals: '* both few boys', '* both two girls', '* a number of five elephants'. SPECn expressions that take the dummy CN are marked [ps]. Here are some examples of basic expressions in category

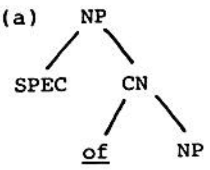
SPECn:

<some, SPECn, [sg], [] > NB: 'some' for stressed 'some'.
<some, SPECn, [pl, ps], [] >
<a, SPECn, [sg], [] >
<both, SPECn, [pl, ps], [] >
<a few, SPECn, [pl, ps], [] >
<a lot of, SPECn, [pl, ps], [] >
<a pair of, SPECn, [sg, ps], [] >
<a number of, SPECn, [pl, ps], [] >
<a bunch of, SPECn, [pl, ps], [] >
<a dozen (of), SPECn, [pl, ps], [] >
<a hundred, SPECn, [pl, ps], [] >
etc.

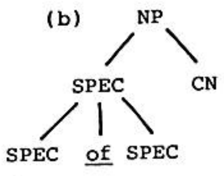
It must be noted, however, that discrete measure terms like 'pair', 'dozen', 'hundred', and 'thousand' also combine with numerals: 'several thousand insects', 'many pairs of shoes'. Syntactically, discrete measure terms seem to be in a class with bulk measure terms like 'kilogram (of)', 'cup (of)'. Discrete measure terms can only be used in connection with count nouns ('* two pairs of butter'). Bulk measure terms can be used with both count and mass nouns ('two kilograms of apples', 'two kilograms of butter'). When preceded by numerals or fractions ('two and a half'), bulk measure terms seem to form constituents that take the place that numerals have with count CNs. I will not incorporate measure terms in my system, as their semantics involves features of mass quantification that are outside the scope of this dissertation.

I now turn to the partitive construction. In the literature, at least three different structures for partitives have been proposed (I use SPEC for any NP-specifier or determiner here, and I do not distinguish between CN and CNn):

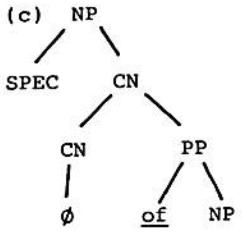
(a)



(b)



(c)

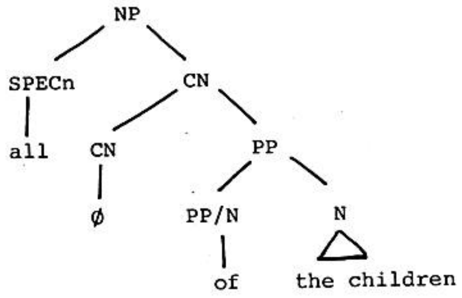


(a) has been proposed in Barwise & Cooper (1984); (b) can be found in Keenan & Stavi (1984), and (c), of course, is Jackendoff's proposal.

For a detailed review of these proposals, cf. Hoeksema (1984). I will not repeat Hoeksema's syntactic arguments for preferring one of these structures over the others. Instead, I will argue, that, categorically speaking, there is no need at all to choose between them. On the assumption that the category shift rules, as we will employ them, have no semantic effects, this shows that, as far as semantics is concerned, the syntactician can have it any way he wants it.

To argue my point, let me start with Jackendoff's structure (with the category-labels slightly modified to fit my categorizations; notably, the lower NP is labelled 'N', the category for definite NPs), and show how the other structures can be derived by applications of the general category shift rules I have introduced in II.2.2.1.

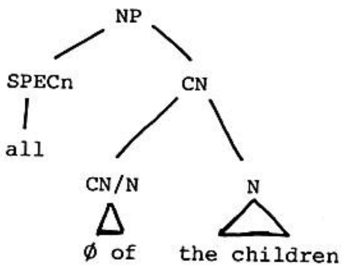
(d)



In this structure SPECn is an abbreviation of NP/CN, PP is an abbreviation of CN\CN, and PP\N abbreviates (CN\CN)/NP. I will need both FAR and GEP. Note, by the way, that in (d) $[_{CN}\ \emptyset\ ]$ cannot be replaced with a CN $\neq \emptyset$; under such a replacement the construction would cease to express a partitive.

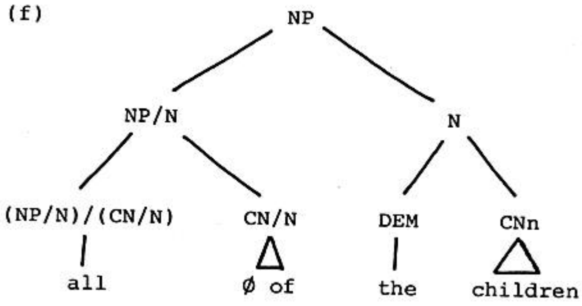
According to FAR, CN may be replaced with CN/(CN\CN). Next, an application of GEP to this derived category yields (CN/N)/((CN\CN)/N), i.e. (CN/N)/(PP/N). This means that we can combine the dummy CN node and the PP/N node to obtain a node of category CN/N, and the following structure emerges:

(e)



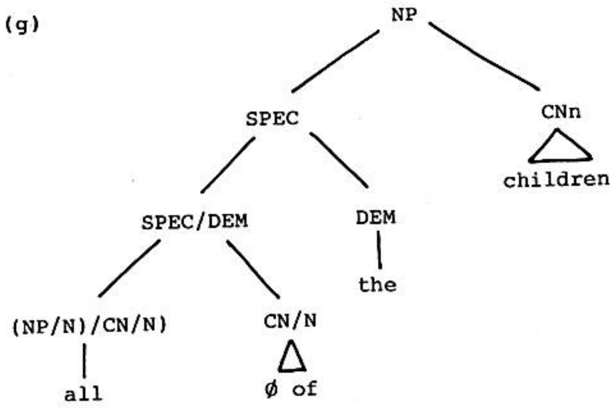
This is structure (a). To obtain structure (b), apply GEP to SPECn: SPECn = NP/CN ==> (NP/N)/(CN/N). This yields structure (f). This structure reveals a similarity between the partitive construction and the predeterminer + NP construction (as in 'half of some books', where 'half of' presumably has category NP/NP):

(f)



An application of GEP to the NP/N node in (f) yields an expansion (NP/CN)/(N/CN), i.e. SPEC/DEM, and we can construct the following tree, which is essentially structure (b) from the above list:

(g)



A final remark about the $[_{CN/N}\ \emptyset\ \text{of}\ ]$ node: the presence of the dummy CN in front of 'of' nicely explains the necessary condition that the specifier that occupies the front position in a partitive must be pseudo-transitive.

Modulo the assumption that the category shifts we have employed do not change the meaning of the structures (cf. chapter III.3.2 for details), we have shown that, as far as semantics is concerned, the syntax of the partitive construction is hardly constrained at all. In view of the fact that the syntactic arguments for the various proposals seem rather inconclusive, one might prefer not to choose at all. I have shown above that a choice can be avoided by incorporating the category shift principles in the syntax of the NP-specifier system.

In the description of the English specifier system in Quirk c.s. (1974), 'all' and 'both' are listed, with fractions like 'half of', 'one-third of', as predeterminers. Predeterminers could be incorporated in our system by giving them category NP/NP or NP/N (and an application of GEP can change this to SPEC/SPEC, SPECn/SPECn or SPECn/DEM). In view of the discussion above, a second categorization for 'all' and 'both' is unnecessary. The occurrence of these expressions in predeterminer position is nothing but a special case of the partitive construction.

II.3 The Analysis of Scope Ambiguity

In this section I will review three linguistic theories that belong to the TGG tradition and which purport to analyze - within that tradition - the semantic phenomenon of scope ambiguity. The three theories, presented respectively in Kroch (1974), May (1977) and Reinhart (1976,1979) have the following hypothesis in common: scope-ambiguities are to be explained on the basis of the surface structure of the sentences in which they occur. After this common start three different roads are taken. Kroch postulates certain lexical features for the different quantifiers, with the aim of formulating the scope reversals that are possible on the basis of the surface scope order of quantifiers in a sentence. Reinhart tries to formulate conditions on surface syntax in terms of which possible scope orderings can be predicted. May uses the surface syntactic structure of a sentence as a foundation for the building of superstructures that belong to a component 'Logical Form', each of which gives a different scope ordering for the quantifiers in the sentence.

II.3.1 Kroch's Theory of Scope Ambiguity

Anthony Kroch starts his dissertation with the remark that in the area of scope phenomena the syntax and semantics of natural language cannot be made to dovetail neatly. He gives examples of sentences that according to him have the same syntactic structure, but that nevertheless differ as regards the scope readings for the logical operators they contain.

(a) John didn't solve all of the problems --> reading: $\neg \wedge$

(b) John didn't solve some of the problems --> reading: $\vee \neg$

(c) John didn't solve many of the problems --> readings: M ¬
¬ M

(d) All of the problems aren't hard to solve --> readings: /\ ¬
¬ /\

(e) Some of the problems aren't hard to solve --> reading: \/ ¬

(f) Many of the problems aren't hard to solve --> reading: M ¬

In order to chart differences of this kind Kroch presents a system of rules to predict the scope ambiguities of sentences that contain several scope-sensitive operators. Kroch's theory consists of (1) optional permutation rules and (2) output filters. The permutation rules state which operator reversals are permitted, starting from surface order of operators and going through successive stages of permutation of the operators. The output filters state which of the readings that can be got by means of application of one permutation rule or a sequence of them, are acceptable, which are less natural and which are out.

In the formulation of these rules and filters Kroch uses lexical features of logical operators (the negation operator, modal operators, and several quantifier-phrases). The lexical features are necessary, not only to make rough and ready logical distinctions, like that between existential and universal quantification, but also to discriminate between different phrases that express the same logical quantifier. To mention an example: existential quantification can be expressed in a number of ways, by means of *some*, *several*, *a number of*, *one of*, but also, more emphatically, by *a single one of*. There is a difference in scope behaviour between these two ways of expressing existential quantification, witness the following examples:

(g) John didn't solve *some/several/a number* of the problems

(h) John didn't solve *a single one* of the problems

(g) has only one possible reading, viz. \/ ¬, while (h) has as its most natural reading ¬ \/. Kroch's scope readjustment rules permit scope reversal between the negation operator and the existential quantifier, in both examples. The difference in scope behaviour is explained by the fact that an output filter applies to example (g) that does not apply to example (h). In the case of (g), the following output condition on some, several, a number blocks the reading ' ¬ \/' (cf. Kroch (1974, 146, output filter 33):

> An order of operators .... ¬ Q .... is blocked if quantifier Q is the logical translation of one of the following specifiers: some, several, a number of, each.

In other cases the lexical properties of certain expressions that stand for scope-sensitive operations in a sentence even cause an acceptability-contrast, as in the following pair.

(i) *Not some of the students stayed to hear the lecture.

(j) Not a single one of the students stayed to hear the lecture.

Kroch's theory permits a number of nice predictions, but for present purposes it is not necessary to review the theory in detail. The fact that Kroch's system uses only information about scope order of operators at the level of surface syntax, combined with the fact that the theory employs lexical features of 'scope-expressions' make it possible to use the Kroch rules as extra constraints on scopes in any system that has a level of surface syntactic representation and which permits the introduction of features on lexical expressions.

II.3.2 May's Theory of Scope Ambiguity

A theory of the scope behaviour of quantified NPs that represents the main direction for incorporation of semantic phenomena in the TGG tradition, is developed in May (1977). Robert May adopts the framework of the EST, in which semantic structure, including scope phenomena, is covered in a separate component of 'Logical Form' (cf. section II.1 above). In fact his whole dissertation is devoted to an appraisal of the effects of a single rule of Logical Form, the rule QR ('Quantification Rule'), a transformation rule that has surface-structures and structures intermediate between surface syntax and Logical Form as its input.

The rule QR has the form of a movement-transformation. It moves a component and leaves a trace. The rule itself does not specify where the moved element has to go, except in very general terms. Extra information about the target position is encoded in 'conditions on transformations' that apply to all possible transformations. A condition on transformations that is important in connection with May's rule QR is the following:

<u>Condition</u> <u>on</u> <u>Analyzability</u>:

(CA) If a rule ϕ mentions SPEC, then ϕ applies to the minimal [+N]-phrase dominating SPEC, which is not immediately dominated by another [+N]-phrase.

This condition represents a specialization of the A-over-A principle that was mentioned in II.1 and which says:

(A/A) In a structure $[..X..[..Y_i..[..Y_j..]..]..]$ no rule can apply to X and Y_j, if the relevant structural conditions are such that the rule can both apply to Y_i and Y_j.

May explains the difference between the two Conditions in an appendix to Chapter 2 of his thesis, where it is also argued that the A-over-A principle does not extend to rules mapping surface structure to LF-structure.

In its terminology the condition on analyzability makes use of X-bar-theory, but compared to Jackendoff May uses a simplified version: the distinction between different projections of a category and the classification of specifiers that goes with this distinction play no rôle here. In the condition on analyzability, '[+N]-phrase' is used to generalize over NPs and APs. SPEC is a category that generalizes over specifiers.

Among NP-specifiers May distinguishes the categories Q, Det, and ∅. Unlike Jackendoff, May takes all these specifiers to be sisters of the N'-node. In Jackendoff's terminology: they are all in N''-specifier position. The category Q ranges over Jackendoff's quantifiers in his wider sense (Art-quantifiers plus Q-quantifiers) plus the indefinite articles a and indefinite some. The category Det ranges over definite articles, demonstratives, reflexives and possessives. This means that May takes the definite article and the indefinite article to belong to different categories. The empty specifier ∅ is the specifier of a proper name, a personal pronoun, a bare mass noun or a bare plural.

May distinguishes among Noun Phrases between Quantified Phrases (NPs with Q as specifier) and Referring Phrases (NPs with Det or ∅ as specifier). This distinction is rather unclear, for, as we have seen, NPs can have several specifiers. Are NPs like 'the many victims' quantified or referring phrases? One would suppose May to consider this example as a referring expression, but there is nothing in his theory that prevents the application of the rule QR: an application of QR is triggered by the presence of a specifier Q, regardless of whether there is also a specifier Det present. Several remedies are possible; the easiest way out is to assume that the distinction depends on the nature of the highest specifier. (But cf. also the note in o.c. p. 43.)

May's rule QR is simply:

(QR) Adjoin Q to S.

QR is a movement-rule that leaves a trace at the position from where an NP is moved. May interprets the traces as variables that are bound by the moved elements in their new positions. The application of the rule QR on surface structures of sentences results in structures that rather closely resemble formulas of first order predicate logic with restricted quantifiers (call this language LRQ). In LRQ-formulas the scope-relations between the quantifiers are fixed. When a sentence with a given surface syntactical structure exhibits a scope-ambiguity, this ambiguity is accounted for on the level of Logical Form iff it is the case that QR can be applied to the Quantified Phrases in surface structure in different ways that yield the envisaged non-equivalent readings.

To ensure that QR works as desired the notion 'NP A_i binds its trace i' must be defined and it must be verified that the traces that are left after the application of QR in the manner specified by the theory, are indeed bound in the desired way. May's definition of binding uses the structural notion of c-command (for 'constituent-command').

Df. A node A in a structure tree c-commands a node B in that tree iff the first branching node that dominates A also dominates B.

Df. The c-command domain of a node A is the set of all nodes X such that A c-commands X.

Df. NP A_i binds its trace e_i iff e_i is in the c-command domain of A_i.

Df. A variable e_i is properly bound iff some NP A_i binds e_i.

May formulates a condition on Logical Form that constrains the application of QR. To state it, one more definition is needed:

Df. The argument-positions of a predicate are the NP-positions for which the predicate is subcategorized (subject, object, etc.), except for the positions where 'it' can occur, e.g. the subject position in 'it is certain that.. '.

Predication Condition:

(PC) Every argument position of a predicate must either be a referring expression or a properly bound variable.

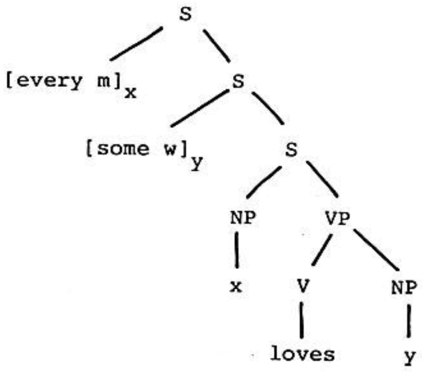
The Predication Condition makes application of QR obligatory if QPs occur in the surface structure of a sentence, and it also compels movement in upward direction, while the Condition on Analyzability ensures that the moved element will be a (possibly complex) NP.

To illustrate the workings of QR, consider the well-worn example (a).

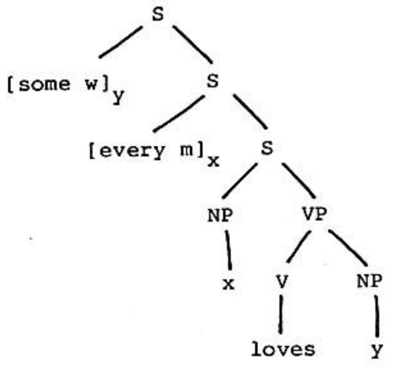
(a) Every man loves some woman.

The sentence contains two QPs, so QR must be applied twice in order to comply with the Predication Condition. This yields the following LF-structures:

(b)



(c)



The connection with formulas of a predicate logical language with restricted quantification is clear. The structures (b) and (c) can be translated respectively as:

(b') /\x ∈ M \/y ∈ W Lxy

and

(c') \/y ∈ W /\x ∈ M Lxy.

If an NP is of the form

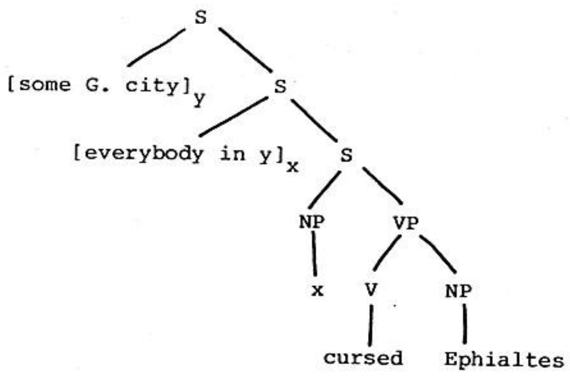
(d) $[_{NP}[_{NP}\ Q_1\ N\ ][_{PP}\ \text{PREP}\ [_{NP}\ Q_2\ N\ ]]]$,

then an application of QR to Q_1 will move the whole NP (this is a consequence of the Condition on Analyzability); an application of QR to Q_2 will move only the NP dominated by PP and extract it from A. This means that May's theory predicts a scope order Q_2 Q_1 for NP-structure with structure (d): if Q_1 would c-command Q_2 in LF, the predication condition would not be met.

As an illustration of this, consider example (e).

(e) Everybody in some Greek city cursed Ephialtes.

(f)



The corresponding logical formula would be:

(f') \/y ∈ G /\x ∈ Py (CUxe)

Here 'G' stands for the property of being a Greek city, 'Py' stands for the property of being a person present at y, 'CU' stands for the cursing-relation, and 'e' stands for Ephialtes.

Now consider sentences (g) and (h).

(g) Everybody cursed Ephialtes in some Greek city.

(h) Ephialtes betrayed everybody in some Greek city.

Example (g) will get two readings: after two applications of QR, either 'everybody' or 'some Greek city' can end up in the higher position. Example (h) is syntactically ambiguous between a structure where the PP belongs to the direct object and a structure where it is a sister to the direct object. Under the first syntactic analysis, (h) is semantically unambiguous: there is only one way to apply QR, which results in an LF-structure (h'). In the other case (h) gives rise to two non-equivalent LF-structures (h'') and (h'''), neither of which is equivalent to (h'). This gives three readings in all. All these predictions fit in rather nicely with one's intuitions about scope ambiguity.

Next, May discusses the application of QR to sentences that contain an embedded S. In these cases the Subjacency Condition that was mentioned in section II.1 becomes relevant. Here is the formulation of this condition that applies to structures of LF.

Subjacency Condition (as it applies to LF structures):

(SC) A Logical Form with structure $\ldots X_t \ldots [_A \ldots [_B \ldots [_C t] \ldots] \ldots] \ldots X_t \ldots$ (where A and B are bounding nodes, i.e. nodes of category NP or S) is ill-formed if (1) X_t immediately binds t and (2) whenever A = B, A does not immediately dominate B.

General comment: the notion 'bounding node' is supposed to be language-specific. Comment on (1): A phrase X_t immediately binds an occurrence *k* of a trace *t* iff X_t binds *k* and there is no occurrence *l* of *t* that is bound by X_t and that c-commands *k*. Comment on (2): this proviso is needed to ensure that the Subjacency Condition does not forbid the strings of S-nodes that immediately dominate each other in the examples given above.

Subjacency has as a result that quantified NPs in embedded sentences can only take scope over operators in the embedded clause: i.e. *quantification is clause-bounded*. (But cf. Chomsky (1977) and Huang (1982) for arguments against this.)

In example (i), QR can adjoin the subject of the embedded sentence to the matrix S and to the embedded S, but only the second option results in a LF-structure that complies with the Subjacency Condition.

(i) Odysseus regretted that one of his friends had been killed.

In the only acceptable LF-structure for (i) the existential quantifier representing the subject of the embedded sentence will have narrow scope with respect to the operator 'regretted that'. Subjacency also predicts that in relative clauses the relativized element has scope over all operators in the relative clause.

Incidentally, there are some theoretical problems with the way of operation of the rule QR. In the first place, there seems to be no constraint on iterated application of QR to a given QP. Any NP that has been moved by QR, still fulfils the conditions under which QR applies, so there is no reason why QR should not apply again. This must be an oversight, for if such iteration is permitted, any restrictions that the subjacency condition would impose on scope ambiguities can be circumvented.

In order to remedy this defect, a revision of the Predication Condition is called for. The most obvious reformulations do not work. The following requirement, e.g., is too strong: "Every Quantified Phrase must properly bind one and only one occurrence of a variable". This reformulation rules out applications of QR to quantified NPs that have been subject to an NP-movement transformation that has left a trace in surface structure, like 'some traitor' in example (j):

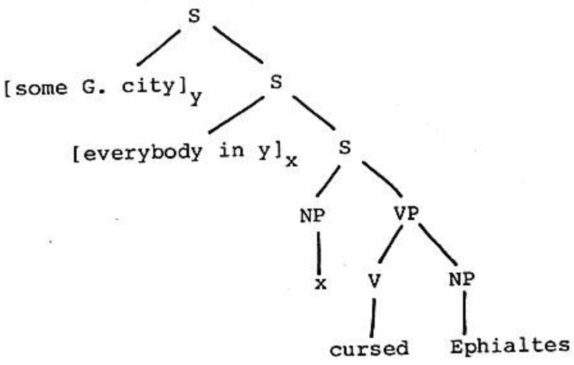
(j) Some traitor is likely e to have helped the Persians.

No LF-structure for (j) would be acceptable at all. Therefore a more specific formulation is needed, like the following: "Every Quantified Phrase must properly bind one and only one occurrence of a variable in argument position". This formulation takes care of example (j), but it is still not good enough. The reason is that not all variables in argument position in LF are traces resulting from applications of QR. Base-generated empty nodes (so-called PRO-elements), personal pronouns, reflexives and reciprocals can act as bound variables too. Thus, e.g. in cases of obligatory object- or subject-control, a variable PRO in argument position is bound by the object or subject NP of the sentence, and the above formulation would forbid an application of QR to this binding NP. (Some kind of co-indexing rule must be at work at LF to provide the link between PRO and the controller.) As it seems universally to be the case that the movement rules that apply to NPs (including QR) do not take these NPs to new argument positions, the following reformulation is possible.

(PC') Every Quantified Phrase must properly bind one and only one occurrence of a trace in argument position.

There is another problem (pointed out to me by Jack Hoeksema). Consider again structure (f):

(f)



The rule QR has been applied twice. First the subject NP has been raised; next QR has been applied again to move the embedded NP 'some Greek city'. Now observe that this second application of QR violates the subjacency condition: 'some Greek city' passes through two bounding nodes, the lifted NP [everybody in y] itself, and the S immediately dominating this NP in LF. Probably, most of May's followers would want to solve this problem by stipulating that the Subjacency Condition does apply to 'syntax proper', not to LF. But, of course, this way of distinguishing between D(eep)-structure plus S(urface)-structure on the one hand, and LF on the other, is rather <u>ad</u> <u>hoc</u>.

Curiously enough, the problem is not even mentioned in the text. In a note on p. 214, May toys with the idea of not regarding the NP node as a bounding node in the version of the Subjacency condition that applies to the results of QR. In my opinion this rather inelegant move is absolutely essential to save the theory.

Even with these bugs fixed there are still quite a few points at which May's theory yields wrong predictions. Here is a list (May is aware of most of these problems):

(1) Direct objects of transitive verbs are predicted to exhibit only a transparant reading (e.g., the reading of 'John seeks a girlfriend' where 'a girlfriend' has narrow scope with respect to 'seeks' is unaccounted for).
(2) The asymmetries in scope behaviour between the various quantified NPs (ambiguity of 'every man loves some woman' vs.

non-ambiguity of 'some woman loves every man') are unaccounted for. As there is no structural difference between the two examples, lexical properties of the specifiers 'every' and 'some' must be involved here (cf. Kroch (1974)).

(3) Definite descriptions are considered as not bearing scope, or, alternatively, as taking narrow scope w.r.t. any and every operator. In particular, this yields frequent wrong predictions for descriptions with an embedded quantified NP: NPs like 'the lord of every creature' are wrongly predicted to have only a reading where the embedded QP has wide scope.

(4) QPs with an embedded preposition + quantified QP are predicted to unambiguously exhibit an 'inversely linked reading'. Thus, e.g., the most natural reading of 'every patient with a non-contagious disease' is not accounted for.

(5) The numerous exceptions to the sweeping statement 'Quantification is clause-bounded' are not taken into account. E.g., the most obvious reading of example (j) is ruled out by May's theory. (In this particular case, a solution along the lines of Fodor & Sag's theory of specificity could be adopted - cf. Fodor & Sag (1982) - but this remedy will not work for examples with NPs that do not exhibit the specific-nonspecific distinction; cf. Chomsky (1977) and Huang (1982) for discussion .)

A fundamental weakness of May's theory is the way in which these obvious counterexamples are explained away, by labelling them 'marked cases' that fall outside of the range of phenomena that a 'Core Grammar' has to account for. In view of the vagueness of the 'marked' - 'unmarked' distinction this is very unsatisfactory. As long as no evidence is provided to the effect that this distinction can be drawn independently of an assessment of what the theory happens to account for, May's move out must be branded an immunization-strategy.

Still, the basic idea behind May's approach, the idea of using rules that map syntactic surface structures to unambiguous LF structures, is appealing enough to serve as a basis for further research. We will see in chapter IV that it is possible to enrich the framework of Montague grammar with a 'Logical Form' constituent that is very much like May's LF-component.

II.3.3 Reinhart's Theory of Scope Ambiguity

A third theory of scope ambiguity that can be located in the TGG-tradition is presented in Reinhart (1976) and Reinhart (1979). In Reinhart (1976) the notion of 'c-command' is introduced and shown to have great syntactic and semantic relevance. Reinhart claims, among other things, that the notion of c-command can be used to predict scope-ambiguities. Unlike May, Reinhart tries to manage on the basis of surface structure only, without postulating transformation rules that map surface structures into a level of Logical Form.

The issue is taken up again in Reinhart (1979). The Relative Scope Principle proposed there is:

> (RSP) A logical structure in which a quantifier binding a variable $\underline{x}$ has wide scope over a quantifier binding a (distinct) variable $\underline{y}$ is a possible interpretation for a given sentence S just in case in the surface structure of S the quantified expression (QE) corresponding to $\underline{y}$ is in the domain of the QE corresponding to $\underline{x}$.
>
> Reinhart (1979), p. 118

In this quotation 'domain' is short for 'c-command domain'. (Cf. the definition in section II.3.2.)

Reinhart gives the following instructions for the application of her RSP. In the first place, in quantified PPs (like 'in all the Greek cities') the whole PP is to be taken as a Quantified Expression. Likewise, in NPs with a quantified possessive as specifier (i.e. in genitive constructions like 'everyone's father') the Quantified Expression is the maximal NP 'everyone's father' instead of the embedded NP 'everyone'. Without this proviso the domain of the quantifier would be unduly restricted (it would be limited to the PP or NP).

Secondly, quantifier-words (i.e. NP-specifiers of syntactic category Q) may be lexically marked with a preference for wide (narrow) scope with respect to certain other operators. This may filter out certain readings that are possible according to the

RSP. In other words: the structural RSP must be supplemented with a quantifier-feature theory in Kroch's sense. Thus, 'Some novelists, everybody likes' has the same surface structure as 'Two languages, everybody speaks', and the fact that it does not exhibit the same scope ambiguity (or has at least a strong preference for the reading \/ /\ ) must be attributed to the tendency of 'some' to take wider scope than 'every'.

Finally, it must be noted that a certain scope reading that is in accordance with the RSP may be ruled out for structure-independent reasons. Cf. the following examples:

(a) The sailor had some sweetheart in every port.

(b) The sailor told some story in every port.

These sentences have the same structure. For both sentences, the RSP predicts the readings /\ \/ and \/ /\, but for structure-independent pragmatic reasons only the first interpretation is possible in example (a).

The most interesting applications of the RSP involve contrasts like the one exhibited in the following pair:

(c) Someone got bored by all of John's stories.

(d) Someone got mocked in all of John's stories.

Examples (c) and (d) differ in syntactic structure: the PP in (c) is verb-phrasal, whereas the PP in (d) is sentential (but note that this observation depends on a background syntactic theory). Thus, the quantified expression in subject position in (c) has the quantified expression in PP position in its domain, but it is not in the domain of the quantified expression in PP position. In (c) both quantified expressions are in each other's domains. Thus the RSP predicts (c) to have only the interpretation \/ /\ and (d) to be ambiguous between this reading and the inverted scope reading, a plausible prediction (if not a correct one). Note that May's theory is insensitive to the structural difference between (c) and (d): both sentences are predicted to exhibit the same ambiguity.

The RSP encounters a theoretical problem. It makes an incomprehensible prediction for sentences in which quantified expressions occur that are not in each other's domains. Reinhart herself gives an example of such a sentence:

(e) Ben's letters to some girls annoyed all the boys.

According to the RSP neither of the quantified expressions 'to some girls' nor 'all the boys' has wide scope over the other one. "This may mean that such sentences require branching quantifier analysis, but I will not elaborate on this point here" (o.c., p. 120).

There is a problem of logic here. The branching reading for sentence (e) is given by (f):

(f) $$\left.\begin{array}{l}\backslash/\text{girls}\\ \\ /\backslash\text{boys}\end{array}\right\rangle A$$

(f) expresses that the quantifiers are *independent* of each other. It says: it is possible to pick a set of some girls and, independently of that, to pick the set of all boys, and to do it in such a way that Ben's letters to those girls annoyed the boys. Unfortunately, for this particular choice of quantifiers, it happens to be the case that (f) is entailed by and entails the linear reading (g).

(g) \/girls /\boys A

As (g) is ruled out by the RSP, the branching reading contradicts the RSP, after all.

The trouble with the RSP is that is too specific (it should not talk about NPs that have non-overlapping c-command domains), that it is formulated as a biconditional where a mere conditional is called for, and that it does not take logical equivalences into account. I propose the following reformulation to remedy these defects:

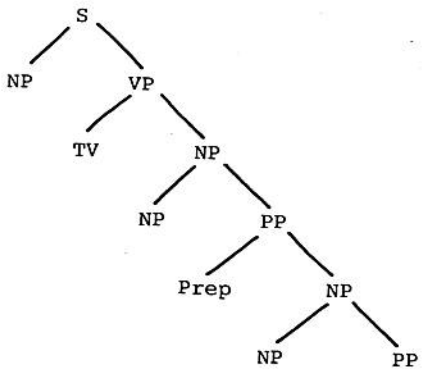
(RSP') If in a sentence structure S at the level of surface syntax a QE_1 c-commands a QE_2, but not vice versa, then an interpretation for S in which the quantifier Q_2 that corresponds to QE_1 has scope over the quantifier Q_1 that corresponds to QE_2 is ruled out, unless this interpretation is equivalent to one in which Q_1 has scope over Q_2.

There are empirical problems as well. One of them - noted also by Reinhart - is the wrong prediction yielded by the RSP for quantified PPs embedded in quantified phrases. I will consider an example that also serves to illustrate how predictions of structural principles like the RSP are contingent on the adopted syntactic analysis.

(h) The Athenians promised a bonus to all soldiers in some Attic city.

Reinhart, who discusses an example like this, assumes the following structure:

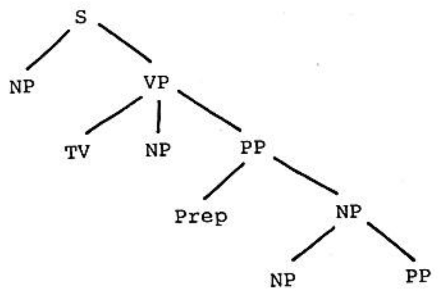
(i)



The RSP (revised version) predicts sentence (h), with structure (i) to have as its only reading '\/b /\s \/c' (for 'a bonus' c-commands both PPs, but not vice versa; 'to every soldier in some Attic city' c-commands 'in some Attic city' but not vice versa).

It might be argued that (h) has a different structure, viz.:

(j)



Under this assumption, the RSP predicts (h) to be ambiguous between the readings '\/b /\s \/c' and '/\s \/b \/c'. We must conclude that, whichever structure for (h) we choose, the most obvious reading , '\/c /\s \/b', is ruled out by Reinhart's principle. (Reinhart proposes an ad hoc modification to remedy this.)

May's theory does much better for examples like (h). May predicts that under the assumption of structure (i), the sentence has as its only reading '\/c /\s \/b'. Assuming structure (j), (h) is claimed to be ambiguous between this reading and '\/b \/c /\s'.

For quantifiers in embedded sentences, Reinhart's principle yields the same questionable result as May's: quantification is predicted to be clause-bounded.

Note further that Reinhart's rule, wrongly it seems, puts more severe restraints on scope ambiguity in simple sentences than does May's theory. It predicts, e.g., 'Everybody speaks two languages' not to be ambiguous, but to exhibit only the reading /\ \/2. Reinhart defends this as follows:

> [...] most putative examples of such ambiguities which are discussed in the literature are ones where one interpretation entails the other (e.g., the interpretation (\/ two languages x) (/\ y) ...) entails the interpretation (/\

> y)(\/ two languages x)... . So our intuitions distinguishing ambiguity in these cases are less clear than in cases where the two interpretations are logically independent.
>
> And in the second place, although there may be cases where speakers' disagreement cannot be reduced to the claim that the sentence in question is vague rather than ambiguous, and we will have to assume then that [while] these speakers permit a violation of [the Relative Scope Principle], it appears that the violation is highly restricted with respect to the NP pairs which tolerate it.
>
> (Reinhart (1979), p. 123)

In the second remark of this quotation Reinhart hints at the observation that whereas subject - object scope order inversion is rather frequent, scope order inversion of the subject and an NP in non-object position is very rare. This fact cannot be denied, and it is in accordance with Reinhart's principle.

Reinhart's first remark is more difficult to accept. In Reinhart's example it is indeed the case that one reading entails the other one. This is entirely due, however, to the nature of the quantifiers involved, witness examples like (k):

(k) Two persons in this room speak two languages.

Here neither of the two possible linear scope orders entails the other one, and still neither reading is ruled out.

Furthermore, if vagueness due to a logical entailment relation between possible scope orders plays a rôle at all, one would expect speakers' intuitions to be such that either the stronger reading is uniformly preferred (e.g. for the reason that it entails the other reading and thus conveys the stronger message), or the other way around (e.g. because the stronger message, given the Gricean maxim 'Be informative!', should be expressed by a statement that unequivocally conveys it). Neither of these seems to be the case.

II.4 The Analysis of Anaphoric Relations

The study of the mechanism of anaphoric linking, with special emphasis on the formulation of constraints on anaphora, is another major topic in the semantics of natural language as it is investigated in the TGG tradition. I will review two important contributions: the theory of Reinhart (1976), modified and commented upon in Reinhart (1983), and the theory presented in Higginbotham (1980).

Let me start with some remarks on terminology. An anaphoric relation or anaphoric link is a relation between a syntactic element that acts as the antecedent and a syntactic element that acts as the anaphor. In the following examples the antecedent and the anaphor are underlined:

(a) Odysseus hoped that he would return.

(b) Odysseus blamed himself for the delay.

Note that Chomsky c.s. reserve the term 'anaphor' for pronouns for which an antecedent is obligatory, i.e. reflexives, reciprocals and ordinary pronouns in specific constructions like 'Odysseus lost his way'. This habit will not be adopted here. I will call such pronouns R-pronouns. Ordinary personal pronouns will be called non-R-pronouns.

In cases where the anaphor in an anaphoric link acts as a variable bound by its antecedent, I will call the anaphoric link a binding link, and the mechanism a bound anaphora mechanism. It seems that NPs can also be anaphorically linked by a mechanism other than variable-binding, a mechanism that - in contradistinction to the variable-binding mechanism - may establish intersentential anaphoric links. Whenever the anaphor in an anaphoric pair does not behave like a variable bound by its antecedent, I will call the anaphoric link a 'referential' link (the quotes are scare quotes).

Many linguists call the antecedent and the anaphoric NP in any anaphoric link 'co-referential'. As this term suggests that the anaphoric link is not a binding link, I will not use it. Whenever I want to remain uncommitted as to the nature of the anaphoric mechanism I use 'anaphoric link'.

Clear examples of binding links are cases of intra-sentential links with a quantified expression as antecedent:

(c) No sailor believed that he would survive the storm.

Clear examples of 'referential' links are cases of inter-sentential links with a proper name as antecedent:

(d) Odysseus prayed to Apollo. He wanted to go home.

I will regard the relation of being anaphorically linked as an equivalence relation: every NP A is anaphorically linked to itself; if A is linked to B, then B is linked to A, and if A is linked to B, and B is linked to C, then A is anaphorically linked to C. Consider the following example.

(e) No sailor believed that he could save himself.

From the fact that the subject of the main clause is anaphorically linked to the subject of the embedded clause, and the fact that the subject of the embedded clause is linked to the direct object, it follows that the subject of the main clause is anaphorically related to the direct object of the embedded clause. (In chapter IV I will make use of these relational properties of the anaphoric link relation, by employing the concept of an 'anaphoric set' for the description of anaphora-constraints.)

II.4.1 Reinhart's Theory of Anaphoric Relations

The main topic of Reinhart (1976) is the study of the constraints that sentence syntax imposes on possible anaphoric relations. Reinhart maintains that the structural conditions that are relevant can be formulated in terms of c-command domains in surface structure. One of the rules proposed covers examples like (a):

(a) *Odysseus blamed Odysseus for the delay.

A different rule is invoked for cases like (b):

(b) *<u>Nobody</u>'s wife loves <u>him</u>/<u>himself</u>.

(These acceptability judgements might be challenged, of course, but for convenience I will accept them at face value. Acceptability judgements on English sentences, here and elsewhere in this dissertation, have been taken over from the literature, or have been confirmed by native speakers.)

In Reinhart (1983), a careful study is made of the distinction between cases where pronouns have a bound variable interpretation, and cases where pronouns have a 'referential' interpretation. Reinhart suggests that while the variable-binding mechanism that accounts for a subclass of anaphoric phenomena works at sentence level, the referential anaphora-mechanism can only be formulated at the more comprehensive text level of strings of sentences. Contrary to what is sometimes assumed in TGG circles, it is generally accepted in logical grammar that not only quantified NPs can bind pronouns, but all kinds of NPs can: the bound anaphora mechanism accepts any NP as an antecedent for an anaphoric link, provided it occupies a suitable structural position.

That proper names can act as variable-binders can be seen from examples of <u>ambiguities</u> between a bound variable interpretation and a 'referential' interpretation of (non-R) pronouns that have a proper name as antecedent:

(c) <u>Odysseus</u> sailed home in order to return to <u>his</u> wife, and so did <u>Agamemnon</u>.

Example (c) is most naturally interpreted as saying that Odysseus returned to Penelope, and Agamemnon to Clytaimnestra. Thus, the 'referential' NP 'Odysseus' must <u>bind</u> the variable 'his'. (A good source for more examples is Sag (1976).)

Reinhart argues that the only syntactic constraints on anaphora apply to the bound anaphora mechanism. The unacceptability of certain constructions that seem to involve a constraint on the 'referential' anaphoric mechanism (like example (a) above) is explained by means of a pragmatic rule.

As the pragmatic anaphora rule only makes sense against the background of the constraints on anaphora, I will first turn to these. The key principle of the bound anaphora mechanism is this:

<u>Constraint on Binding</u>

(CB) In the (intrasentential) <u>binding</u> anaphora-construction, the antecedent <u>must</u> c-command its anaphor.

This constraint entails the following: if a pronoun A c-commands an NP B in surface structure, then A cannot be interpreted as a variable bound by (the operator corresponding to) B.

NPs that must always be interpreted as variable-binding operators are typical quantified expressions like 'nobody'. The constraint on binding tells us that example (b) is out. To explain the fact that example (d) is in, it must be assumed that here the 'referential' anaphora mechanism is at work:

(d) <u>Odysseus</u>' wife loves <u>him</u>.

The constraint on binding was proposed by Reinhart. The following constraint is from Chomsky (1973). Reinhart proposes to regard it as a rule that applies to the bound anaphora mechanism.

Rule of Obligatory Anaphora

(ROA) A reflexive or reciprocal pronoun A must be interpreted as anaphorically linked to an NP B that c-commands A in surface structure and that is such that neither a tensed S-node nor a specified subject intervenes between B and A.

(Cf. Reinhart (1983:74))

This rule says that R-pronouns must have an antecedent inside a specified syntactic domain, later (in the Theory of Government and Binding) called their 'Minimal Governing Category'.

This rule has a counterpart stating that non-R-pronouns cannot have their antecedents inside the syntactic domain where reflexives have theirs:

Rule of Forbidden Anaphora:

(RFA) If A is a pronoun that is not a reflexive or reciprocal, then it cannot be interpreted as anaphorically linked to any NP B that c-commands A and that is such that neither a tensed S-node nor a specified subject intervenes between B and A.

(Cf. Reinhart (1983:74))

Some examples will illustrate the importance of the reference to tensed S-nodes and specified subjects in the rules. A tensed S-node intervenes in (e) and (f):

(e) Clytaimnestra knew that she would kill Agamemnon.

(f) *Clytaimnestra knew that herself would kill Agamemnon.

A specified subject intervenes in (g) and (h):

(g) Clytaimnestra believed Electra to despise her.

(h) *Clytaimnestra believed Electra to despise herself.

See for more examples and linguistic support: Chomsky (1973), Lasnik (1976), and the literature quoted there.

It should be noted that the ROA and the RFA may yield wrong predictions in cases of anaphora with more than one pronoun or reflexive. Consider the following example:

(i) *<u>Orestes</u> feared that <u>he</u> would kill <u>him</u>.

Suppose we had the following construction: 'Orestes' and 'he' are linked, 'Orestes' and 'him' are linked also, but 'he' and 'him' are not. This case would not be forbidden by the RFA.

The following general principle remedies this defect:

<u>Principle of Anaphoric Equivalence</u>:

(PAE) If, in a given syntactic structure, NP B is anaphorically linked to NP A, and NP C is also anaphorically linked to A, then B is anaphorically linked to C.

Example (i) shows that it is essential for correct predictions that the anaphoric link relation be considered an equivalence relation. The anaphoric pattern of (i) is ruled out by the fact that, if 'Orestes' and 'he' are anaphorically linked, and 'Orestes' and 'him' are anaphorically linked also, the PAE forces an anaphoric link between 'he' and 'him', which has as a result that the RFA applies. I propose to add the PAE to the rules ROA and RFA.

The following pragmatic rule is invoked by Reinhart to supplement the constraints on the binding anaphora mechanism.

<u>Pragmatic Anaphora Rule</u>:

(PAR) <u>Speaker's strategy</u>: When a syntactic construction you are using allows bound anaphora interpretation, then use it if you <u>intend</u> your expressions to be anaphorically linked, unless you have reason to avoid the bound-anaphora mechanism.

> Hearer's strategy: If a speaker avoids the bound anaphora options provided by the syntactic structure he is using, then, unless he has reason to avoid the bound-anaphora mechanism, he did not intend his expressions to be anaphorically linked.
>
> (Cf. Reinhart (1983:76))

The PAR explains the oddness of (a). In case the speaker would have meant there to be an anaphoric link between subject and object, he could have used a reflexive. The same reasoning explains the oddness of (j):

(j) *He blames Odysseus.

The acceptability of (k) is explained by the fact that no bound-anaphora construction is possible here: neither of the two occurrences of the proper name does c-command the other, so the 'referential' anaphora mechanism must be at work.

(k) Odysseus' wife loves Odysseus.

Let me explain the proviso that the PAR contains: 'unless there is reason to avoid the bound-anaphora mechanism'. This is needed to cover examples like (l), where the subject and the object NP refer to the same person, but the speaker has reason to avoid the anaphoric construction of (m), for the simple reason that (m) expresses a quite different statement.

(l) She is Odysseus' wife.

(m) Odysseus' wife is herself.

Likewise, the acceptability of the Geach-example (n) is accounted for by the PAR, as the anaphora construction (o) expresses something different.

(n) Only Odysseus pities Odysseus.

(o) Only Odysseus pities himself.

Reinhart's work suggests that it is hopeless to look for a general theory that reduces all anaphora facts to one mechanism. The next task for a general theory of anaphora seems to be to describe the workings of both the 'binding' and the 'referential' anaphora mechanism, and to investigate how the two mechanisms are related. Some part of this program will be carried out in this dissertation: I will show in chapter IV how the constraints on the bound anaphora mechanism that were stated above can be incorporated in an extended Montague-framework. In chapter V, I turn to the referential anaphora mechanism.

II.4.2 Higginbotham's Theory of Anaphoric Relations

Higginbotham (1980) discusses the phenomena that give rise to the Constraint on Binding and the Rule of Forbidden Anaphora in section II.4.1. He does not consider the phenomena that underlie the Rule of Obligatory Anaphora: the behaviour of R-pronouns is not discussed. A further difference is that Higginbotham supposes that a syntactic mechanism underlies the cases where Reinhart invokes her pragmatic rule.

While Reinhart (1983) is rather critical of the direction of the semantic research in the TGG tradition, Higginbotham trots the main TGG road. Higginbotham uses May's rule QR, one of the rules mapping from surface structure to logical form, as a starting point. Further he adopts the NP-indexing mechanism that is proposed in Chomsky (1980). Chomsky distinguishes two distinct mechanisms of NP indexing: <u>co-indexing</u> and <u>contra-indexing</u>. The first of these relates R-pronouns to their antecedents by assigning the same 'referential index' to the R-pronoun and the antecedent. ('Referential index' is of course a misleading label. Higginbotham remarks in a footnote that the term is not to be taken literally.)

The co-indexing mechanism works at surface structure level. The contra-indexing mechanism supposes that all NPs at surface structure level have been assigned a referential index. (It seems reasonable to forbid 'accidental co-indexing': no NPs can be assigned the same referential index at surface level unless one of them is an R-pronoun that has the other one in its minimal governing category.) The contra-indexing mechanism forbids certain anaphoric relations by assigning an anaphoric index consisting of a set of referential indices to all NPs except R-pronouns. The anaphoric index of an NP A (which could more appropriately have been called '<u>contra</u>-anaphoric index') consists of the set of referential indices of all NPs that c-command A. Two NPs A and B cannot be interpreted as anaphorically related if the referential index of one of them is a member of the anaphoric index of the other.

Under certain circumstances members of anaphoric indices can be deleted: if a pronoun A is not c-commanded in the minimal X = NP or $\bar{S}$ by an NP with referential index i, where X is a governing category of A (a rough approximation of what this is, is given in the formulation of the Rules of Obligatory and Forbidden Anaphora in section II.4.1 above; cf. for a precise definition Chomsky (1980)), then the index i, should it occur in the anaphoric index of A, is deleted.

This indexing machinery still covers only a part of the Rule of Forbidden Anaphora from section II.4.1. We get the right results for pronouns with referential expressions outside of their minimal governing category as antecedents, as in example (a).

(a) *Penelope* believed that *she* was a widow.

The anaphoric link between 'Penelope' and 'she' that is indicated by the underlinings is possible here because the referential index of 'Penelope' (say '2') is deleted from the anaphoric index of 'she'. As a result neither 'Penelope' nor 'she' has the referential index of the other as a member of its anaphoric index, and an anaphoric link between the two NPs is not forbidden. Note that in this system the anaphoric link between 'Penelope' and 'she' is *not* indicated in surface structure or logical form structure. The only information that can be derived from these structures is that the anaphoric link is *possible*. Thus the sentence (b), where the pronoun 'she' is used deictically, will get the same representation in SS and LF as (a):

(b) Penelope believed that $\overset{\nearrow}{\text{she}}$ was a widow.

This may be acceptable, but it has as an unpleasant consequence that the account does not generalize to cases like (c), where the antecedent is a quantified expression.

(c) *No woman* believed that *she* was a widow.

Consider the relation between (c) and (d):

(d) No woman believed that $\overset{\nearrow}{\text{she}}$ was a widow.

(Again ↗ indicates that the pronoun is used deictically.) In terms of anaphoric links, the relation between (c) and (d) is the same as that between (a) and (b). In (a) and (c) there is an anaphoric link between the subject of the main clause and the subject of the embedded clause, in (b) and (d) such a link is absent. Still, the difference between (a) and (b) is *not* reflected in Higginbotham's version of LF-structure, while that between (c) and (d) is.

In order to cover cases of bound anaphora, as in (c), Higginbotham proposes a mechanism of *re-indexing*. The following optional *re-indexing rule*, is introduced, like QR, to relate surface structures to LF:

(RR) In a configuration $\ldots e_i \ldots \text{pronoun}_j \ldots$, j may be re-indexed to i.

Here *e* stands for an empty node (i.e. a trace of a moved NP), or a PRO-element (i.e. a base-generated empty node). The RR is subject to the following *re-indexing condition*:

(RC) For all i, j, if pronoun_j re-indexes as pronoun_i, then every occurrence of j in the structure to which re-indexing applies is to be replaced by an occurrence of i.

Another constraint on re-indexing is, that situations are ruled out where as a result of this operation a pronoun has its own referential index as a member of its anaphoric index. Given the way the referential and anaphoric indices are to be understood, this is plausible.

To see how RR and RC relate to the rules that were discussed in II.4.1, note that if in a surface structure of a sentence of English an NP A c-commands another NP B, it is generally (though not always) the case that A occurs to the left of B. Thus, RR and RC taken together account for the cases where a quantified antecedent c-commands a pronoun that it binds.

But not in all examples discussed by Higginbotham where RR and RC apply to a trace left by an application of QR, is it the case that the quantified expression that left the trace c-commands the pronoun that is re-indexed in surface structure. In fact, RR plus RC predict that the class of cases where a quantified antecedent can bind a pronoun is somewhat larger than the class of c-command cases (cf. o.c., section 5.). While Higginbotham mentions some examples that indicate that the c-command constraint on quantified antecedent pronoun binding is too strict, the re-indexing mechanism he proposes is too lax. Another restriction on re-indexing, the cross-over constraint, that will not be discussed here, is needed.

The indexing machinery from Chomsky (1980) and Higginbotham (1980) (developed further in Chomsky (1981)) might grudgingly be accepted if there would turn out to be no simpler way to describe the full complexity of anaphoric processes in natural language. Meanwhile, it would still be pertinent to ask what all these different indices mean semantically, and to what semantic process the proposed procedure of re-indexing corresponds.

If it would be impossible to decide on empirical grounds which of the two theories discussed here, the theory sketched in Reinhart (1983) or the theory proposed in Higginbotham (1980), is best suited as a basis for further work on anaphora, then Reinhart (1983) would be preferable on grounds of elegance alone.

But in fact it is the case that Reinhart's theory is preferable on empirical grounds also. To see why this is so, note that in Higginbotham's theory, for a (non-R-)pronoun to be interpreted as bound by an antecedent, the pronoun must have the same index as its antecedent. If we suppose that all NPs (except R-pronouns and their antecedents) have been assigned different referential indices in surface structure, then the only way for two NPs none of which is an R-pronoun to get the same referential index is by means of the operation of re-indexing. As a result of the fact that re-indexing can only apply to pairs of pronouns and empty nodes and the fact that the only NPs that leave empty nodes in LF are the quantified expressions to which QR has been applied, only quantified expressions can ever end up as having the same index as a (non-R-)pronoun. But the ambiguity of examples like (e) indicates that pronouns that are anaphorically linked to 'referential' NPs can be ambiguous between a referential and a bound-variable interpretation.

(e) Odysseus says that he is a king, and Laertes says so too.

Higginbotham's theory does not account for such ambiguities, and it is difficult to see how this defect could be remedied.

II.5 Concluding Remarks

The theories reviewed in this chapter all draw a distinction between NPs that are quantified expressions and NPs that are not. Jackendoff, May and Higginbotham call the NPs that are not quantified expressions 'referring expressions', and they use a lexical criterion for the dichotomy: if an NP has a specifier that belongs to a certain syntactically determined lexical group, then the NP is a quantified expression, otherwise it is a referring expression. There is no absolute agreement on what constitutes the lexical class of quantificational NP-specifiers: Jackendoff lists the indefinite articles 'a' and 'some' as non-quantificational, while May considers 'some woman' as a quantified NP. None of these authors deems it necessary to give a semantic definition of the distinction between quantified and referring NPs.

When May originally drew the distinction between quantified and referring NPs, taking Higginbotham and others in his tow, he may well have been influenced by the picture of first-order predicate logic, where there is a clear difference between the universal and the existential quantifier on the one hand and the constant individual terms on the other. As soon as more powerful logical tools than those of first order predicate logic are taken into consideration, the distinction between quantifiers and individual constants becomes much less compelling. The distinction that May and Higginbotham have in mind cannot captured by calling all NPs that can act as variable binders 'quantified expressions', and all others 'referring expressions'. The reason is that, using the method of λ-abstraction and application, all NPs can be considered as operators that can bind variables: cf. the next chapter for details. (Linguistic arguments against this uniform treatment of NPs, especially in the area of so-called 'weak-crossover' phenomena, will not be pursued here.)

It must also be noted that as a result of the way in which Jackendoff, May and Higginbotham draw the distinction between referring and quantified NPs, the description of scope phenomena is restricted to a set of NPs that does not include definite descriptions: this means that e.g. the different ways of Russellian analysis of definite descriptions, where the notion of scope is crucially involved, are not covered by the proposed scope mechanism.

Reinhart does not give a lexical characterization of the distinction she draws between NPs that must always bind their anaphors, and NPs that permit a referential link to their anaphors. She states that the distinction is semantic, but no definition is offered. Part of a further elucidation of the 'referential' anaphoric mechanism that is postulated by Reinhart will certainly have to be a clearer characterization of the class of NPs that it applies to (cf. also Haïk (1984)).

A further task that emerges is the clarification of the link between the scope mechanism and the (bound) anaphora mechanism. Clearly, scope possibilities and anaphoric possibilities are related and mutually constrain each other. If we take the theories of May and Higginbotham together, and compare the result with Reinhart's theory, then Reinhart scores better on anaphoric phenomena, whereas May-Higginbotham provide a slightly more adequate description of scope facts. (The findings of Kroch can be incorporated in either of the theories as special constraints.)

Reinhart has observed that all NPs can act as binders of anaphors. It lies near to suppose that the mechanism that accounts for both scopes and bound anaphora (an NP-raising mechanism, an NP-indexing mechanism, or whatever), applies indiscriminately to all kinds of NPs: the mechanism fixes anaphoric links, and the logical properties of the NP-interpretations determine in which cases there is also a scope effect.

In the next chapter the way in which problems of scopes and anaphora are approached in Montague Grammar will be considered. In chapter IV, I will develop an extension of Montague grammar that uses a combined scope-anaphora mechanism, and that can be said to bridge the gap between the EST framework and the Montague framework. It incorporates both a full-fledged Montague semantic component, and a level of Logical Form in the spirit of the theories of May and Higginbotham. Finally, it also includes Reinhart's bound-anaphora constraints.

III THE MONTAGUE PERSPECTIVE ON QUANTIFICATION

III.0 Introduction

The first and foremost aim of logico-semantic analysis of natural language along the lines sketched by Richard Montague, is giving an account of reasoning in natural language and elucidating the concept of meaning for natural language expressions. In this endeavour the study of the relation of entailment between interpreted natural language sentences is of paramount importance. Logico-semantic analysis of natural language draws a parallel between natural languages and formal languages: both are studied with this same aim in view.

This parallelism is stressed in the opening sentence of Richard Montague's paper 'Universal Grammar' (Montague 1970b):

> There is in my opinion no important theoretical difference between natural languages and the artificial languages of logicians; indeed, I consider it possible to comprehend the syntax and semantics of both kinds of languages within a single natural and mathematically precise theory.

Note that Montague does <u>not</u> contend that no differences between natural and formal languages exist; in particular, he does not deny that the construction of a syntax and semantics for natural language comprises an empirical dimension absent in the study of artificial languages. Montague's assertion is rather that, in spite of the differences that can be found, it is possible to use a common framework to capture the way syntax and semantics of both natural and artificial languages are related.

A method much favoured in contributions to logico-semantics of natural language in the spirit of Montague Grammar is the <u>method of fragments</u>. Papers in logico-semantics characteristically propose solutions to semantic problems by treating them in the context of a rigorously defined fragment of natural language. A philosophical reason for this could be the fact that a rigorous semantics for a natural language in its totality cannot be given, due to the semantic paradoxes created by the possibilities for self-reference present in all natural languages. These paradoxes can be avoided by defining truth only for fragments that do not permit vicious self-reference. More important are the methodological advantages. The method of fragments makes it possible to eliminate any complicating factors that are considered irrelevant to the problems at hand by the simple expedient of imposing suitable limits on the fragment presented. Much insight can be gained by in-depth analysis of well-chosen fragments. On the other hand, there can be no guarantee that one does not abstract away from essential features of natural language by restricting attention to fragments (cf. II.1 above).

As in the previous chapter, I will start with a sketch of assumptions underlying the framework. Next, I will introduce the tools that are used in Montague grammar. First, in III.2, we turn to the logical translation languages that figure, in some versions of Montague Grammar at least, in an intermediate level between the component of syntactic structure and that of semantic interpretation. Then, in III.3, the rôle of categorial grammar in the framework will be explained, and a format for syntactic rules will be fixed.

After these preparations we are ready to turn to the Montagovian treatment of NPs, in III.4. I will extend Montague's semantics of NPs by providing a semantics for the NP specifier system that was proposed in II.2.2.2. In III.5 the Montague-rule for fixing quantifier scopes and anaphoric binding relations will be discussed. In a final section, I will discuss the rôle of meaning postulates in Montague Grammar, and I will mention a way of avoiding certain kinds of them.

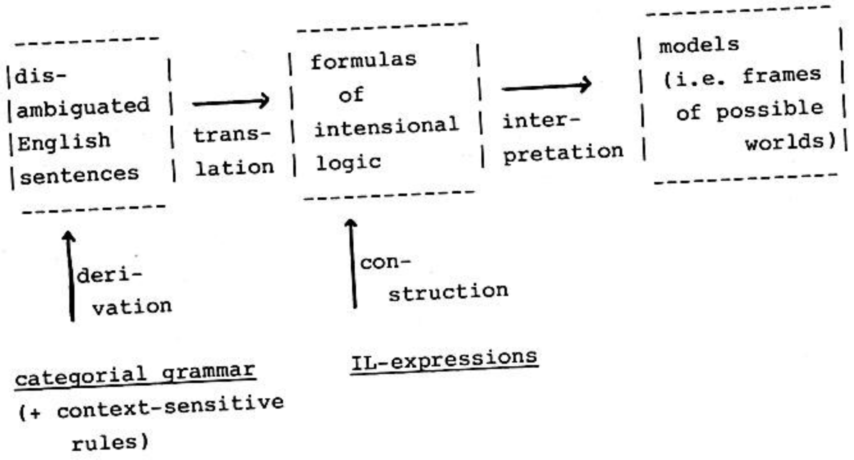
III.1 Underlying assumptions of Montague Grammar

In an analysis of natural language fom a logico-semantic perspective such as the one adopted in Montague (1970a), (1970b) and (1973) (henceforth these papers will be referred to as EFL, UG and PTQ respectively, and in quoting from them I will follow the page numbering in Montague (1974)), syntactic structures and the semantic interpretations that are assigned to sentences and sentence constituents are strongly interconnected. Indeed, Montague rejects the view that a respectable syntactic theory for English could be developed independently of semantic considerations:

> There will often be many ways of syntactically generating a given set of sentences, but only a few of them will have semantic relevance; and these will sometimes be less simple, and hence less superficially appealing, than certain of the semantically uninteresting modes of generation. Thus the construction of syntax and semantics must proceed hand in hand.
>
> EFL, p. 210.

A level intermediate between syntax and semantics is introduced in some of Montague's papers: the level of formulas of intensional logic that are translations of syntactic structures. The inclusion of this level is optional, as is illustrated by the fact that the level of IL-translations is absent in EFL.

In PTQ, syntax, intensional logic and semantics are related as follows:



The disambiguated natural language sentences in the leftmost box are obtained by means of a process of derivation from a set of rules of categorial grammar, plus some very powerful context-sensitive rules (the rules for relative clause formation and those for 'quantifying-in' NPs). The disambiguation of well-formed expressions of the syntax is achieved by specifying their manner of derivation: a disambiguated natural language sentence is the sentence plus its derivation tree.

The process of constructing IL-formulas out of basic IL-expressions is much more straightforward than the construction of disambiguated natural language sentences. Like all formal languages, but unlike natural languages, IL has a perspicuous syntax. IL-formulas immediately reveal their syntactic structure. No IL-formula is syntactically ambiguous.

Every rule of the syntactic component of the grammar is matched by a corresponding translation-prescription. As a result, the IL-formula that translates a disambiguated natural language sentence is fully determined, for the derivation tree lists the rules of categorial grammar that have been employed.

The principle that to every syntactic rule there corresponds a semantic rule, a rule that explains how the translation of the expression formed by the syntactic rule can be derived from the syntactic expressions that were the input of the CG-rule, is called the *Principle of Compositionality of Meaning*, or the *Compositionality Principle* for short. The compositionality principle says that the semantic interpretation of a complex expression is a function of the semantic interpretations of the constituting parts.

IL-expressions are used in Montague grammar to characterize the objects they denote in IL-models. These objects can also be mentioned directly. If this is done, an interpretation of a categorial language in a model can be defined without the introduction of a level of EL- or IL-translations in between. As the model-theoretic machinery involved is rather complicated, the IL-expressions (or expressions from a similar typed logical language) provide a very convenient means to talk about the intended objects. In this chapter and the next I will use a level of logical translations, rather than describe model-theoretic objects directly.

Montague imposes certain constraints on what possible IL-models may look like, in order to make these models appropriate for the interpretation of natural language. These constraints provide semantic information about certain constants of IL. For example, there is a constraint which says that the constants of type <s,e> used in the translations of proper names are *constant* functions from world-instant indices to entities. This requirement expresses the fact that proper names in natural language are *rigid designators*: their interpretation does not depend on a world-time index. In still other words: proper names do not have sense, they only have reference. The IL-formulas that Montague uses to express these constraints, are called *meaning postulates* (after Carnap). Of course it does not matter whether one chooses to impose constraints by stating that certain IL-formulas should hold for 'suitable' IL-models, or by phrasing the constraints in model-theoretic terms and imposing them directly on the IL-models. In section III.6 it will be shown how the meaning postulates that Montague uses in PTQ can be avoided.

III.2 Logical Translation Languages

The intensional language IL used in PTQ differs from first order predicate logic in two ways. In the first place IL is a 'typed logic'; every well-formed expression of IL is of a certain type, and by combining well-formed expressions of IL, well-formed IL-expressions of higher types can be construed. There is no highest type in IL, and quantification over variables of any type is allowed. First order predicate logic, by contrast, has only formulas as well-formed expressions, and allows quantification over variables that range over individual entities only. Next, IL is intensional. An intensional language is a language that is sensitive to contexts, situations, possible worlds, world-time slices, or whatever you wish to call it. Well-formed expressions of intensional languages have an intension and an extension: the extension is the reference of the expression in a given context (or situation, or possible world, or world-time slice); the intension of an expression is a function from the set of all contexts (or situations, or possible worlds, or world-time slices) to the extension of that expression in that context. First order predicate logic is an extensional language: there are no possible worlds involved here; there is only direct, extensional reference. (Strictly speaking, 'extensional' and 'intensional' are qualifications of logical languages plus their interpretations, not of logical languages per se.)

Type-theoretic languages were developed by Russell in an attempt to get around set-theoretic paradoxes like the Russell-paradox. They have been picked up lately as a tool for the logico-semantic analysis of natural languages. In type-theoretic languages nowadays, talk about types of the referents of well-formed expressions is mixed up with talk about the types of these expressions themselves. Presumably this confusion of language and interpretation is inherited from the days when Russell developed his theory of types. We could introduce a different term for one of these two uses of 'type', but as long as the distinction between expression-type and referent-type is kept in mind there is no harm in the ambiguity.

Before presenting two intensional languages, the logical language IL that Montague uses and the more powerful language Ty2, I will present a simpler type-theoretic language: EL, extensional type logic. The language EL will be used later on as a translation medium, in all cases where the incorporation of intensions would obscure the problems at issue. Basically EL is Montague's IL with intensions stripped off.

III.2.1 The language EL

EL has two basic expression-types: e (the type of expressions that have entities as referents) and t (the type of expressions that have truth-values as referents). Further expression types can be derived as follows: if a and b are types, then <a,b> is a type. Nothing else is a type.

The language EL has among its symbols infinitely many variables of any given type of the language. EL has a (possibly empty) set of constants for each type. EL has the quantifiers '\/' and '/\', and the logical connectives '&', 'v', '->', '¬' and '<->'. Further, EL has parentheses '(' and ')', brackets '[' and ']', the identity symbol '=', and the operator 'λ'.

The definition of the well-formed expressions (WFEs) of EL, and their types, is as follows:

(1) Variables and constants of type $\underline{a}$ are WFEs of type $\underline{a}$.

(2) If A is a WFE of type <a,b>, and B is a WFE of type a, then A(B) (i.e. the application of A to B) is a WFE of type b.

(3) If ϕ, ψ are WFEs of type t, then we can form negations, conjunctions, disjunctions, implications and equivalences, and stay in the class of WFEs of type t.

(4) The usual rule for quantification: if ϕ is a WFE of type t, and v is a variable (of any type), then \/v(ϕ) and /\v(ϕ)

are WFEs of type t.

(5) Identities are WFEs of type t: if A and B are WFEs of the same type, then (A = B) is a WFE of type t.

(6) The rule for function-formation by means of λ-abstraction: if B is a WFE of type b, and v is a variable of type a, then λv[B] is an WFE of type ‹a,b›. (λv[B] refers to a function from objects of type a to objects of type b; cf. the interpretation rule below.)

(7) The usual closure condition: for any type a, nothing is a WFE of type a, except as a result of a finite number of applications of (1) - (6).

An expression A is a WFE iff, for some type a, A is a WFE of type a. The set of WFEs of type t is called the set of formulas of EL. (Parentheses and brackets will sometimes be omitted in the interest of readability, in cases where no danger of ambiguity exists.)

For any expression type a there is in the models of EL a corresponding reference type r(a) of objects. As was mentioned in section III.2, the distinction between a and r(a) is usually disregarded. Following this common practice, we can say that in an EL-model M there is a subdomain of objects D_a for every EL-type a. The domain D of the model is the union of all these subdomains. Some examples of subdomains: D_t is the set {0,1} (the domain of truth values); D_e is the domain of individual entities; $D_{\langle e,t\rangle}$ is the domain of characteristic functions of individual entities, i.e. the domain of sets of individual entities.

We employ the following notation. For any sets X,Y, we let X^Y denote the set of all functions with domain Y and range $\subseteq$ X. Now we can say, for any types a and b:

$$D_{\langle a,b\rangle} = D_b^{\,D_a}$$

D_t is the same in all EL-models. Once the subdomain D_e of an EL-model is given, all other subdomains can be defined recursively. Therefore, an EL model M can be characterized as a pair $\langle D_e, F\rangle$, where D_e is the set of entities of M, and F is an interpretation function that maps all constants of EL to appropriate *denotations*. Now the *interpretation* (or '*denotation*' or '*extension*') of any given WFE of EL can be defined recursively, using the information that F provides.

We extend F to a function $\llbracket\ \rrbracket$ from the set of WFEs to D. For this we need Tarski's concept of an *assignment* g of appropriate denotations to the variables of EL. The difference with the case of first order predicate logic is that we now have variables of all possible types, instead of entity-type variables only. An EL-assignment function g for $M = \langle D_e, F\rangle$, is a function that, for every type a, maps the variables of type a to objects in D_a.

Let A be a WFE of EL, let $M = \langle D_e, F\rangle$ be an EL-model, and let g be an assignment function for EL. The *interpretation* of A with respect to model M and EL-assignment g for M , notation

$$\llbracket A \rrbracket_{M,g}$$

is defined as follows:

(1) If A is a constant, then $\llbracket A \rrbracket_{M,g} = F(A)$

If A is a variable, then $\llbracket A \rrbracket_{M,g} = g(A)$

(2) If A = B(C), then the interpretation of A is the result of applying the interpretation of B to that of C (all interpretations relative to g), i.e. $\llbracket A \rrbracket_{M,g} = \llbracket B \rrbracket_{M,g}(\llbracket C \rrbracket_{M,g})$

(3) For WFEs of type t, the truthfunctional connectives behave in the usual way, as described in their truth-tables: if ϕ is a WFE of type t, then $\llbracket \neg\phi \rrbracket_{M,g} = 1$ iff $\llbracket \phi \rrbracket = 0$, etc.

(4) As usual, the rules for existential and universal quantification make essential use of the assignment function g:

If ϕ is a WFE of type t, and v is a variable of type a, then $[\![\backslash/v\ \phi]\!]_{M,g} = 1$ iff for some object $d \in D_a$:

$$[\![\phi]\!]_{M,g[d/v]} = 1,$$

where g[d/v] is like g except for the possible difference that $g[d/v](v) = d$.

If ϕ is a WFE of type t, and v is a variable of type a, then $[\![/\backslash v\ \phi]\!]_{M,g} = 1$ iff for all objects $d \in D_a$:

$$[\![\phi]\!]_{M,g[d/v]} = 1,$$

where g[d/v] is as above.

(5) An identity statement is true iff the expressions at the two sides have the same interpretation:

If A, B are WFEs of the same type, then

$$[\![A = B]\!]_{M,g} = 1 \text{ iff } [\![A]\!]_{M,g} = [\![B]\!]_{M,g}$$

(6) Finally, we ensure that λ-formulas are interpreted as appropriate functions. Again the assignment g plays a crucial rôle in the definition:

If B is a WFE of type b, and v is a variable of type a, then $[\![\lambda v[B]]\!]_{M,g} = H$, where H is the function with domain D_a and range included in D_b, such that, for all objects $d \in D_a$,

$$H(d) = [\![B]\!]_{M,g[d/v]}$$

The six clauses in the above list precisely match the six clauses of the definition of the well-formed expressions of EL. This means that we have defined the interpretation function for all WFEs of EL.

A comparison with the truth-definition for formulas of first order predicate logic that was given in I.1.4 makes clear that the above definition is a straightforward variation on the theme set by Alfred Tarski taking the type-hierarchy and the devices of λ-abstraction and λ-application into account.

It should be noted however, that one could also take λ-abstraction, function application and identity as basic operations, and define universal and existential quantification, negation, disjunction and conjunction in terms of these (cf. Gallin (1975)). We have, e.g.:

$$/\backslash x\ \phi(x) \quad <=>_{\text{def}} \quad \lambda x[\phi(x)] = \lambda x[\mathrm{TRUE}]$$

This mathematical subtlety shows the power of λ-abstraction. It may serve as a reminder that the addition of the λ-operator cannot be viewed as just another slight modification of predicate logic.

III.2.2 The languages IL and Ty2

The language IL employed in PTQ has the same basic expression-types as EL. As in EL, we have the rule: if a and b are types, then <a,b> is a type. A new rule for type formation has been added: if a is a type, then <s,a> is a type. Here <s,a> is the type of expressions that denote functions from indices (Montague takes an index to be a pair consisting of a possible world and an instant in time, but other choices are possible) to objects of type a. Functions of type <s,a> are called intensions of objects of type a.

Like EL, IL has sets of constants and variables for all types of the language. IL has all the logical symbols of EL, plus the modal operators '□' and '◇'(for 'it is necessary that' and 'it is possible that'), the temporal operators 'P' and 'F' (for 'somewhere in the past, it has been the case that', and 'somewhere in the future, it will be the case that'), and the intensional operators '^' (for taking the intension of an object) and '$^\vee$'(for application of an intension to an index).

The definition of the WFEs of IL is a straightforward extension of that for EL-expressions.

(1) - (6) as in the definition of EL.

(7) WFEs of type t may be preceded by modal or temporal sentence operators: if ϕ is a WFE of type t, then $\Box\phi$, $\Diamond\phi$, $P\phi$, $F\phi$ are WFEs of type t.

(8) All WFEs may be intensionalized: if A is a WFE of type a, then $^\wedge A$ is a WFE of type <s,a>.

(9) All intensional WFEs may be extensionalized: if A is a WFE of type <s,a>, then $^\vee A$ is a WFE of type a.

(10) The closure condition.

Again: if there is no danger of ambiguity, I will occasionally omit parentheses and brackets.

We turn to the semantics of IL. (For a didactic presentation of what follows, cf. Dowty, Wall & Peters (1981).) The models M of IL are so-called Kripke-frames. Quite generally, a Kripke-frame M for an intensional type-theoretic language consists of a set of possible worlds W, a two-place relation R ('accessibility') on W, and a domain function $\mathbb{D}$ that assigns to every $w \in W$ its universe: a domain of entities $\mathbb{D}(w)$.

Montague has introduced some modifications. In the first place, because IL contains temporal operators, Montague takes intensions to be functions with domain WxT, where W is the set of worlds in the model, and T is the set of instants of time. T is (totally) ordered by the relation of 'temporal precedence'. If we focus on a world w, we can 'trace' the course of events in w by moving along T. Montague takes *all* world-instant pairs to be mutually accessible, and hence explicit mention of the accessibility-relation R is unnecessary. Finally, Montague chooses to let the domain of entities for each world be the same. Therefore the function $\mathbb{D}$ from worlds to domains of entities can be dropped. All that is needed is one domain of entities D_e.

As in the case of EL, a model M of IL has a domain D consisting of (possibly empty) subdomains for all possible types. The domains for the extensional types D_t, $D_{\langle e,t\rangle}$ etc. remain the same; domains for intensional types are added. Some examples: $D_{\langle s,e\rangle}$ is the domain of intensions of individual entities (or, to adopt Montague's terminology, the domain of individual concepts); $D_{\langle s,t\rangle}$ is the set of functions from world-instant pairs to the set $\{0,1\}$ (the domain of *propositions*). For every type a, Montague calls the set $D_{\langle s,\langle a,t\rangle\rangle}$ the set of *properties* of objects of type a. He also uses the notation S_a for $D_{\langle s,a\rangle}$, and he calls this set the set of *senses* of type a.

The domain D of an IL-model can be defined recursively once D_e and WxT, the domain of entities and the set of indices, respectively, are given. An IL-model M is a quadruple $\langle D_e, W \times T, <, F\rangle$, where $<$ is a total ordering of the set T (intuitively: the relation of temporal precedence), and F is an interpretation function that maps all constants of IL to appropriate intensions. An intension or sense for a WFE of type a is a function from WxT to elements of D_a, i.e. an object of type $\langle s,a\rangle$, or, in other words, an element of S_a. An extension for a WFE of type a is an element of D_a.

Montague wants to allow that a constant of type a refers to different objects of type A in different world-instant pairs $\langle w,t\rangle$ and $\langle w',t'\rangle$. Therefore the valuation function F maps all constants to appropriate senses. The assignment functions that we need are exactly like those for EL. An IL-assignment g for $M = \langle D_e, WxT, <, F\rangle$ is a function that, for all types a, maps the variables of type a to elements of D_a. (It is no problem at all to extend IL-assignments with interpretations for distinguished variables serving to translate context-dependent expressions like 'I', 'here', etc.)

The definition of IL-extensions is only slightly different from the case of EL.

For constants of IL, we use the value of F, applied to the current index: $[\![A]\!]_{M,g,\langle w,t\rangle} = F(A)(\langle w,t\rangle)$. For variables of IL, we use the assignment: $[\![A]\!]_{M,g,\langle w,t\rangle} = g(A)$. (Recall that assignments are defined as extensions.)

The definitions that correspond to formation rules (2) - (6) are like those for EL. For (7) - (9) the definitions are as follows.

(7) The necessity operator is interpreted as 'necessarily always': If ϕ is a WFE of type t, then $[\![\Box\phi]\!]_{M,g,\langle w,t\rangle} = 1$ iff for all $\langle w',t'\rangle \in WxT$: $[\![\phi]\!]_{M,g,\langle w',t'\rangle} = 1$.

The possibility operator is read as 'possibly some time':
$[\![\Diamond\phi]\!]_{M,g,\langle w,t\rangle} = 1$
iff for some $\langle w',t'\rangle \in WxT$: $[\![\phi]\!]_{M,g,\langle w',t'\rangle} = 1$.

The definitions for the temporal operators are straightforward: $[\![P\phi]\!]_{M,g,\langle w,t\rangle} = 1$ iff for some $t' < t$,
$[\![\phi]\!]_{M,g,\langle w,t'\rangle} = 1$;
$[\![F\phi]\!]_{M,g,\langle w,t\rangle} = 1$ iff for some $t' > t$,
$[\![\phi]\!]_{M,g,\langle w,t'\rangle} = 1$.

(8) The intensionalization operator is interpreted as a function from indices to extensions: if A is of type a, then $[\![{}^\wedge A]\!]_{M,g,\langle w,t\rangle} = h$, where h is the function from WxT to D_a such that for all $\langle w,t\rangle \in WxT$:

$$h(\langle w,t\rangle) = [\![A]\!]_{M,g,\langle w,t\rangle}.$$

(9) The extensionalization operator is interpreted as application to the current index: If A is a WFE of type $\langle s,A\rangle$, then $[\![{}^\vee A]\!]_{M,g,\langle w,t\rangle} = [\![A]\!]_{M,g,\langle w,t\rangle}(\langle w,t\rangle)$.

We have defined the extension $[\![A]\!]_{M,g,\langle w,t\rangle}$ for WFE A, in model M, with respect to assignment g and index $\langle w,t\rangle$. Now the intension of A in M with respect to g, notation: $[\![A]\!]_{M,g}$, is the function h with domain WxT that maps every index $\langle w,t\rangle$ to the extension $[\![A]\!]_{M,g,\langle w,t\rangle}$.

IL has the peculiarity that it lacks explicit variables over indices. It has proved to be expedient to use a language in which variables over indices occur (cf. e.g. Groenendijk & Stokhof (1981)). The language Ty2 (for 'two sorted type theory'), proposed in Gallin (1975), is an extension of IL that does have index-variables. I will briefly introduce it here, because it will be used in section III.6. (For simplicity, the temporal operators will be left out; the modification that is needed to incorporate tense is given in Janssen (1983), ch. III.)

The set of types of Ty2 includes that of IL. Ty2 has basic types s, e, and t, and, as usual, the rule: if a and b are types, then $\langle a,b\rangle$ is a type. The language of Ty2 has variables of every type, and a (possibly empty) set of constants for every type. The set of logical symbols is that of IL without '$^\wedge$' and '$^\vee$'. The definition of Ty2-WFEs, Ty2-models and the interpretation of the Ty2 WFEs in the models is a simple variation on the tunes for EL and IL. The interpretation function for a Ty2-model maps every Ty2 constant of type a to an object of type a. Note that the distinction between intensions and extensions has vanished.

Let $M = \langle D_e, W, F\rangle$ be an IL-model (for simplicity, the instants of time have been left out), and let $M' = \langle D_e, W, F'\rangle$ be a Ty2-model, where F' is such that for every constant C_a of IL there is a constant $C_{\langle s,a\rangle}$ of Ty2 with $F(C_a) = F'(C_{\langle s,a\rangle})$. We define a mapping @ of IL-formulas to Ty2-formulas that preserves the semantics, in the sense that for every WFE A of IL we have: A is satisfiable in M iff A@ is satisfiable in M' (the proof uses induction on the complexity of A).

In the definition of @, a single distinguished s-type variable i is needed. An assignment g for Ty2 will map i to a member of W.

(1) If A is an IL-variable, then A@ = A
If A is an IL-constant of type a, then $A_a@ = A_{\langle s,a\rangle}(i)$.

(2) If A and B are expressions of types $\langle b,a\rangle$ and b, respectively, then $[A(B)]@ = A@(B@)$.

(3) If ϕ is an IL-WFE of type t, then $[\neg\,\phi\,]@ = \neg\,\phi@$. Similarly for the other truthfunctional operators.

(4)-(6) Quantified expressions, identity-statements, λ-abstractions: similarly.

(7) If ϕ is an IL-WFE of type t, then
$[\,\Box\,\phi\,]@ = /\backslash i\ [\,\phi\,]@$;
$[\,\Diamond\,\phi\,]@ = \backslash/ i\ [\,\phi\,]@$.

(8) If A is an IL-WFE, then $[\,{}^{\wedge}A\,]@ = \lambda i\ (A@)$.

(9) If A is an IL-WFE of type $\langle s,a\rangle$, then $[\,{}^{\vee}A\,]@ = A@(i)$.

Gallin (1975) and Janssen (1983) extensively discuss Ty2. I will merely illustrate the differences and similarities between IL and Ty2 by giving some examples of IL-WFEs with the corresponding Ty2-WFEs.

English expr.	IL-translation (PTQ)	Ty2-translation
necessarily	$\lambda p[\ \Box\ {}^{\vee}p]$	$\lambda p[/\backslash i\ (p(i))]$
John	$\lambda P[\ {}^{\vee}P({}^{\wedge}JOHN)]$	$\lambda P[P(i)(\lambda i[\underline{JOHN}(i)])]$
unicorn	UNICORN	$\underline{UNICORN}(i)$
walk	WALK	$\underline{WALK}(i)$
John walks	${}^{\wedge}WALK\ ({}^{\wedge}JOHN)$	$\lambda i[\underline{WALK}(i)](\lambda i[\underline{JOHN}(i)])$

Here p is a variable of type <s,t>, P is a variable of type <s,<<s,e>,t>>, JOHN is a constant of type e, $\underline{\text{JOHN}}$ is the 'corresponding' Ty2-constant of type <s,e>, WALK and UNICORN are constants of type <<s,e>,t>, $\underline{\text{WALK}}$ and $\underline{\text{UNICORN}}$ are the 'corresponding' Ty2-constants of type <s,<<<s,e>,t>>. The reader may check for himself that function @ defined above maps the IL-expressions to their Ty2 counterparts.

Note the special feature of this enrichment of the language (people with a taste for pomposity might even want to call it a 'paradox'): the move from IL to Ty2 makes the logic easier. Special IL-laws for ^ and v now turn out to be ordinary cases of λ-application principles. E.g. the rather mysterious law of cup-cap cancellation, ${}^{\vee\wedge}A = A$, becomes simply: $\lambda i[A(i)](i) = A(i)$.

Ty2 will be employed in section III.6 below, where I will show how the use of this language enables one to get rid of the PTQ meaning postulates.

III.3 The Syntax of English in Montague Grammar

III.3.1 Categorial Syntax and Montague Grammar

Both Richard Montague and David Lewis (Lewis (1970)) adopt the theory of categorial grammar as their syntactic tool. I will review the categorial grammars that are used by Lewis and Montague, with special attention to the way in which noun phrases are treated. I will use Lewis' notation, because it is more perspicuous than Montague's.

Any categorial grammar starts from one or more basic categories. Montague takes two syntactic categories as basic: the category 'S' of sentences and the category 'N' of names. Lewis adds a third basic category 'CN' for common nouns. The choice of the categories is motivated semantically. The category that a certain well-formed syntactic expression has, reflects the type of the object that is to be its interpretation. If we disregard intensions, the types of the model-theoretic objects that are denoted by expressions of category 'S' and 'N', respectively, are 't' (for truth values) and 'e' (for entities).

Once basic categories are given, derived categories can be constructed, in the manner illustrated in section II.2.2.1. Montague uses both single and double slashes to form derived categories. His general schema for forming derived categories: when A and B are categories, then (A/B) and (A//B) are derived categories. This is needed to distinguish between intransitive verbs and common nouns: IVs have category (S/N), CNs category (S//N). Lewis does not need this expedient because in his system CN is a primitive category.

Montague and Lewis do not explicitly employ category shift rules like the GEP and FAR, although FAR is used implicitly. Montague uses a non-directional version of categorial grammar, and he employs syntactic construction rules that incorporate miscellaneous operations for adjusting word order, case and number assignment, and verb-inflection. Lewis uses an unidirectional rightward looking categorial grammar and proposes to handle rectification of word order by means of a transformational component.

The categories of the lexical items of a categorial grammar completely determine the grammar: this information is enough to derive a set of context-free phrase structure rules. Conversely, given a context-free phrase structure grammar, a categorial grammar can always be constructed by assigning appropriate categories to the terminal symbols. The construction of a categorial grammar out of a context-free phrase structure grammar is not unique, however, for a categorial grammar is explicit about function-argument structure, whereas a context-free phrase structure grammar is not. This is Montague's reason for preferring a categorial grammar over a context-free phrase structure grammar as his syntactic tool. In case we choose to enrich the categorial grammar with type changing principles (cf. II.2.2.1 and III.4.3), it is an open question whether the resulting language can still be described with a context free grammar (cf. Buszkowski (1982)).

All rules of categorial grammar that Montague employs have one of the following forms:

(a) A/B B -> A

(b) A//B B -> A

(c) B A/B -> A

(d) B A//B -> A

Because Montague allows virtually every syntactic modification to be incorporated in a syntactic operation, there is no need for him to use a bidirectional categorial syntax: reversal of functor-argument order simply is handled by the specification of the syntactic operation.

The categorization of IVs in PTQ, (S/N), expresses that IVs are syntactic objects that combine with a name (an expression of category N) to form a sentence (an expression of category S). If we disregard intensions to avoid presently irrelevant complexities, we can say that in Montague Grammar the semantic objects corresponding to intransitive verbs are sets of entities. A set of entities is equivalent to a characteristic function with the set of all entities as its domain. Corresponding to the basic syntactic categories there are basic semantic types: entities (the bearers of names) have type e; truth-values, the denotations of sentences (intensions aside), have type t. Thus the objects corresponding to intransitive verbs, being functions from entities to truth-values, have type <e,t>.

The semantic objects corresponding to common nouns are also sets of entities, so these objects also have type <e,t> (barring intensions again). This shows that there is no <u>semantic</u> distinction between intransitive verbs and common nouns. In view of the envisaged correspondence between syntax and semantics, they should be assigned to the same category. Montague's device of double slashes is used to distinguish categories that are semantically similar but must be kept apart for syntactic reasons.

What should be the syntactic category of quantified Noun Phrases? When combined with intransitive verbs, quantified NPs form sentences. Quantified NPs can not be in the same category with names, for names correspond to entities and a quantified NP need not correspond to an entity ('nobody' is a quantified NP, but there certainly is no corresponding entity). The only alternative categorization ensuring that quantified NPs can combine with intransitive verbs to form sentences, is (S/(S/N)), the category of expressions that take an intransitive verb to form a sentence. The instance of (a) that is employed here is:

(e) S/(S/N) (S/N) -> S

The semantic type that corresponds to the category (S/(S/N)) - always ignoring intensions - is <<e,t>,t>, the type of functions that map sets of entities to truth-values, i.e. the type of sets of sets of entities.

If common nouns get category (S//N) and quantified NPs category (S/(S/N)), then the NP-specifiers that together with a common noun form quantified NPs must get category

((S/(S/N))/(S//N)). An NP-specifier takes a common noun and forms an NP. It would be possible to distinguish lexically between NP-specifiers that yield descriptions and NP-specifiers that yield quantified expressions, in the spirit of the linguistic literature discussed in the previous chapter. Indeed, in view of the fact that descriptions are more like names than like quantified expressions, an appropriate category for the NP-specifiers that yield descriptions would be (N/(S//N)). This would result in the assignment of descriptions to category N. I will show in section III.4.3 that this categorization has the merit that it paves the way for a very elegant treatment of the partitive construction.

Montague and Lewis do not take this road. They opt for a uniform categorial treatment of all quantified NPs and descriptive NPs and take all NP-specifiers to be of category ((S/(S/N))/(S//N)). The close correspondence between syntax and semantics in Montague Grammar has as a result that this uniform syntactic treatment is mirrored in the semantics. The semantic type that corresponds to the category assigned to NP-specifiers - again barring intensions - is ‹‹e,t›,‹‹e,t›,t››, the type of functions that take sets of entities and yield sets of sets of entities. Both descriptive NPs and quantified NPs will become interpreted as sets of sets of entities.

If this were all, the 'intuitive' syntactic category NP would still be split in two categories N (for proper names) and (S/(S/N)) (for quantified expressions and descriptions). Instead of the single rule (e) (corresponding to the phrase structure rule S -> NP VP) we would need two rules. All linguistic rules that apply to NPs would have to be doubled, as separate rules would be needed for the expressions in category N and for those in category (S/(S/N)).

The method employed by Lewis and Montague to fill this potential gap between two kinds of NPs is to 'blow up' the category of names to that of quantified NPs and descriptions. Here, implicitly, they use an instance of the FAR category shift rule. Proper names get category (S/(S/N)), abbreviated as NP, instead of N, and they denote, in an extensional treatment, objects of type ‹‹e,t›,t›, sets of sets of entities. The proper name 'John' now denotes the set of all sets that contain John. As a consequence the category 'N' becomes a 'ghost category' without instances. Lewis proposes to revise the category system by taking NP, S and CN as basic. NP-specifiers get category NP/CN. Verb phrases now get category S/NP, i.e. the function-argument relation between subject and VP has been reversed.

III.3.2 A Format for the Rules of Grammar

The rules for the syntax of English that Montague has proposed in his papers have some disadvantages. In the first place, there are no constraints at all on the rules of grammar. Anything that is needed above and beyond the principles of categorial syntax is allowed. For a proper linguistic understanding of the complexity of syntactic phenomena, it is expedient to use the simplest possible format for the rules that describe them. In the second place, Montague's syntactic rules generate strings without any internal structure.

There is an advantage in modifying the syntax of Montague grammar in such a way that structured descriptions of English are generated (or 'recognized') instead of strings. Then, the syntactic rules can refer to properties of the structured descriptions that they take as inputs. In early extensions of the PTQ fragment, e.g. in Bennett (1975), syntactic markers on strings are used to encode information about syntactic structure. Bennett provides all verbs in the lexicon with the marker '#'. This marker indicates, if it is still present at the level where an singular NP and a VP are concatenated to form an S-expression, that the verb is to be replaced by its third person singular form. Syntactic rules that turn verbs into infinitives delete the marker '#'.

Bennett uses this ploy to remedy a defect of the syntactic rule of PTQ that forms expressions of category S out of NPs and VPs. This rule replaces only the <u>leftmost</u> verb that is encountered in the VP by its third person singular form. But PTQ has rules of VP-conjunction and -disjunction, so for conjoined or disjoined VPs the S-rule gives the wrong result. The original PTQ fragment does not generate example (a) correctly.

(a) Every man loves a woman and kisses her.

The verb <u>kiss</u> in the VP will not be replaced by its third person singular present form. In structured Montague Grammar the effect of the '#' marker can be obtained by a definition of 'finite verb' in terms of structural position.

In order to be more explicit about the rules of grammar, I propose the following context-free format for the syntactic rules:

$$\begin{array}{llll} A & := & B_1 \; .... & B_n \; . \\ [\alpha] & & [\beta_1] & [\beta_n] \end{array}$$

This stands for: a structure is permitted by the grammar in which a node labelled A dominates nodes labelled B_1, ... B_n, in their left-right order. $[\alpha]$, $[\beta_1]$, ... $[\beta_n]$, are sets of features. These are used for number and gender agreement, etc. I have nothing original to say about the much-discussed topic of conventions on feature-assignment, but I will freely use whatever I need in this area. Probably a principle like the Head Feature Convention that is used in GPSG should be adopted. I will assume that a function f exists that maps the node labels to appropriate logical types.

The translation rule that corresponds to a given syntactic rule must give the translation of A in terms of the translations for B_1, ..., B_n. We refer to the nodes in the left-right order in which they appear in the syntactic rule as 0, 1, .., n, and to their translations as 0', 1', ..., n'.

As an example, here is Montague's PTQ rule for forming a sentence out of an NP an a VP:

$$\begin{array}{lll} S & := & NP \quad\;\; VP \\ & & [3sg] \;\; [3sg] \end{array}$$

$$0' = 1' \; (\lambda i \; [2'])$$

The translation rule uses the language Ty2.

The grammatical rules define a context-free language, but note that this feature may get lost as soon as conditions on the admissibility of structures ("filters") are imposed.

III.4 The Syntax and Semantics of Noun Phrases

III.4.1 Montague's Treatment

The architecture of Montague grammar has as a result that the uniform treatment of names, descriptions and quantified phrases in the categorial component of PTQ is mirrored by a uniform treatment at the level of translation into a logical language and the level of interpretation. In order to show the relation between the extensional and intensional 'versions' of Montague Grammar, I will use both EL and IL in this section. I call the combination of the categorial grammar of PTQ and EL 'the extensional system', and the combination of the categorial grammar of PTQ and IL 'the intensional system'. It will emerge from what follows that, as regards the semantics of NPs, the similarities between the extensional and the intensional systems of Montague Grammar far exceed the differences. (In subsequent chapters, I will often confine myself to extensional treatments for this reason.)

In the extensional system, a mapping function f from the categories of the PTQ syntax to the types of the language EL, is defined as:

$f(N) = e$

$f(S) = t$

$f(A/B) = f(A//B) = \langle f(B), f(A) \rangle$

where A and B are arbitrary categories of the categorial syntax.

For the intensional system, the definition of f is slightly more complex:

$f(N) = e$

$f(S) = t$

$f(A/B) = f(A//B) = \langle\langle s, f(B)\rangle, f(A) \rangle$

This definition reflects Montague's <u>intensional</u> <u>blow-up</u>, i.e. the fact that Montague interprets *all* syntactic functors (A/B) and (A//B) as functions that take *senses* of type B as arguments. All function-argument contexts are taken as intensional to begin with. If a function has extensional arguments, i.e. arguments that do *not* vary from one index to the next (as e.g. the function that is the denotation of an *extensional* transitive verb like 'kiss' or 'find' at a certain world-instant pair), a meaning postulate is used to effect the proper "reduction".

The overall structure of the fragment of English that is presented in PTQ was given in the picture in III.1 above. Montague starts with an assignment of the basic expressions of his fragment (the expressions that belong to the *lexicon*) to categories in a categorial grammar. Proper names, like *John*, *Bill*, *Mary*, are in category NP, where 'NP' is an abbreviation for '(S/(S/N))'.

In the extensional system, proper names are interpreted as objects of type <<e,t>,t>, i.e. (characteristic functions of) sets of sets of entities. In the intensional system proper names have objects of type <<s,<<s,e>,t>>,t> as extensions, and objects of type <s,<<s,<<s,e>,t>>,t>> as intensions, i.e. their extensions for a given world-instant pair are (characteristic functions of) sets of properties of individual concepts, and their intensions are properties of properties of individual concepts. The intension of 'John' is the property of all properties of the individual concept of John. A meaning postulate is invoked to ensure that the individual concept of John is a *constant* function from world-instant pairs to entities, or in other words, that 'John' is a rigid designator.

The NP-specifiers 'every', 'a(n)' and 'the' that occur in the PTQ-fragment are not in the lexicon but are introduced syncategorematically: the NP-specifiers are not treated as expressions of the fragment in their own right, but are introduced by means of a syntactic rule that tells us how NPs can be formed out of common nouns. Common nouns (*man*, *woman*) that are in the lexicon are called 'basic common nouns'. The category of common nouns (S//N) will be abbreviated henceforth as 'CN'. Also, I will use the abbreviations 'VP' or 'IV' for (S/N).

The syntactic rule that forms NPs out of CNs runs: If A is an expression of category CN, then <u>every</u> A is an expression of category NP (likewise for 'a(n)' and 'the'). Thus derived noun phrases like 'every man', 'the house' and 'a woman' are in the same category with proper names. With the syntactic rule that forms derived NPs goes a semantic rule that tells us how the meaning of the derived NP depends of the meaning of the common noun that occurs in it.

In the extensional system this semantic rule says that, if the common noun A has translation A', then <u>every A</u> has translation:

(a) $\lambda P\ [/\backslash x\ (A'(x)\ {->}\ P(x))]$

Here P is a variable that ranges over sets of entities, i.e. an expression of the logical language of type $\langle e,t\rangle$ (= f(VP)). The type of expression (a) is $\langle\langle e,t\rangle,t\rangle$ (= $\langle f(VP),t\rangle$).

In the intensional system the translation A' of a common noun A is of type $\langle\langle s,e\rangle,t\rangle$ (= f(CN), the type of sets of individual concepts). Let P be a variable of type $\langle s,\langle\langle s,e\rangle,t\rangle\rangle$ (= $\langle s,f(VP)\rangle$, the type of properties of individual concepts), and x a variable of type $\langle s,e\rangle$ (x ranges over individual concepts). Then <u>every A</u> has translation (in IL):

(a') $\lambda P\ [/\backslash x\ (A'(x)\ {->}\ {}^{v}P(x))]$

(a') is a well-formed IL-expression of type $\langle\langle s,\langle\langle s,e\rangle,t\rangle\rangle,t\rangle$ (= $\langle\langle s,f(VP),t\rangle$). Similarly for <u>the A</u> and <u>a(n) A</u>. (For <u>the A</u>, Montague uses Russell's theory of definite descriptions). The NP-specifiers can of course also be incorporated in the lexicon as basic expressions in syntactic category NP/CN. The PTQ-fragment has only three NP-specifiers, but in Bennett (1975) and in Barwise & Cooper (1981) Montague's treatment is extended to numerous other ones.

There are uncountably many indexed pronouns in the PTQ-fragment: <u>he</u>$_0$, <u>he</u>$_1$, <u>he</u>$_2$, etc.

In the extensional system these pronouns get translations $\lambda P[P(x_0)]$, $\lambda P[P(x_1)]$, $\lambda P[P(x_2)]$,..., where the variables x_0,...

have type e and the variable P has type $\langle e,t \rangle$. In the intensional system, variables $x_0, \ldots$ of type $\langle s,e \rangle$, and a variable P of type $\langle s, \langle\langle s,e \rangle, t \rangle\rangle$ are needed. The translations are $\lambda P[{}^{v}P(x_0)]$, $\lambda P[{}^{v}P(x_1)]$, $\lambda P[{}^{v}P(x_2)], \ldots$

Using these pronouns, syntactic expressions can be constructed that are translated into EL- or IL-WFEs containing free occurrences of entity-type or individual-concept variables. A translation for a WFE A that contains instances of a pronoun with index n can be referred to as $A'(x_n)$, indicating that an entity-type or individual-concept variable x_n occurs in the translation A' of A.

Complex common nouns are formed by means of rules that combine a sentence ϕ containing at least one indexed pronoun with a common noun A. There is a rule that combines 'woman' and 'he_2 walks' to form 'woman such that she walks', or 'woman' and 'John likes he_4' to form 'woman such that John likes her'. The combining rule is a functor that specifies the index of the pronoun to be relativized, and states the syntactic changes that have to take place in the expressions to be combined. The resulting expression can be written as $F_i(A,\phi)$, where F_i is the syntactic functor and i is the index of the pronoun that is relativized. If sentence ϕ has translation $\phi'(x_4)$ and common noun A has translation A', then $F_4(A,\phi)$ has translation (b):

(b) $\lambda x_4[(A'(x_4) \;\&\; \phi'(x_4))]$

Note that for this mechanism of relative clause formation to work properly, it is crucial that the pronouns in PTQ do have indices.

The PTQ-rule for relative clause formation illustrates that Montague does not hesitate to employ devices that are much more powerful than the principles of categorial syntax. Linguistically, it would be more interesting to try and be more parsimonous in allowing principles beyond those of categorial syntax. In order to get a deeper insight in the nature of natural language, one's aim should be a description of syntactic and semantic mechanisms in terms that are as simple as possible.

III.4.2 Some Proposals for Extensions

Some early proposals to extend the class of NP-specifiers in PTQ can be found in Bennett (1975). Bennett extends the PTQ-framework to accommodate plural NPs and he adds many new NP-specifiers, such as 'many', 'few', 'a few', 'both', 'most', 'at least one', 'at most one', 'the one','the two', etc.. Like Montague in PTQ, Bennett introduces his specifiers syncategorematically. In all, Bennett has 66 syntactic functions that form NPs out of CNs. The number of specifiers added, however, does not exceed 20. For almost every specifier that is introduced, Bennett is forced to split up the rule covering it, because in his treatment the syntactic classes of NPs and CNs fall apart into several subclasses, in different categories. NPs are distinguished in NPs at the group level and NPs at the individual level. Likewise for CNs, VPs, etc..

Bennett extends IL by adding the following new operators:

$$\bigvee_{\text{at least } n} \qquad \bigvee_{\text{exactly } n} \qquad \text{MOST}$$

plus operators for 'few', 'some', 'several' and 'many' that depend on what Bennett calls a 'frame of specification'. A frame of specification associates with every occurrence of one of these four pragmatically loaded determiners a specification: a four-place sequence of integers that specifies what constitutes few, some, several and many, respectively. (A full-fledged theory of the pragmatic resolution of vagueness would be needed to describe what constitutes an appropriate specification for 'few', 'some', 'several' or 'many' in a given context.)

A typical linguistic reaction to Bennett's extension of PTQ is summed up in the following quotation:

> The normal reaction of linguists to this sort of treatment is a feeling of repugnance for the use of so many rules, the overall impression being that the system of syncategorematic

> rules cannot account for the many syntactic correspondences among determiners.
>
> Verkuyl (1981,581)

A first step in countering this objection is the introduction of one or more separate categories of NP-specifiers in the grammar. Next, some syntactic and semantic order among them should be established.

Barwise & Cooper, like Bennett, extend the range of NP-specifiers in Montague Grammar, but unlike Bennett they put their specifiers in a separate category, they confine themselves to an extensional treatment, and they disregard subtleties of plural quantification like the distinction between distributive and collective readings, a distinction that led Bennett to split up his categories NP, VP and CN. Their article has given rise to a revival of interest in the theory of generalized quantifiers (cf. section I.1.5).

Barwise & Cooper use a framework that is similar to the PTQ-framework pictured in II.2. Like in PTQ there is a level of translation into a logical language. In the language LGQ all specifiers receive a trivial translation: 'every' is translated as EVERY, 'most' as MOST, 'many' as MANY, etc.., where EVERY, MOST, MANY, ... are expressions of type <<e,t>,<<e,t>,t>>. It is not perspicuous in the notation which of these expressions belong to the logical vocabulary and which are non-logical constants that depend on the interpretation function of the model. Later on, when they define how LGQ is to be interpreted, Barwise & Cooper make it clear that the following expressions of LGQ have a constant interpretation in every model: SOME, EVERY, NO, BOTH, NEITHER, and for every natural number n: $\underline{n}$ (at least n), $\underline{!n}$ (exactly n), and THE $\underline{n}$.

The expressions NEITHER, BOTH, and THE $\underline{n}$ cannot be rendered in EL, for Barwise & Cooper adopt a presuppositional treatment: formulas of LGQ in which they occur lack truth-values in models where the presuppositions are not fulfilled. But otherwise, all expressions from the above list can be represented in the logical vocabulary of EL or IL. For the specifier MOST the situation is different. Barwise & Cooper translate 'most' as a constant, and they let the interpretation function of the model take care of it.

There is an important difference between the operator 'MOST' and the other logical operators that Bennett has added to IL: 'at least n A are B', 'exactly n A are B' could have been defined in terms of IL-formulas, so in fact the operators 'there are at least n' and 'there are exactly n' are mere *abbreviations*. Given a frame of specification, the same holds for 'there are few', there are some', 'there are several', 'there are many'. One might choose to incorporate 'most' in the frame of specification as well. Instead, Bennett translates 'most' with 'MOST', where MOST is interpreted as a new restricted quantifier. Now the situation is different: the extension of the logical language with this operator increases the expressive power of the language. (A proof is in appendix C of Barwise & Cooper (1981); an earlier proof is in Wallace (1965). Barwise & Cooper also prove that it is impossible to define restricted (binary) MOST in terms of unary MOST.)

Barwise & Cooper could have extended the logical vocabulary of their translation language to include the higher order quantifier 'MOST'. This move would have made explicit that 'most' (in the sense 'more than half') is an expression that receives the same interpretation in every model.

Both Bennett and Barwise & Cooper follow Montague's uniform treatment of NPs. If one is willing to allow category shift rules, then an alternative treatment of NPs becomes possible. In the next section, I will discuss the semantics of the category shifts that we need, and in III.4.4 I present a semantics for the NP-specifier system that was proposed in section II.2.2.2. My proposal is a further extension of the Montague approach to the semantics of NPs, intended to incorporate the singular-plural distinction and to do more justice to some of the linguistic pecularities of the NP specifier system.

III.4.3 Rules For Category Shifts

The notation of categorial grammar can be used to generalize over the node labels that have been introduced in III.3.2. Using only single slashes, we let A/B stand for any node label that translates to the same type as A/B.

For convenience, I repeat the FAR as it was stated in II.2.2.1:

(FAR)

A ==> B/(A\B)

A ==> (B/A)\B

If we decide to disregard directionality, these two rules collapse into one (the slashes do not convey information about directionality):

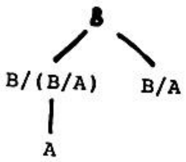
A ==> B/(B/A)

Adopting the format that was introduced in III.3.2, we can now formulate the pattern of the FAR rule, with the corresponding translation shift, as follows (a and b are the types that A and B translate to, respectively):

B/(B/A) := A

$0' = \lambda P_{\langle a,b\rangle} [P (1')]$

Here is an example of a structure tree in which this rule is employed:



I will use the FAR in connection with the categorization for the NP-specifier system that was proposed in II.2.2.2. Note that this proposal is <u>different</u> from what is usual in Montague grammar. In my proposal, the expressions of category N may be proper names and definite NPs. They are interpreted as objects of type $\langle e,t \rangle$, because (in the plural case) they may denote <u>groups</u> of e-type things. Singular proper names are interpreted as <u>singletons</u> of e-type objects. The mapping f from categories to types can be straightforwardly extended once it is known that $f(N) = \langle e,t \rangle$, $f(CN) = \langle e,t \rangle$, $f(CNn) = \langle\langle e,t \rangle,t \rangle$, and $f(S) = t$ (barring intensions). E.g., $f(VP) = f(S/N) = \langle f(N),f(S) \rangle = \langle\langle e,t \rangle,t \rangle$; $f(NP) = f(S/VP) = \langle\langle\langle e,t \rangle,t \rangle,t \rangle$, $f(SPEC) = f(NP/CNn) = \langle f(CNn),f(NP) \rangle = \langle\langle\langle e,t \rangle,t \rangle,\langle\langle\langle e,t \rangle,t \rangle,t \rangle\rangle$.

An instance of the FAR rule is the following blow-up for proper names and definite NPs (under the categorization of section II.2.2.2):

NP := N

$$0' = \lambda P_{\langle\langle e,t \rangle,t \rangle} [P\ (1')]$$

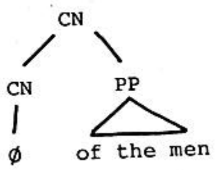
It is presupposed here that proper names and definite NPs are mapped to type $\langle e,t \rangle$ (cf. III.4.4 for more details on the semantics). Otherwise (under the mapping f for the extensional system given in III.4.1) we would have the following translation shift: $\lambda P_{\langle e,t \rangle} [P(1')]$.

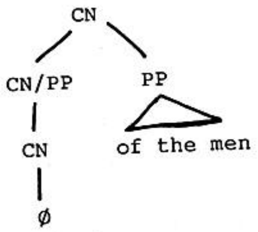
Another instance of the FAR that we have used in II.2.2.2 is the following (PP maps to type $\langle\langle e,t \rangle,\langle e,t \rangle\rangle$, CN to type $\langle e,t \rangle$):

CN/PP := CN

$$0' = \lambda P_{\langle\langle e,t\rangle,\langle e,t\rangle\rangle} [P (1')]$$

It is clear from the translation component of the rule that the following structures have the same interpretation:





The other type-shift rule that was introduced in II.2.2.1 was the GEP. It was stated there as follows:

(GEP)

A/B ==> (A/C)/(B/C)

B\A ==> (C\B)\(C\A)

Again, if we disregard directionality these two rules collapse into one. In the notation of III.3.2, and with a matching translation rule, the GEP becomes:

(A/C)/(B/C) := A/B

$$0' = \lambda P_{\langle c,b\rangle} [\lambda Q_c [1'(P(Q))]]$$

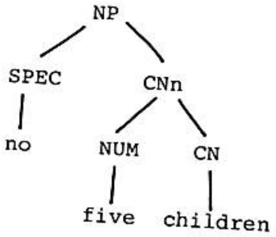
To see that the following rule is an instance of the GEP, one should recall that SPEC abbreviates NP/CNn, which translates to type $\langle f(CNn),f(NP)\rangle = \langle\langle\langle e,t\rangle,t\rangle,\langle\langle\langle e,t\rangle,t\rangle,t\rangle\rangle$, that SPECn abbreviates NP/CN, which translates to type $\langle\langle e,t\rangle,\langle\langle\langle e,t\rangle,t\rangle,t\rangle\rangle$, and that NUM abbreviates CNn/CN, which translates to type $\langle\langle e,t\rangle,\langle\langle e,t\rangle,t\rangle\rangle$ (cf. II.2.2.2 above and

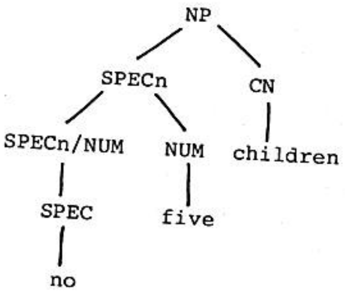
III.4.4 below for more details).

SPECn/NUM := SPEC

$$0' = \lambda P_{\langle\langle e,t\rangle,\langle\langle e,t\rangle,t\rangle\rangle} [\lambda Q_{\langle e,t\rangle} [1'(P(Q))]]$$

Note that the expression $1'(P(Q))$ has type $\langle\langle\langle e,t\rangle,t\rangle,t\rangle = f(NP)$, and $\lambda Q\ [1'P(Q))]$ has type $\langle\langle e,t\rangle,f(NP)\rangle = \langle f(CN),f(NP)\rangle = f(SPECn)$, just as it should. It is clear from the translation rule that the following structures will get the same translation:





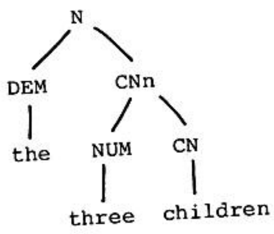
This shows that semantically it is irrelevant whether we take numerals as part of the common noun or as part of the specifier.

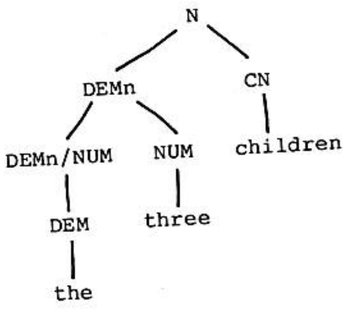
Another instance of the GEP pattern (recall from II.2.2.2 that DEMn is the label of a structure that combines with a CN to form an N, and DEM abbreviates N/CNn):

DEMn/NUM := DEM

$$0' = \lambda P_{\langle\langle e,t\rangle,\langle\langle e,t\rangle,t\rangle\rangle} [\lambda Q_{\langle e,t\rangle} [1'(P(Q))]]$$

Note that $1'(P(Q))$ has type $\langle e,t\rangle = f(CN)$, and $\lambda Q[1'P(Q))]$ has type $\langle f(CN),\langle e,t\rangle\rangle = \langle f(CN),f(N)\rangle = f(DEMn)$, which is again the right type. Again it follows that semantically it is irrelevant which of the following structures we adopt (CNn stands for 'numbered CN' and translates to type $\langle\langle e,t\rangle,t\rangle$):



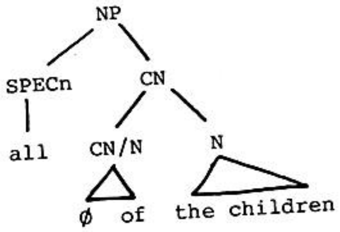


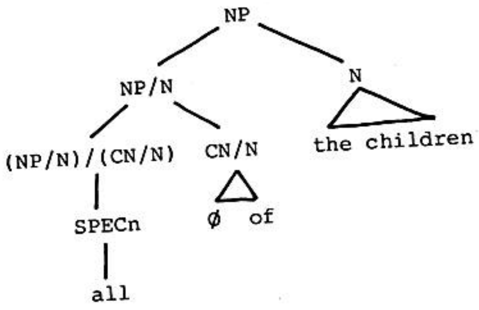
One last instance of the GEP pattern:

(NP/N)/(CN/N) := SPECn

$$0' = \lambda P_{<<e,t>,<e,t>>} [\lambda Q_{<e,t>} [1'(P(Q))]]$$

This rule entails that the following structures are semantically equivalent (cf. the discussion in II.2.2.2 of the predeterminer status of 'all' and 'both') :





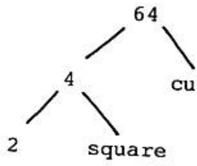
It is quite clear that behind all these examples there is a common mathematical principle: if a certain result can be got by first applying a function F to an argument A to obtain an intermediate result I, and then applying a function G to I, then the same result can be obtained by taking the composition of G and F, denoted as G o F, and applying this function to A. (A classical paper on function-composition in a categorial framework is Lambek (1958); cf. also Buszkowski (1982) and Van Benthem

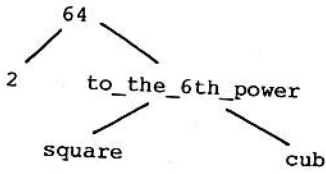
(1983c) for some recent results on the semantics of category shifts.)

The same mathematical principle guarantees that the following arithmetical calculations give the same result:

$$(2^2)^3 = 4^3 = 64 \qquad \text{versus} \qquad (2^2)^3 = 2^6 = 64.$$

In the first calculation we first apply the function 'square' to 2 and obtain the intermediate result 4, and next we apply the function 'cube' to this intermediate result to obtain the final result. In the alternative calculation first the composition of 'square' and 'cube' is calculated, and then this function is applied to 2. The parallel becomes still more apparent if we adopt a tree-notation to distinguish the structures:





The only difference with the examples above is that in the case of the NP-specifier system we have rightward looking functors, whereas the functors 'square' and 'cube' are leftward-looking.

In the following section we will look at the semantic details of the categorial treatment for the NP-specifier system that was proposed in II.2.2.2.

III.4.4 A Compositional Treatment of the NP Specifier System

In this section I will propose translations to match the categorization of the specifier system that was given in II.2.2.2. The semantics will be extensional. I use the language EL, with some abbreviations added. Note that my proposal differs from Montague's treatment. The reasons are: (i) the incorporation of the singular/plural distinction, which causes N to be mapped to ‹e,t› instead of e, as plural Ns may be groups instead of individual entities (singular Ns are mapped to singletons; the change in the category-type mapping carries over to complex categories); (ii) the incorporation of an account of the partitive construction that makes use of a categorial distinction between definite NPs (category N) and non-definite NPs (category NP, i.e. S/VP). Be it noted also that my account of plurality is one option among several. Another option would be admitting groups-as-objects in the domain of entities D_e. This would keep the Montegovian category-type mapping unchanged, but it would necessitate the addition of mechanisms to chart the internal structure of (some of the) e-type objects.

As was mentioned already in II.2.2.2, the syntax and semantics for numerals that I propose is in the spirit of Bennett (1975) and Verkuyl (1981). I am especially indebted to Verkuyl's work. Verkuyl proposes a characterization plus translations for numerals and for the specifier <u>these</u>. In the initial categorization of my proposal, numerals get the same category as in Verkuyl's proposal, and I adopt the same translation rules, but my categorization for <u>these</u> is different from Verkuyl's. Also, I do not agree with Verkuyl's thesis that for semantic reasons the numeral must be taken to belong to the CN instead of to the specifier. As has been demonstrated in the previous section, semantically there is nothing to choose between these two options, for they are systematically related by the proposed category shift rules.

I will use the function TYPE to map EL-WFEs to their types. The following abbreviations are used (suppose TYPE(X) = TYPE(Y) = ‹TYPE(x),t›):

'(X ⊆ Y)' abbreviates '/\x (X(x) -> Y(x))'; '\/x ∈ X (Y(x))' abbreviates '\/x (X(x) & Y(x))'; and 'X∩Y' abbreviates 'λx[X(x) & Y(x)]'

In connection with my treatment of the singular-plural distinction it is useful to have an abbreviation for expressions that denote singletons: if a is a WFE, then '{a}' abbreviates 'λz[z=a]' (z is a variable of the same type as a).

If B and a are WFEs with TYPE(B) = <<TYPE(a),t>,t>, then 'X({y})' abbreviates 'X(λz[z=a])' (z is a variable of the same type as a). (Note that this notational convention is <u>different</u> from the parentheses-convention that Montague uses in PTQ.)

I will sometimes abbreviate '\/y X(y)' as 'X ≠ ∅'. The following abbreviations will prove useful in the EL-translations that account for distributive and unspecific readings, respectively.

If A is a WFE and Y is a variable with TYPE(A) = <TYPE(Y),t> (Y may have any type), then: 'A*(Y)' abbreviates '/\z(Y(z) -> A({z}))' (z is a variable with <TYPE(z),t> = TYPE(Y)). This abbreviation is used for distributive predication. The next abbreviation is used for unspecific predication. '$A^{u}(Y)$' abbreviates:

$$/\backslash\ z(Y(z) \rightarrow \backslash/W\ ((A(W)\ \&\ W(z))\ \&\ /\backslash Z\ ((A(Z)\ \&\ Z(z)) \rightarrow Z = W))),$$

where z, W, and Z are variables of the appropriate types.

Finally, for any WFE A such that type(A) = <b,t> for some type b, '#(A)= n' abbreviates the EL-formula saying that the cardinality of the set, the characteristic function of which is denoted by A, is <u>n</u>. I.e., '#(A) = n' (where n is a natural number) abbreviates:

$$\backslash/x_1,\ldots,x_n\ (x_1 \neq x_2\ \&\ \ldots\ \&\ x_{n-1} \neq x_n\ \&\ A(x_1)\ \&\ \ldots\ A(x_n)\ \&$$
$$/\backslash y((y \neq x_1\ \&\ \ldots\ \&\ y \neq x_n) \rightarrow \neg A(y)))$$

where x_1, .., x_n, y are variables of type b such that TYPE(A) = <b,t>. Similarly for '#(A) > n', '#(A) < n', '#(A) ≥ n', '#(A) ≤ n'.

For our account of the singular-plural distinction, we will lift the types of VP-translations. VP-expressions translate into EL-constants of type <<e,t>,t>. The constant WALK that is used in the translation of the VP 'walk' denotes the set of all sets of entities that (together) engage in the activity of walking. If a single individual a engages in walking, we will suppose that the singleton {a} is a member of the denotation of WALK. The verb 'walk' has the property of distributivity: if a set of individuals walks, then each member of the set walks. Using the abbreviation that was introduced above, we can account for this - following Bartsch (1973) - by means of a stipulation for the denotation of the constant WALK (X is a variable of type <e,t>):

(a) /\X (WALK(X) -> WALK*(X)).

Examples of intransitive verbs that do not have the property of distributivity are 'quarrel' and 'gather'. It is often said that verbs like 'quarrel' and 'gather' do not admit a distributive reading at all. This is incorrect, for consider the following example:

(b) The committees quarrelled.

This example clearly admits an interpretation in which each individual committee quarrelled. If one would like to impose a condition on the constants GATHER and QUARREL, it should not be that no individual entities can engage in the activity denoted by the verb, but rather that only individual entities that are of a special kind can do so. Only those individual entities can, that do themselves have members capable of contributing to the activity denoted by the verb. A committee or an army corps is such an entity, a chairman or an army commander is not.

In connection with examples like (b), it is customary to distinguish between at least two kinds of predication: collective predication (all committees engaged in one big fight) and distributive predication (the individual committees quarrelled separately.) The distinction is also relevant for examples like the following, well-known from the literature on the semantics of plurality:

(c) The five gallants sang a serenade.

It seems that (c) is at least ambiguous between a collective and a distributive reading. One might even argue that (c) is in fact ambiguous between a whole bunch of readings: John and Bill first sang a serenade together, then Fred had a go on his own, and finally Jerry and Dick joined forces; and so on for all possible cluster combinations. The postulation of such an ambiguity boom is not very attractive, and for this reason it has been suggested that sentence (c) exhibits a third kind of predication, which, following Bunt (1981), I will call 'unspecific'. (Scha (1981) calls this reading the 'second collective reading'.)

A predication that involves a set A is unspecific iff each member of the set A is an element of some unique subset of A that satisfies the predicate. Using one of the abbreviations introduced above, 'B is unspecifically predicated of A' can be expressed as: '$B^u(A)$'.

It is a matter of controversy whether the distinction between 'distributive', 'collective' and 'unspecific' predication must be resolved at the level of the NP or at that of the VP. It is customary to distinguish at the NP level between distributive, collective and unspecific versions of all the specifiers. One could also opt for a distinction between plural VPs that apply distributively, collectively or unspecifically to their plural subjects. (And similarly for the ways in which TVs can apply to their direct objects, etc..) Below I will give details on these two solutions, but I have reservations about both. The following example shows that matters of tense and aspect interact with the distributive/collective/unspecific ambiguity.

(d) The five gallants were singing a serenade.

The example is not ambiguous at all: it only has the reading where the five were singing together. This and similar examples suggest that a full-fledged theory of plural predication must be linked to the tense/aspect system.

Still another kind of predication, christened 'cumulative' in Scha (1981), is exhibited in the following example:

(e) Five gallants sang a dozen ballads.

The predication in (e) is cumulative if the example is taken in the sense that the five gallants sang twelve songs all in all. I will disregard cumulative readings in the rest of this section, but it seems to me that such readings can be got by allowing the quantifying-in of the subject and the object NP simultaneously (the branching quantifier structures that result have the desired properties). Scha (1981) argues the other way around, by the way. He introduces cartesian products to account for cumulative readings, and he then proposes to reduce branching quantification to cumulative quantification. In my view, the disadvantage of this solution is that Scha's cumulative quantification structures are only very loosely connected with surface syntactic structures.

Example (e) is interesting for another reason as well. It shows that a theory which distinguishes between distributive, collective and unspecific plural NPs will generate a lot of readings for (e) that the sentence simply does not exhibit: all combinations of readings in which the subject NP is read unspecifically are ruled out.

The following examples suggest that both the NP and the VP can force a collective or distributive reading:

(f) Each of the two gallants sang a serenade.

(g) Both gallants sang a serenade.

(h) The two gallants sang a serenade together.

(i) The two gallants sang twelve ballads each.

In examples (f) and (g) it is clearly the NP that forces the distributive reading. (f) constitutes a special case of the fact that singular NPs always give rise to distributive readings. The plural specifier 'both' in (g) seems to have the same effect. In (h) and (i), on the other hand, it is more reasonable to suppose that 'together' and 'each', the elements that force a collective, resp. distributive reading, are part of the VP, and that the semantics of the VP is decisive here.

Bennett (1974) accounts for the distributive - collective distinction by means of a dichotomy of the categories IV and CN that necessitates a syntactically unwelcome multiplication of lexical entries. It is also possible to make the distinction at the NP-level (cf. e.g. Scha (1981), Bunt (1981)). The disadvantage of this approach is that it does not account for the possible disambiguating rôle of the VP. Below I will illustrate plurality-disambiguation at the VP level and plurality-disambiguation at the NP-level, but again: I have reservations about both solutions, neither of which does take tense and aspect into account.

Given that we translate basic intransitive verbs as constants of type <<e,t>,t>, syntactic rules for VP-number-assignment could be formulated as follows (we use the notation that has been introduced in section III.3.2).

The rule for singular VPs:

$$\underset{[sg]}{\mathrm{VP}} := \mathrm{VP}$$

$$0' = 1'$$

The rule for unspecific plural predication:

$$\underset{[pl,u]}{\mathrm{VP}} := \mathrm{VP}$$

$$0' = \lambda X_{\langle e,t\rangle}[1'^{u}(X)]$$

The rule for distributive plural predication:

$\mathrm{VP}_{[pl,dst]}$:= VP (each)   'each' is optional

$0' = \lambda X_{\langle e,t\rangle}[1'{*}(X)]$

The rule for collective plural predication:

$\mathrm{VP}_{[pl,col]}$:= VP (together)   'together' is optional

$0' = 1'$

In a fuller treatment, we should also take care of the distinction between several kinds of predication with respect to the direct object and indirect object positions.

Let us turn to the NP-specifier system. CN-expressions translate into WFEs of type <e,t>, CNn-expressions ('numbered CNs') translate into WFEs of type <<e,t>,t>, N expressions translate into WFEs of type <e,t>, and NP expressions into WFEs of type <<<e,t>,t>,t>. NUM-expressions now get translations of type <f(CN),f(CNn)>, DEM-expressions translations of type <f(CNn),f(N)>. SPEC-expressions translate into type <f(CNn),f(NP)>, and SPECn-expressions into type <f(CN),f(NP)>.

I will restrict myself to the semantics for the NPs that are based on +count CNs, as the semantics of mass-nouns is outside the scope of this dissertation. My aim is to incorporate the singular/plural distinction, without unnecessary proliferation of categories for the components of the specifier system. I will show that complex determiners like 'all of these twelve (men)', 'my many (friends)', 'no five (books)', etc., can be formed compositionally.

At the end of my presentation I will illustrate how one could distinguish between distributive/collective/unspecific predication at the NP-level, should one wish to do so. (The price to be paid is a proliferation of entries for the specifiers that form plural NPs.)

[+count] CNs translate into constants of type ‹e,t›, so we have, e.g. the following lexical entries:

‹man, CN, [+c,sg], MAN›,
     where MAN is an EL-constant of type ‹e,t›.
‹men, CN, [+c,pl], MAN›.
     where MAN is the same EL-constant as in the previous entry.

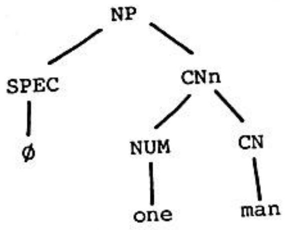
Note that in the above entries the features [sg] and [pl] play a syntactic (morphological) rôle only. The translations of 'man' and 'men' are the same; <u>semantically</u> there is no difference.

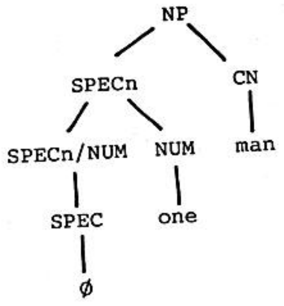
‹Ø, CN [+c, ps\ps], THING›, where THING is an EL-constant of type ‹e,t› that is interpreted as D_e.

The numerals are interpreted as functions that map a set A of type ‹e,t› to a set B of subsets of A that have the right cardinality. NUM abbreviates CNn/CN and translates to type ‹‹e,t›,‹‹e,t›,t››. Here are the lexical entries for the numerals, including the translations (X and Y are variables of type ‹e,t›):

‹one, NUM, [sg,ps,+c], λX [λY [(X ⊇ Y & #(Y) = 1)]] ›
‹Ø, NUM, [sg,+c], λX [λY [(X ⊇ Y & #(Y) = 1)]] ›

Comment: [$_{CNn}$ one man] and [$_{CNn}$ Ø man] both get interpreted as the set of all singletons containing a man. CNn combines with the empty SPEC node (see below) to form [$_{NP}$ Ø [$_{CNn}$ one man]], which gets interpreted as as the set of all sets of sets that contain a singleton containing a man. One of the category-shifting rules given in the previous section ensures that the following are equivalent structures.





This means that the meaning of $[_{SPECn}$ one] can be derived compositionally from those of $[_{SPEC}\ \emptyset\ ]$ and $[_{NUM}$ one]. A syntactic constraint is needed to prevent the combination of the empty SPEC node and the empty singular NUM node.

$\langle\emptyset$, NUM, [pl,+c], $\lambda X[\lambda Y[(X \supseteq Y \ \&\ Y \neq \emptyset)]]\ \rangle$
$\langle$two, NUM, [ps,ps,+c], $\lambda X[\lambda Y[(X \supseteq Y \ \&\ \#(Y) = 2)]]\ \rangle$
etc.
$\langle$few, NUM, [pl,ps,-det,+c],
$\lambda X[\lambda Y[(X \supseteq Y \ \&\ Y \neq 0 \ \&\ \#(Y) < n)]]\ \rangle$
where n is a contextually determined norm number.
$\langle$many, NUM, [pl,ps,-det,+c], $\lambda X[\lambda Y[(X \supseteq Y \ \&\ \#(Y) > n)]]\ \rangle$
where n is a contextually determined norm number.

The members of DEM (= N/CNn) are interpreted as functions mapping sets of subsets of the CN-interpretation to sets of type <e,t>. In the EL-components of the following lexical entries, P is a variable of type <<e,t>,t>:

$\langle$the, DEM, [],
$\lambda P\ [\lambda y\ [\backslash/Y\ (P(Y)\ \&\ /\backslash X\ (P(X) \to X \subseteq Y)\ \&\ Y(y))]]\ \rangle$

This entry calls for some comments: 'the' is interpreted as the function that maps a set A of type <<e,t>,t> to the set $\bigcup$ A in case $\bigcup$ A is a member of A, and to the empty set otherwise. This stipulation has the effect that 'the boys' is interpreted as the unique set of all boys in case there are boys, to the empty set otherwise. We have as interpretation for 'the boys':

$$\lambda y\ [\backslash/Y\ (Y \subseteq BOY\ \&\ Y \neq 0)\ \&$$
$$/\backslash X\ (X \leq BOY\ \&\ X \neq 0) \rightarrow\ X \subseteq Y)\ \&\ Y(y))]$$

This is easily seen to be equivalent to:

$$\lambda y\ [(BOY(y)\ \&\ BOY \neq \emptyset)]$$

Similarly, 'the five boys' is interpreted as the unique set of boys in case there are exactly five boys. In case there are more than five boys, $[_{CNn}$ five boys $]$ will denote a set A containing several sets of five boys. In this case $\bigcup$ A will not be a member of A, and $[_{N}$ the five boys $]$ will denote the empty set. The translation for 'the five boys' reduces to:

$$\lambda y\ [(BOY(y)\ \&\ \#(BOY) = 5)]$$

For 'the few boys' and 'the many boys' we also get the desired results. Note that 'the few boys' is (correctly) interpreted as 'the boys, of which there are only a few'.

Finally, note that the proposed interpretation for 'the' has the attractive feature that it works fine with both singular and plural members of CNn. The lexical entry for 'the' shows that it is indeed possible to derive the meanings of 'the three boys', etc., compositionally, by analyzing such phrases as:

$$[_{N}\ DEM\ [_{CNn}\ NUM\ CN\ ]]$$

Demonstratives and genitive pronouns are in the same category with 'the'. In order to treat them in a Montague framework I assume that a context assignment is available to take care of indexicals. How this works exactly is not material here. In the translation for 'my', I will suppose that 'x_{sp}' is a distinguished variable that is mapped by the context assignment to the speaker. I also use a variable 'R' of type $\langle\langle e,t\rangle,\langle e,t\rangle\rangle$. This variable stands for the 'genitive relation' between the speaker and a set of things that the speaker bears that relation to. Further, I assume that a family of operators 'Θ_i' is available that can be used to indicate deictic identification of a set (an <e,t>-object) in a certain context (Verkuyl (1981) uses one such operator in his translation for these). The indices are needed to keep track of different acts of identification in the same context, as in "This is nicer than this" (cf. Lewis (1970) for details). Again, the exact implementation does not matter much.

<these, DEM, [pl], $\lambda P [\lambda y [\Theta_i X [P(X)] \& X(y)]]$ >

Here 'Θ_i' is an operator that indicates deictical identification. By picking different indices one can treat examples involving several acts of deixis, as in: "These five boys hate these five boys".

<this, DEM, [sg], $\lambda P [\lambda y [\Theta_i X [P(X)] \& X(y)]]$ >
<my, DEM, [], $\lambda P [\lambda y [\Theta_i X [P(X) \& \backslash/R\ R(x_{sp},X)] \& X(y)]]$ >

In the translation for 'my' the operator 'Θ_i' is used to pick out a unique set from among those available (if there is no unicity, the use of the personal pronoun is misleading). The use of 'my five books' presupposes that among all available sets of five books there is exactly one set that is intended. Again: nothing hinges on these technical details; the translation for 'my' is given for purposes of illustration only. The other genitive pronouns can be treated similarly. As a result of my proposal for categorization, definite descriptions and their kind are lumped together with proper names.

The interpretation of VPs as objects of type <<e,t>,t> necessitates an interpretation of singular proper names as singletons. The proper name 'John' has the following lexical entry (JOHN is an EL-constant of type e):

<John, N, [sg], {JOHN} >,

The following rule lifts structures of category N to category NP.

(N-lifting)

NP := N

$0' = \lambda P_{\langle\langle e,t\rangle,t\rangle}\ [P(1')]$

This ensures that definite descriptions and proper names end up in the same category with other NPs.

Here are the members of category SPEC (recall that SPEC abbreviates NP/CNn and translates to type <f(CNn),f(NP)> = <<<e,t>,t>,<<<e,t>,t>,t>>):

<each, SPEC, [sg,ps,+det], $\lambda P\ \lambda Q\ [\ P \subseteq Q]$ >
<every, SPEC, [sg,+det], $\lambda P\ \lambda Q\ [\ P \subseteq Q]$ >
<sm, SPEC, [ps,+det], $\lambda P\ \lambda Q\ [\backslash/X\ (P(X)\ \&\ Q(X))]$ >
    ('sm' is used for unstressed 'some')
<$\emptyset$, SPEC, [], $\lambda P\ \lambda Q\ [\backslash/X\ (P(X)\ \&\ Q(X))]$ >

Comment: The entry for $[_{\mathrm{SPEC}}\ \emptyset\ ]$ has the result that 'sm five men' and 'five men' get the same interpretation; $[_{\mathrm{SPEC}}\ \emptyset\ ]$ can combine with $[_{\mathrm{NUM}}\ \emptyset\ ]$; this accounts for the existential readings of bare plurals. (As was noted above, a separate stipulation seems to be needed to rule out existential 'bare singulars'.)

<no, SPEC, [ps,+det],
    $\lambda P\ \lambda Q\ [\ /\backslash X\ (P(X) \rightarrow /\backslash Y\ (\ X \subseteq Y \rightarrow \neg Q(Y)))]$ >

Comment: 'no' is interpreted as the function that maps each set A of type <<e,t>,t> to the set B of type <<<e,t>,t>,t> such that B consists of all sets of type <<e,t>,t> that do not have supersets of members of A as elements. This has as a result that 'no boys' gets interpreted as the set of type <<<e,t>,t>,t> the members of which do not have sets that include boys as elements, and 'no five boys' as the set of type <<<e,t>,t>,t> that consists of all <<e,t>,t> sets that do not have a set containing five or more boys as a member. Note that the entry for 'no' works well for both singular and plural members of CNn.

For semantic reasons, I propose *not* to adopt the most obvious treatment for 'all', which is given by the following lexical entry:

$$\langle \text{all, SPEC, [pl,ps,+det]}, \lambda P[\lambda Q[/\backslash X\ (P(X) \rightarrow Q(X))]] \rangle$$

This entry would predict that it is possible to construe 'all five boys' compositionally, and it would result in the following translation for this NP:

$$\lambda Q\ [/\backslash X\ ((/\backslash y \in X\ (BOY(y))\ \&\ \#(X) = 5) \rightarrow Q(X))].$$

This EL-formula denotes the set of all sets that contain every set of five boys as a member. Such a translation is not correct, for in fact 'all five boys' should denote the set of all sets that contain the *unique* set of five boys, i.e. 'all five boys' should be read as 'all of the five boys'.

I will consider 'all of the five boys' as the 'proper' grammatical construction, from which 'all five boys', in case one wants to allow this NP, should be derived. I will put 'all' in the class of specifiers that do not allow a numeral, the class SPECn that combines directly with CN.

A specifier that should have a second entry is 'few', for we have to account for the ambiguity between 'few men' in the sense in which 'few man walk' does not contradict 'no men walk', and 'few men' in the sense of 'a few men'. Note that it follows from the above lexical entries that $[_{SPEC}\ \emptyset\ [_{CN}$ few men]] will get interpreted as 'a few men'. We still need an entry for 'a few' and one for 'few' (in the other sense) in category SPECn.

Here is a list of lexical entries for the class SPECn (SPECn abbreviates NP/CN and translates to type $\langle\langle e,t\rangle,\langle\langle\langle e,t\rangle,t\rangle,t\rangle\rangle$):

$$\langle \text{a(n), SPECn, [sg]}, \lambda X[\lambda P[\backslash/x\ (X(x)\ \&\ P(\{x\}))]] \rangle$$
$$\langle \text{sóme, SPECn, [sg]}, \lambda X[\lambda P[\backslash/x\ (X(x)\ \&\ P(\{x\}))]] \rangle$$
$$\langle \text{sóme, SPECn, [pl, ps]}, \lambda X[\lambda P[\backslash/Y\ (X \cap Y \neq \emptyset\ \&\ P(Y))]] \rangle$$
$$\langle \text{all, SPECn, [pl,ps]}, \lambda X[\lambda P[/\backslash Y\ (Y \subseteq X \rightarrow P(Y))]] \rangle$$
$$\langle \text{few, SPECn, [pl,ps]}, \lambda X[\lambda P[/\backslash Y\ ((Y \subseteq X\ \&\ P(Y)) \rightarrow \#(Y) < n)]] \rangle$$

for some contextually determined n.

<both, SPECn, [pl,ps], $\lambda X[\lambda P[\#(X) = 2 \ \& \ P^*(X)]]$ >
<neither, SPECn, [sg], $\lambda X[\lambda P[\#(X) = 2 \ \& \ [\neg P]^*(X)]]$ >

Note that the translations ensure that 'both' and 'neither' are always read distributively.

<a few (of), SPECn, [pl,ps],
$\lambda X[\lambda P[\bigvee Y \ (Y \neq 0 \ \& \ Y \subseteq X \ \& \ \#(Y) < n \ \& \ P(Y))]]$ >
for some contextually determined n.
<a lot (of), SPECn, [pl,ps],
$\lambda X[\lambda P[\bigvee Y \ (Y \subseteq X \ \& \ \#(Y) > n \ \& \ P(Y))]]$ >
for some contextually determined n.
<a dozen (of), SPECn, [pl,ps],
$\lambda X[\lambda P[\bigvee Y \ (Y \subseteq X \ \& \ \#(Y) = 12 \ \& \ P(Y))]]$ >
etc.

If one would like to account for the distributive/ /collective/unspecific distinction at the NP level, then this could be done by giving two extra versions for every member of category SPEC or SPECn that forms a plural NP. One example:

<$\emptyset$, SPEC, [pl, col], $\lambda P[\lambda Q[\bigvee X \ (P(X) \ \& \ Q(X))]]$ >
<$\emptyset$, SPEC, [pl, u], $\lambda P[\lambda Q[\bigvee X \ (P(X) \ \& \ Q^u(X))]]$ >
<$\emptyset$, SPEC, [pl, dist], $\lambda P[\lambda Q[\bigvee X \ (P(X) \ \& \ Q^*(X))]]$ >

Linguistically, the multitude of NP-specifiers that this move engenders is not very attractive. Also, it seems to create more problems than it solves, for we now have to account for the fact that a lot of the extra readings that are predicted for examples like (e) above actually fail to occur.

Finally, we turn to the partitive construction. I will only treat constructions where partitive 'of' takes a plural NP. The reason is that the combination of partitive 'of' and a singular NP gives rise to mass-quantification phenomena that are outside the scope of this dissertation. (Cf. Bunt (1981) for an extension of the Montague framework in which both count-noun and mass-noun quantification are taken into account, and Hoeksema (1984) for details on the semantics of partitives in [-count] contexts.)

The translation for partitive 'Ø of' in category CN/N[pl] is as simple as can be:

<Ø of, CN/N[pl], [], λX[X] >

One may also take 'of' to be in category PP/N (= (CN\CN)/N), and give it the following entry:

<of, PP/N[pl],[], λX[λY[λz[(X(z) & Y(z))]]] >

After some category shifting and the corresponding λ-conjuring tricks, this yields as translation for

$[_{CN/N}\ [_{CN}\ \emptyset\ ]\ [\ \text{of}\ ]\ ]$

the following:

λY[λz[(THING(z) & Y(z))]].

This translation is equivalent to the translation in the entry for 'of' in category CN/N.

The partitive construction accounts for NPs like 'one of these few of the soldiers', and 'some of my many friends'. If one would extend the discrete EL-models that we have assumed with suitable interpretations for mass-nouns and the part-of relation defined on them, the above account could be stretched to cover partitives based on singular N-expressions ('Half of Athens (was in ruins)', 'Some of the building (had remained undamaged)') and on mass N-expressions ('All of the wine (had been drunk)').

This concludes the discussion of the syntax and semantics of the NP specifier system. It has been shown that a categorial treatment that does justice to the syntactic peculiarities of the NP specifier system, as it is studied by authors like Jackendoff, but which is much more explicit about the semantics, is indeed possible.

III.5 Scopes and Bound Anaphora in Montague Grammar

PTQ has special rules to effect scope reversals of logical operators and to provide anaphoric links. These 'quantifying-in' rules combine an NP with an expression of category S, CN or VP, by substituting the NP for an indexed pronoun in the expression. In the syntactic quantifying-in rule, for every index number n, a syntactic function QI_n is used . $QI_n(A,B)$ inserts the NP A into the expression B on the place of the leftmost pronoun with index n that occurs in B. If A is not a pronoun and there are other occurrences of pronouns with index n in B, their index is deleted. If A is a pronoun (with index k), then all indices n on pronouns in B are replaced by k. (A peculiarity of the quantifying-in rules in PTQ is that quantifying-in can be 'empty', because the rules as stated in PTQ do not mention the condition that the phrase that is quantified into does contain an occurrence of the indexed pronoun that the substitution is made for. This case can easily be excluded.)

The semantic effect of quantifying-in is given by the translation instruction that goes with syntactic function QI_n. Let B be a syntactic expression of category S, and let '=>' stand for 'translates as', and let A' be the translation of A, and B' the translation of B. Then we have (in the extensional system):

(a) $QI_n\ (A,B) \Rightarrow A'(\lambda x_n\ [B'])$

The variable x_n is of type e. The translation in the intensional system is analogous.

If B is an expression of category CN, then we have:

(b) $QI_n\ (A,B) \Rightarrow \lambda y\ [A'(\lambda x_n\ [B'(y)])]$

Again, this is the extensional version; the variables x_n and y are of type e. The intensional version is analogous. Similarly for the case where QI_n is applied to an NP and a VP. As can be seen from these examples, quantifying in of pronouns serves no semantic purpose. Montague allows it because he wants quantifying-in to apply uniformly to all NPs.

The quantifying-in rules are context sensitive rules that regulate the process of substituting an NP in a certain expression, with very drastic effects on the interpretation of that expressio. These rules serve not only to remove ambiguities that result from the mutual scope behaviour of quantifiers. They are also used to establish anaphoric links between an antecedent NP and a bound pronoun. Finally, they serve to account for ambiguities that result from the interaction of NPs and the negation operator, or from the interaction of NPs and an intensional operator.

The transparent/opaque distinction between the two readings of 'John seeks a unicorn' can be accounted for without using the quantifying-in mechanism. It is possible to transform verbs that are opaque in object position into their counterparts that are transparent in that position. Suppose that all transitive verbs that are opaque in object position have feature [Oo], and all transitive verbs that are transparent in object position have feature [To]. Then the following rule maps object-opaque TVs into object-transparent TVs:

$$\underset{[To]}{TV} \quad := \quad \underset{[Oo]}{TV}$$

$$0' \quad = \quad \lambda \mathbb{P}\lambda x[{}^{\vee}\mathbb{P}({}^{\wedge}\lambda y[\bigvee v(1'(x,{}^{\wedge}\lambda P[{}^{\vee}P(y)]) \ \& \ y = {}^{\wedge}v])]$$

The types of the variables are as follows: $\mathbb{P}$ has type ‹s,f(NP)›, P has type ‹s,‹‹s,e›,t››, x and y have type ‹s,e›, and v has type e. The 'functionality-nonfunctionality shift' for IVs like 'change' can be accomplished by a similar rule.

The PTQ-system does not account for subject-opacity of the kind that is exhibited in the most obvious reading of the standard example "A unicorn seems to be approaching". The reason is that IVs are treated as arguments to NPs, not the other way around. Note that it does not help that IVs get interpreted as functions that take individual concepts as arguments: the individual concept of a unicorn will be a constant function from indices to entities. An account of subject-opacity seems to presuppose that IVs are interpreted as functions that take intensions of NP-denotations as arguments. In such a system a rule that changes [Os] IVs into [Ts] IVs can be formulated.

The transparent/opapue ambiguities out of the way, we are left with scope ambiguities and anaphoric linking as tasks for the quantifying-in mechanism. Quantifying-in is primarily a mechanism intended to resolve scope ambiguities. The account of anaphoric links that it also provides is more or less a side effect. It is clear that quantifying-in can only account for bound anaphora; never for other kinds of anaphoric links.

The quantifying-in rules in PTQ (and in many extensions) allow virtually anything in the way of scope inversions: even the most scope-sensitive Montague-grammarian will be able to account for all of the readings he 'feels'. In many cases, indeed, too many readings are predicted.

Montague keeps the boom of predicted ambiguities within certain limits by imposing meaning postulates that - sometimes - have the effect of establishing a logical equivalence between the formulas that translate different derivations of the same S-string. (In Montague's terminology two formulas are logically equivalent iff they are true in the same models satisfying a given set of meaning postulates.)

In all versions of Montague Grammar either the PTQ-method of 'quantifying-in' is maintained, or it is replaced by the NP-storage technique. The storage technique will be discussed in chapter IV.

The ubiquitous example (c) will be used to illustrate the effects of 'quantifying in'.

(c) Every man loves a woman.

One way to treat this example in PTQ is by directly combining the expression 'every man' in category NP with the VP 'love a woman'. The translation rule that goes with the syntactic rule employed here ensures that 'every man' has wide scope over 'a woman'. A scope reversal can be effected by first producing the sentence 'every man loves him_3', and then use the syntactic rule that combines an expression A of type NP with a sentence that contains a pronoun with index n to form a sentence where A is substituted for the pronoun.

The following example explains why it is necessary to allow quantifying-in at the VP level. Sentence (d) has a reading where 'every man' has wide scope over 'a woman', and 'her' is anaphorically related to 'a woman'.

(d) Every man loves a woman and kisses her.

To get the intended reading the expression 'a woman' must be quantified-in at the VP level, in the expression 'man such that he loves him_2 and kisses him_2'. Quantifying in at the CN level can be necessary in examples where a relative clauses A modifies a CN that already contains a relative clause B, and B contains an NP that is anaphorically related to a pronoun in A.

In example (c) above, the process of quantifying-in, applied to the NP 'a woman' and the sentence 'every man loves him_4', yields the following translation (in the extensional system):

$$\lambda P[\bigvee x(\text{WOMAN}(x) \;\&\; P(x))]$$
$$(\lambda x_4[\bigwedge y(\text{MAN}(y) \rightarrow \lambda P[P(x_4)](\lambda z[\text{LOVE}(y,z)]))])$$

After some applications of λ-conversion this reduces to:

$$\bigvee x\ (\text{WOMAN}(x) \;\&\; \bigwedge y\ (\text{MAN}(y) \rightarrow \text{LOVE}(y,x)))$$

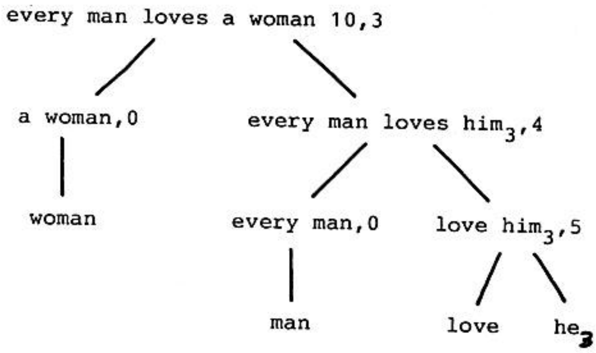
This is indeed the inverse scope reading of (c). Here *man* translates as MAN, *woman* as WOMAN, *love* as $\lambda P\lambda y[P(\lambda z[\text{LOVE}(y,z)])]$, where P is a variable of type $\langle\langle e,t\rangle,t\rangle$, y and z are variables of type e, and LOVE is a constant of type $\langle e,\langle e,t\rangle\rangle$. I use the notation LOVE(y,z) for LOVE (z)(y). The translation for *love* eliminates the need for a meaning postulate to relate a constant of type $\langle\langle\langle e,t\rangle,t\rangle,\langle e,t\rangle\rangle$ to one of type $\langle e,\langle e,t\rangle\rangle$. For more details on this technique for avoiding meaning postulates, cf. section III.6.

The example makes it clear that the device of quantifying-in necessitates a distinction between *syntactic structure* and *derivational history*. The structure (e) can be derived in a number of ways, and *not* all of these derivations result in the same interpretation:

(e) $[_S[_{NP}$ every man$]$ $[_{VP}[_{TV}$ loves$]$ $[_{NP}$ a woman$]]]$

Sentences of the fragment are disambiguated by derivational history trees (or 'analysis trees', as Montague calls them), *not* by syntactic structure trees like (e). A derivational history tree for sentence (d) in the inverse scope reading is:

(f)



Here the numbers behind commas following the expressions identify the syntactic operations (PTQ-numbering) that have been used. At the nodes of the tree are well-formed strings.

The quantifying in rules in PTQ do not refer to syntactic structure. (No syntactic rules in PTQ do.) In the modified version of PTQ that generates structured descriptions instead of strings a syntactic rule has structured descriptions as input and output. Consequently, in structured PTQ derivational history trees are 'adorned': each node-string in them is replaced by the appropriate labelled bracketing. Each labelled bracketing represents a structure tree, so a derivational history tree can be seen as a tree with structure trees at its nodes. (For this perspective on structure in Montague grammar cf. Partee (1973) and Janssen (1983), Ch. VII.)

In the unmodified PTQ-fragment QI_n simply refers to the *leftmost* pronoun with index n. This disregard of syntactic structure creates serious problems in connection with quantifying-in. In order to demonstrate this, I provisionally extend the PTQ-system with the determiner *no*. Its translation (in the extensional system) is:

(g) $\lambda Q\ \lambda P[/\backslash x(Q(x) \rightarrow \neg P(x))]$

Now consider example (h):

(h) Every man such that he loves no woman kisses her.

Clearly, a anaphoric link between *no woman* and *her* is impossible. Still, the PTQ rules permit quantifying-in of *no woman* in the S-expression 'every man such that he loves her$_3$ kisses her$_3$', and an anaphoric link between *no woman* and *her* is established. The resulting translation (in the extensional system) is:

(i) $/\backslash x(\mathrm{WOMAN}(x) \rightarrow \neg /\backslash y((\mathrm{MAN}(y)\ \&\ \mathrm{LOVE}(y,x)) \rightarrow \mathrm{KISS}(y,x)))$

The example indicates that it is necessary to restrict QI$_n$. It appears to depend on the nature of the antecedent whether an anaphoric link is permitted or not in sentences like (h): example (j), with anaphoric links as indicated by the underlinings, is perfectly all right.

(j) Every man such that he loves *Mary* kisses *her*.

The problem appears to be that QI applies indiscriminately to all NPs, so one could try to solve it by simply restricting QI to certain kinds of NPs. The theory of generalized quantifiers suggests a characterization of the class of NPs to which QI may apply - in cases like (j) - in terms of the monotonicity-property (cf. the references given in I.1.5).

Df. An NP-denotation Q is *right monotone* *increasing* iff
$/\backslash\ A, B, B'\ \ ((\ QAB\ \ \&\ \ B \subseteq B'\ ) \rightarrow\ QAB'\ )$

Examples of NP-denotations having this property are the denotations of proper names and those of definite and indefinite descriptions. The following restriction on QI might be proposed:

(Tentative) restriction on QI:

> If QI quantifies in an NP A for pronoun occurrence B_i in structure C, then either B must c-command all other pronoun occurrences in C with index i, or A must have a right monotone increasing denotation.

Unfortunately, any attempt in this direction is doomed to fail; although a characterization of NPs permitting an anaphoric link between an antecedent in a relative clause and a pronoun in the main clause - as in the intended readings of (h) and (j) - in terms of properties of NP-denotations may be feasible, the quantifying-in mechanism will often engender the wrong readings:

(k) Every man such that he loves a woman kisses her.

As is well-known, the reading of (k) with an anaphoric link as indicated by the underlinings but with narrow scope for a woman with respect to the subject of the sentence is impossible in PTQ. The problem is that the pronoun in (k) is an example of a 'donkey-pronoun' (cf. I.2.4 above).

It seems that we must look in a different direction for a solution: we impose a general structural restriction on QI forbidding the establishment of anaphoric binding links as in (h) and (j), we allow QI to apply to all NPs that fulfil the given structural condition, and we relegate the anaphoric linking in examples like (j) to a different anaphoric mechanism. The discussion of Reinhart's theory of anaphora in section II.4.1 suggests that this strategy is to be preferred to the attempt to restrict QI as to the kinds of NPs that can be quantified in. An additional anaphoric mechanism is needed anyway to account for anaphoric linking across sentence boundaries, and for donkey-pronouns, E-type pronouns, etc. The structural restriction on QI must ensure that quantifying-in does not establish anaphoric links between an antecedent NP A and a pronoun B in cases where A does not c-command B.

It is cumbersome to formulate this restriction for Montague's original PTQ-fragment, because the syntactic rules of PTQ generate strings instead of structured descriptions. In a version of PTQ that employs labelled bracketings (i.e. structured expressions), the envisaged restriction on QI is easily imposed. I will not bother to spell out the modified rule here. A further modification of the mechanism of quantifying-in will be presented in the next chapter. This modification, induced by the wish to bridge the gap between Montague grammar and TGG, will provide an account of bound anaphora, scopes and reflexivization. Reflexives will be generated _in situ_ by the sentence syntax, and structural properties of the syntactic configuration determine to what antecedents they can be linked.

I conclude this section by briefly drawing attention to an important respect in which the anaphoric mechanism that is provided by the quantifying-in rules in Montague Grammar differs from the indexing anaphoric mechanisms that are current in TGG. While the co-indexing mechanisms for handling anaphoric links that have been proposed in TGG establish a _symmetric_ relation of 'bearing the same index', the quantifying-in rules in Montague Grammar reflect the fact that the relation between an NP that is quantified-in and a pronoun that is bound is _asymmetric_. This means that the concept of 'antecedent' in an anaphoric relation is reflected more clearly in Montague Grammar than in TGG.

In a recent discussion of Binding Theory in TGG (Higginbotham (1983)), a proposal has been made to replace the mechanism of co-indexing by a mechanism that takes the _direction_ of anaphoric links into account. In chapter IV an anaphoric mechanism will be introduced that fits this requirement. Like the quantifying-in rules in PTQ, this mechanism reflects the facts that the relation between antecedent and bound anaphors is asymmetric, and that between anaphors bound by the same antecedent symmetric.

III.6 How to Avoid Meaning Postulates

The price that Montague paid for his function-argument blow-up of proper names, transitive verbs etc., and for his intensional blow-up of expressions that are not intensional in nature (proper names again, extensional verbs, extensional common nouns, etc.) is the introduction of Meaning Postulates to undo the effects of these blow-up moves where they are not needed. There is a straightforward way of avoiding these Meaning Postulates that are the effect of blow-ups altogether, by taking care of them in the lexicon. Hints to this approach can be found in several places in the literature (cf. e.g. Bartsch (1978) and the discussion in Dowty (1979), ch. III).

In PTQ, proper names are expressions in category NP that translate into IL-WFEs of type $\langle\langle s,\langle\langle s,e\rangle,t\rangle\rangle,t\rangle$. 'John' receives the translation $\lambda P[{}^{\vee}P({}^{\wedge}JOHN)]$, where JOHN is an IL-constant of type e, and P is a variable of type $\langle s,\langle\langle s,e\rangle,t\rangle\rangle$. Next, a meaning postulate is invoked to ensure that the <u>sense</u> of the constant JOHN is a <u>constant</u> function from indices to entities.

If we move from IL to Ty2, intensionalisation is expressed by λ-abstraction over the distinguished s-type variable i, extensionalization by application to i, and the rule for applying function A to the intension of B becomes: $A(\lambda i[B])$, where i is the distinguished s-type variable.

Now we can provide 'John' with a translation that avoids invoking a meaning postulate. The lexical entry for 'John' becomes:

$$\langle John,\ NP,\ [sg],\ \lambda P[P(i)(\lambda i[JOHN])]\ \rangle$$

Again JOHN is a constant of type e, and P is a variable of the same type as before. The variable i is the distinguished variable of type s that is assigned to the current index. Note that 'λi JOHN' denotes a constant function from indices to entities, for the abstraction over indices is vacuous: JOHN does not contain the designated index variable i. The meaning postulate has become superfluous: it has been incorporated in the lexicon.

The same technique works for non-functional CNs (all basic CNs in PTQ other than 'price' and 'temperature'. The lexical entries for 'price' and 'man' now become, respectively:

<price, CN, [], PRICE(i) >

<man, CN, [], λx[\/u(MAN(i)(u) & x=λiu)] >

Here PRICE is a constant of type <s,<<s,e>,t>>, MAN a constant of type <s,<e,t>>, x a variable of type <s,e>, i the distinguished index variable, and u a variable of type e. The entry for 'man' ensures that this expression gets interpreted as a set of *constant* individual concepts, i.e. as a set of functions that have one and the same entity as their value for every index. (The sets of individual concepts denoted by 'price' and 'temperature' will in general not be constant, for a price or a temperature can rise and fall across indices.) This makes PTQ-postulate 2 redundant.

Actually, PTQ-postulate 2 is rather strong. One might argue that it is enough to demand that 'man' denote a set of individual concepts having men as their values at the current index (the values at the other indices simply do not matter). This can be accomplished by the following lexical entry:

<man, CN, [], λx[MAN(i)(x(i))] >

The types of the constant MAN and the variable x remain as before.

The meaning postulate for basic IVs other than 'rise' and 'change' can be removed in a similar way. The lexical entries for 'change' and 'walk', respectively, become:

<change, IV, [], CHANGE(i) >

<walk, IV, [], λx[\/u(WALK(i)(u) & x=λiu)] >

CHANGE is a constant of type <s,<<s,e>,t>>, WALK a constant of type <s,<e,t>>. The entry for 'walk' is similar to that for the 'ordinary' common nouns. As in the case of the 'ordinary' common nouns, a weaker alternative is possible.

As a final example, the lexical entries for the transitive verbs that are extensional in both their subject and their object positions, and for the transitive verbs that are intensional in object position, extensional in subject position:

<find, TV, [],
λ ℙλx[\/u(ℙ(i)(λi[λy[\/v(FIND(i)(u,v) & y=λiv)]]) & x=λiu)] >

Here FIND is a constant of type <s,<e,<e,t>>>, ℙ is a variable of type <s,f(NP)> = <s,<<s,<s,e>,t>>,t>>, and the types of the other variables are as before. Note that the translation has type <<s,f(NP)>,f(VP)>, which is indeed the right type in the intensional PTQ-system.

<conceive, TV, [], λ ℙλx[\/u(CONCEIVE(i)(u, ℙ) & x=λiu)] >

CONCEIVE is a constant of type <s, <<s,f(NP)>,<e,t>>>. The case of 'seek' is slightly different: Montague's postulate for this verb not only undoes the effects of the intensional blow-up of the subject position, but it also establishes a link to the constants used in the translations of 'try' and 'find'. If one wants to incorporate this meaning postulate in the lexicon, the following 'generative word semantics move' is called for:

<seek, TV, [],
λ ℙλx[\/u(TRY-TO(i)(u, λi[ℙ(i)(λi[λy[\/v (FIND(i)(u,v) &
y = λiv)]]]) & x = λiu)] >

The variables are of the same types as before, TRY-TO is a constant of type <s,<<s,t>,<e,t>>>, and FIND is as before.

All other PTQ meaning postulates can be made redundant in a similar way, by incorporating them in the lexicon. The example of 'seek' may serve to illustrate, however, that it seems a matter of arbitrary decision just how much 'generative word semantics' should be performed in the lexicon, and which constants should be treated as basic.

III.7 Conclusion

In this chapter we have reviewed the Montague account of natural language quantification. In an exposition of the underlying assumptions of Montague Grammar, the general framework, and various aspects of the theory pertaining to quantification phenomena, we have noted some of its strenghts and weaknesses. Next, we have performed some 'cosmetic surgery' on the framework, by providing a recipe for avoiding some of Montague's meaning postulates, and by laying down a format for syntactic rules that is explicit about admissible syntactic operations. Finally, while staying within the spirit of the Montague-enterprise, we have proposed a compositional syntax and semantics of the English specifier system. In the course of this endeavour we had to change types in order to provide a systematic account for the singular-plural distinction. From our proposal for the English specifier system it emerges that the requirements of a compositional semantics for the system still leaves quite some margin for syntactic choices: semantically, the English specifier system is less restricted than might be supposed at first sight.

CHAPTER IV

MONTAGUE GRAMMAR AND LOGICAL FORM

IV.0 Introduction

In this chapter I will again be concerned with the constraints on scope and anaphora proposed by linguists working in the TG framework, that have been discussed in chapter II.

One technique that has played an important rôle in previous proposals to incorporate insights from Transformational Grammar into Montague Grammar, and in attempts to handle constraints like those discussed in chapter II, is the technique for 'storing' NP-translations proposed in Cooper (1975). The technique will be reviewed in IV.1. A very simple fragment of English will be defined and an extensional semantics for this fragment will be given using the Cooper-storage technique. The aims of this exercise are to show that Cooper-storage can be used to impose May's constraints of scope ambiguity, and to provide reference material for a methodological discussion of the storage technique.

In IV.2 the status of a Logical Form component in a grammatical framework will be investigated. A proper understanding of the rôle of LF is the key to a synthesis between Montague Grammar and Transformational Grammar. My proposal for such a synthesis is put forward in general lines. In IV.3 I sketch a framework of Montague Grammar that I call 'MG+', and which incorporates a component of Logical Form.

IV.1 The Technique of NP Storage

IV.1.0 Introduction

There is quite a tradition of proposals to build bridges between Montague grammar and transformational grammar. In Lewis (1970) the suggestion has been made to add transformations to the categorial component of a framework of logico-semantic grammar that very closely resembles Montague grammar. Partee (1973) and (1975) also advocate the admitting of transformations in Montague syntax. As syntactic transformations are not my primary concern, I will not discuss these proposals.

It might be argued that Generalized Phrase Structure Grammar represents another attempt to bridge the gap between TGG and Montague Grammar (cf. e.g. Gazdar (1981)). An account of scopes and anaphora, my principal concern in this comparison, is conspicuously absent in GPSG, however, and therefore I will not discuss that framework.

Cooper & Parsons (1976) engage in theory-comparison by defining two TG fragments and by proving that these fragments are equivalent to the PTQ-fragment. In the first of the TG fragments a distinction is made between deep and surface syntactic structures. Deep structures are used to disambiguate sentences: the translation into IL takes deep structure rules as its input. The result is a generative semantics framework. The deep structures turn out, not too surprisingly, to rather closely resemble PTQ's derivation trees. The other TG fragment generates ambiguous syntactic structures that are disambiguated by an indexing mechanism. Basically the task of this mechanism is to ensure that the indexed NPs are not interpreted in the position they occupy in surface structure; instead, the NP meaning is 'stored', and a variable is interpreted in its place. At a later stage the NP is quantified in, using lambda-abstraction over the variable that has served as a 'place holder'.

The generative semantics TG fragment in Cooper & Parsons (1976) represents a road that has been abandoned by TG grammarians for quite a while; therefore, it need not be discussed here. The interpretive TG fragment, on the other hand, is close to the modern TGG framework that includes an LF component. The technique used here is similar to the Cooper-storage technique proposed in Cooper (1975). Cooper-stores are introduced to incorporate functions in Montague grammar that in transformational generative grammar are performed by an LF-component.

A fundamental tenet of all versions of TG theory (including the EST framework and later refinements) is that syntax is autonomous. The principle of the autonomy of syntax forbids the introduction of syntactic structure that is only motivated by semantic purposes. Montague Grammar clearly violates the principle: the presence of indexed pronouns has only semantic motivation; the disambiguation by means of quantifying-in rules likewise is semantically motivated. The EST version of TGG complies with the principle of the autonomy of syntax, be it by some slight of hand: the 'syntax proper' of the EST is autonomous, the LF-component of course is not. Thus in the EST the adherence to the principle of the autonomy of syntax forces the stipulation that Logical Form is not a part of syntax proper.

Strip (structured) PTQ of the quantifying in rules and the distinction between syntactic structure trees and derivation trees vanishes. Derivation trees can now be equated with syntactic structure trees, because there is only one way to produce a given structure. In order to get the readings that were formerly accounted for by way of quantifying-in one must consider the syntactic structures (annex derivation structures) as ambiguous. The NP-storage mechanism serves to disambiguate syntactic structures by fixing the scopes of NPs; it replaces the quantifying-in rules in Montague's PTQ. The mechanism is proposed in Cooper (1975) and worked out in Cooper (1983). A very interesting fragment in which Cooper stores are put to use is the one presented in Bach & Partee (1981) and Partee & Bach (1981).

Cooper gives two reasons for replacing the quantifying-in rules of PTQ: (i) The principle of the autonomy of syntax is violated in the PTQ fragment. Due to the quantifying-in rules there are infinitely many derivation trees for a given syntactic structure; the need for this abundance is purely semantic. (ii)

The presence of indexed pronouns in the PTQ fragment is a flaw. They should at least be avoided in the well-formed sentential expressions produced by the grammar, and preferably also in the well-formed expressions of other categories (the latter wish can be seen as an attempt to comply with Partee's so-called "well-formedness constraint"(cf. Partee (1979b)), given the intimation that indexed pronouns should be barred from well-formed sentences).

IV.1.1 A mini-fragment

I will demonstrate the working of the Cooper-store mechanism on a rudimentary extensional fragment of English. A level of translation in a logical language EL is included in the framework. Some pieces of notation: let $x_{m,1}$, $x_{m,2}$, etc., be a denumerable list of variables of type e for male entities (I will use '$x_{m,i}$' to refer to any of these). Let $x_{f,1}$, $x_{f,2}$, etc., be a list of variables for female entities, and $x_{n,1}$, $x_{n,2}$, etc., a list of entities that are neither male nor female, or that are not marked for gender. (For a discussion of the semantic approach to gender agreement cf. IV.1.3.) Further, x, y, .. are variables of type e that are not in one of the above lists. P and Q are variables of type ‹e,t›, and S is a variable of type ‹‹e,t›,t›.

Again we employ the following notational convention: if A is a WFE of type ‹e,‹e,t››, then A(y)(x) will be written as A(x,y). To keep the fragment as simple as possible, I will not incorporate plural NPs, and I will not distinguish between SPEC and DEM, as in III.4.4. Instead, I will follow Montague's uniform treatment of NP-specifiers.

Basic categories and corresponding logical types:

NP	‹‹e,t›,t›
SPEC	‹‹e,t›,‹‹e,t›,t››
CN	‹e,t›
VP	‹e,t›
TV	‹‹‹e,t›,t›,‹e,t››
PP	‹‹e,t›,‹e,t››
PREP	‹‹‹e,t›,t›,‹‹e,t›,‹e,t›››

Lexical entries

The format of the lexical entries is: ‹lexical item, category, set of features, translation in EL›. Here are some examples:

<John, NP, [3,sg,m], $\lambda P[P(j)]$ >

j is a constant of type e.

Similarly for 'Bill', 'Mary', 'Amsterdam', etc..

<he, NP, [3,sg,m,-obj], $\lambda P[P(x_{m,i})]$ >

<him, NP, [3,sg,m,+obj], $\lambda P[P(x_{m,i})]$ >

<she, NP, [3,sg,f,-obj], $\lambda P[P(x_{f,i})]$ >

<her, NP, [3,sg,f, +obj], $\lambda P[P(x_{f,i})]$ >

<it, NP, [3,sg,n], $\lambda P[P(x_{n,i})]$ >

i is a natural number. Note that there are infinitely many possible translations for the pronouns, and that the gender of the pronouns transpires in the variables used in their translations. The feature [±obj] is a case feature.

<man, CN, [3,m,sg], $MAN_{<e,t>}$ >

Similarly for 'woman', 'book', 'city', 'country', etc..

<walks, VP, [3,sg], $WALK_{<e,t>}$ >

Similarly for 'talks', etc..

For the translation of transitive verbs we will again emply the method that was explained in III.6, in order to avoid the introduction of meaning postulates.

<sees, TV, [3,sg], $\lambda S \lambda x[S(\lambda y[SEE_{<e,<e,t>>}(x,y)])]$ >

Similarly for 'loves', 'hates', 'visits', 'reads', etc..

<some; SPEC, [3],$\lambda P\ \lambda Q$ [\/x (P(x) & Q(x))] >

$\langle$the, SPEC, [3], $\lambda P\, \lambda Q\, [\backslash/x\ /\backslash y\ ((P(y)\ <\!-\!>\ y=x)\ \&\ Q(x))]$ $\rangle$

$\langle$every, SPEC, [3,sg], $\lambda P\, \lambda Q\, [/\backslash x\ (P(x)\ -\!>\ Q(x))]$ $\rangle$

$\langle$no, SPEC, [3], $\lambda P\, \lambda Q\, [\ /\backslash x(P(x)\ -\!>\ \neg\, Q(x))]$ $\rangle$

$\langle$in, PREP, [], $\lambda S\, \lambda P\, \lambda x\, [\ S\ (\lambda y\ [(IN_{\langle e,\langle e,t\rangle\rangle}(x,y)\ \&\ P(x))])]$ $\rangle$

Format of the rules of grammar

The fragment generates 'bracketed' English instead of 'plain' English: the well-formed expressions that the fragment allows are structural descriptions (labelled bracketings, structure trees) of English.

The rules of the fragment mention syntactic structures, features, and EL-translations. Every rule has three components: a syntactic component, a quantifier-store handling component, and a semantic component. The syntactic component maps structural descriptions into structural descriptions. The store-handling component specifies the way in which the *quantifier-store* of the top node of the structure is affected (the format of the quantifier-store which will be specified below). The semantic component specifies the translation in EL of the output structural description in terms of the input structural expression(s) and their quantifier stores. The rules may be subject to certain *conditions*.

The following general condition holds for all rules: combinations that involve feature clashes are forbidden. (In a larger fragment that admits NPs with other features than [3,sg], subject-verb agreement is taken care of in this way; the general condition forbids the combination of the plural subject 'the men' and the singular VP 'walk*s*')

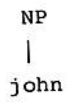
There are three kinds of rules. The *basic structure rule* has a syntactic part that builds basic structural descriptions out of lexical items, the *formation rules* have a syntactic part that builds complex syntactic structural descriptions out of simpler structural descriptions, and the *derivation rules* have a syntactic part that maps structural descriptions into identical structural descriptions (the derivation rules are used to effect storage changes).

Each structural description has an associated quantifier store. The quantifier store ST associated with a given structure contains the set of NP-translations that have been stored. Each stored NP-translation has an associated <u>index set</u>. Thus, an <u>element</u> of ST for a given structure has the form ⟨A, {i,j,..}⟩, where A is an NP-translation and i,j,.. are natural numbers (indices).

The format of the rules of grammar is as specified in III.3.2, but with a quantifier-store component added: the rules of the grammar have three components, instead of two. The first component of each rule is the syntactic specification. As was explained in III.3.2, the numbers 0, 1, 2,... refer to the items in the syntactic specification, in left-right order. The second component indicates what happens to the quantifier-store. ST(0), ST(1), ST(2),... refer to the quantifier stores of these items. "ST(0) = ST(1)" says that the store of the first item mentioned in the syntactic specification is identical to the store of the second item. Finally, the third component gives the semantic specification. It tells us how the translation of the specified syntactic structure depends on the translations of its parts. If application of a rule is contingent on certain structural conditions, these conditions are listed below the rule.

Basic Structure Rule

Basic structures are formed by specifying that a basic category may label a node that exclusively dominates a lexical expression having that category. Thus, the following is a basic structure:



The rule format is as follows: for every lexical entry ⟨A, B, [β], A'⟩ we have:

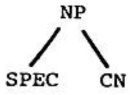
BR B := A
    [β]

ST(0) = $\emptyset$

0' = 1'

Syntactic Formation Rules

The syntactic formation rules specify what non-basic structures look like, and how their quantifier stores and translations depend on those of their parts. E.g. the first line in rule FR1 says that an NP-node may look like this:



Because the precise operation of the feature mechanism is not relevant, I have omitted the lists of features.

FR1 NP := SPEC CN

ST(0) = ST(2)

0' = 1'(2')

FR2 VP := TV NP

ST(0) = ST(2)

0' = 1'(2')

Condition: 2 does not have feature [-obj]

FR3 S := NP VP

ST(0) = ST(1) $\cup$ ST(2)

0' = 1'(2')

Conditions: 1 does not have feature [+obj]; no index i occurs both in some index set of ST(1) and in some index set of ST(2). (This second condition is needed to avoid wrong bindings. If the index i would occur in both ST(1) and ST(2), quantifying-in of one of the NP-translations that is stored with index i would bind the variable that stands proxy for the NPs in both NP-positions, and a wrong sentence interpretation would result.)

FR4 PP := PREP NP

ST(0) = ST(2)

0' = 1'(2')

Condition: 2 does not have the feature [-obj].

FR5 CN := CN PP

ST(0) = ST(2)

0' = 2'(1')

Condition: 1 immediately dominates a lexical item. (The condition ensures that complex CNs like 'man in a park in Amsterdam' are syntactically unambiguous.)

FR6 VP := VP PP

$ST(0) = ST(1) \cup ST(2)$

$0' = 2'(1')$

General remark about the store handling component: in all FR rules the store of the dominating node is the union of the stores of the nodes below it. Apparent exceptions to this rule are caused by the fact that some nodes <u>always</u> have empty stores, because they cannot dominate an NP.

Derivation rules for NP-storage and retrieval

The rules DR1 and DR2 constitute the storage mechanism. DR1 tells us that any NP translation may be stored. The procedure is that the NP translation is replaced by a pronoun translation, and the pair consisting of the NP translation and the singleton set that contains the index of the variable used in translating the pronoun is added to the store. This same index is added to all index sets in the store. There is a condition on DR1, that is necessary to prevent wrong bindings in the process of quantifying in (i.e. applying DR2).

DR2 regulates the process of taking NP-translations out of store and quantifying them in at S-level. (If one wants to allow quantifying in at different levels as well, extra rules are needed.) The formulation of the rule guarantees that, whenever a certain S-structure has a non-empty store, the stored NP(s) can be quantified in. For stored NPs that are not part of one another the order of quantifying-in is arbitrary. If an NP containing a stored part is itself stored, however, it is obligatory that the NP stored last be quantified in first. (Cf. the next section for some illustrations of this feature.)

Legenda: '<==' means that the structure on the lefthand side can be derived from the identical structure at the righthand side. As before, the numbers refer to the items mentioned in the first line, in left to right order. The derivation rules do effect the quantifier store and the translation. The following two operations on quantifier stores will be used. If [ST] is a quantifier store, then $[ST]^{+i}$ is the result of adding index i to every index set in [ST], and $[ST]^{-i}$ is the result of removing index i from every index set in [ST].

DR1 "Store NP"

NP <== NP

$ST(0) = [ST(1)]^{+i} \cup \{\langle 1', \{i\}\rangle\}$
where i is a natural number and $[ST(1)]^{+i}$ is as defined above.

$0' = \lambda P[P(x_i)]$

Condition: i does not occur in any index set in ST(1).

DR2 "Retrieve NP at S-level"

S <== S

$ST(0) = [ST(1) - \{\langle A, \{i\}\rangle\}]^{-i}$.
where $\langle A, \{i\}\rangle$ is a member of ST(1), and the operation $[\ ]^{-i}$ is as defined above.

$0' = A(\lambda x_i [1'])$

Subject-verb agreement is taken care of by means of the general condition that forbids feature clashes. Case and gender adjustment can be handled by means of features too. For some discussion of the problems that a gender adjustment rule may pose for a storage approach, cf. IV.1.3.

IV.1.2 Constraints of Scopes and Anaphora

The above implementation of Cooper-storage in a complete, albeit somewhat tiny fragment makes it easy to discuss the possibilities for scope and anaphora constraints in such a framework.

Anaphoric links between pronouns can be established in the mini fragment in two ways: (i) by means of using the same variable in both pronoun translations, and (ii) by storing a pronoun translation and replacing it with a pronoun translation that uses a variable also used to translate another pronoun. Recall that in PTQ anaphoric links between two pronouns can also be established in two ways: by means of giving them the same index in the first place, or by means of quantifying-in a pronoun. Anaphoric links between a full NP and a pronoun are established by storing and quantifying-in the antecedent full NP, also like in PTQ.

Nevertheless, the mini-fragment is less constrained than PTQ: in PTQ a non-pronominal NP that binds a pronoun always occupies the leftmost position; in the mini-fragment this need not be the case. No constraints on possible anaphoric links and scopes have as yet been incorporated in the fragment.

A first problem of the mini-fragment is the fact that there are no prohibitions on the binding by an NP occurrence A of a pronoun-occurrence B such that A does not c-command B. The reading of (a) with an anaphoric link (established by binding) as indicated by the underlinings that should have been ruled out, is nevertheless generated by the fragment.

(a) *<u>He</u> hates <u>every</u> <u>man</u>.

Example (a) with this forbidden reading can be got by storing the translation of <u>every</u> <u>man</u>, using a pronoun translation with a variable that has the same index as the variable used in the translation of the subject-pronoun.

The remedy: put an extra <u>condition</u> on rule FR3, which now becomes:

FR3 S := NP VP

$ST(1) = ST(1) \cup ST(2)$

$0' = 1'(2')$

Conditions: 1 does not have the feature [-obj]; no index occurs both in some index set of ST(1) and in some index set of ST(2); x_i does not occur freely in 1' for any index i that belongs to an index set of ST(2).

For the fragment as it is, the simple extra condition has the desired effect: the pronoun-occurrences in 1 obviously cannot be c-commanded by any NP-occurrences in 2. The condition forbids the binding of these pronoun occurrences in 1 by NP-occurrences in 2.

Note that the new condition mentions a property of the EL-translation of 1. It refers to indices of free variables in 1'. Every free variable in 1' occurs in the translation of a pronoun, and because the syntactic form of a pronominal NP does not give us a clue to the variable used in translating it (the pronouns are not indexed in the syntax), it is impossible to rephrase the condition as a condition on syntactic structure.

Now, to mention a further problem: the mini-fragment generates sentence (b) with (among other possibilities) the translation that goes with the anaphoric link indicated by the underlinings:

(b) *<u>He</u> likes <u>him</u>.

The same difficulty occurs in PTQ. The problem is caused by the absence of a distinction between reflexive pronouns and ordinary pronouns in the fragment. Partee & Bach (1981) have shown that reflexives can be treated by means of Cooper-storage. In their fragment the reading of (b) that is indicated by the underlinings is ruled out. Partee & Bach's approach to relativization is not elegant, because it entails the introduction of a lexical ambiguity for reflexives that has no syntactic motivation. Partee and Bach distinguish between subject-controlled and object-controlled reflexives by giving them different translations (abbreviated as SELF1 and SELF2, respectively). My own proposal for the incorporation of reflexives will be presented in the fragment of MG+ in VI.3.

In rule DR1 (the rule that implements NP-storage), the index of an NP that is to be stored is added to the index-set of all NPs that are already in store. In combination with rule DR2 for quantifying-in, this procedure imposes a Last In, First Out (LIFO) constraint on the set of stored NP-translations.

The Last In, First Out constraint on storage serves to prevent quantifying-in of NPs in the wrong order. To give an example that was discussed in connection with May's theory of quantification:

(c) Every man in some city cursed Ephialtes

In case 'some city' is stored with index <u>i</u>, and 'every man in -' is stored too, with index <u>k</u>, the index set of 'some city' in store becomes {i,k}. If one would allow quantifying-in in any order the NP 'some city' could be quantified in first. (Cf. the earlier remarks about this example in the review of May's theory of Logical Form, in II.3.2.) In the corresponding translation this would involve λ-abstraction over the variable x_i in a formula that does not contain the pronoun translation $\lambda P[P(x_i)]$ (for the pronoun translation $\lambda P[P(x_i)]$ is part of the translation for 'every man in -', an NP translation that is still in store). The variable x_i in the stored translation of 'every man in -' would not get bound, and the result would be a wrong interpretation for the sentence. The rule DR2 allows only for the quantifying-in of NP-translations in store that have a singleton index set. The index of the NP that is quantified in is removed from the index sets of all NPs still in store. Therefore, in the example, it is impossible to quantify in 'some city' first.

In Cooper's original formulation of the storage process, stored NPs can be quantified in in any order, but Cooper adds the proviso that there be no instances of vacuous λ-abstraction in the translation of any syntactic structure. Cooper needs the ban on vacuous λ-abstraction to filter out the cases where an NP A is quantified in while an NP B such that B is embedded in A is still in store. As has been illustrated in connection with example (c), such cases of quantifying-in in the wrong order will always result in vacuous λ-abstraction.

In my implementation of the Cooper-storage mechanism I have tried to avoid all unnecessary reference to properties of EL-formulas. In the approach of the mini-fragment the message: 'If you have NP-translations in store that result from NP-nodes that are embedded in each other, then quantify them in in the order opposite to the one in which you have stored them', is contained in the formulation of the rules for NP-storage and quantifying-in, so the ban on vacuous λ-abstraction is unnecessary.

As a result of the LIFO constraint on stored NPs that are part of each other, it turns out to be easy to incorporate Robert May's theory of scope in the fragment. Recall that May distinguishes between Quantified NPs and referential NPs. Give the NPs with specifier 'some' and 'every' the feature [+q]. May's theory can be incorporated by the addition of the following simple constraint:

<u>Q-constraint</u>: NPs with the feature [+q] must always be stored.

To see that this has the desired effect, consider sentence (d):

(d) Some man in every town hates every woman in some country.

The Q-constraint forces us to store 'some man in every town', 'every town', 'every woman in some country' and 'some country'. The LIFO principle that has been built into DR2 forbids quantifying-in of 'every town' and 'some country' before 'some man in -' and 'every woman in -', respectively, have been quantified in at S-level. Within the confines of the mini-fragment, the effect of DR2 plus the Q-constraint is exactly the same as that of May's rule QR. (May's constraint that quantification be clausebound can be incorporated in a more extended fragment by demanding an empty store at S-level.)

IV.1.3 Some Methodological Comments

Given a sentential syntactic structure of the mini-fragment, consider all translations that have an empty store. This set constitutes the final set of translations of the sentential structure. All possible quantifier scope orders and all anaphoric possibilities for the sentential structure under consideration will be represented in this set.

Cooper maintains that the framework of Cooper-storage obeys a weakened form of compositionality. According to the weakened principle of compositionality, not the translation, but the set of translations of a given syntactic expression is derived compositionally. The requirement of weak compositionality can be formulated as follows (a translation pair is a pair consisting of an EL- or IL-translation and a quantifier store):

> Every syntactic structure determines a set of translation pairs, and the set of translation pairs of any given structure is fully determined by the sets of translation pairs of the constituent structures and the way in which the structure is construed from its constituents.

The mini-fragment complies with the requirement.

There are some problems with the implementation of Cooper storage, however. In the first place, note that most of the conditions on the rules of the fragment are stated in terms of the quantifier store contents. The stores are part of the semantic component, so the conditions that were purported to be conditions on syntactic structure, turn out not to be syntactic in nature. This means that a presupposition of the principle of compositionality, vid. that syntax and semantics are distinct, is infringed.

A second problem is gender agreement. Anaphoric links are not part of the syntax, but of the semantics, for they depend on the variables that are used in translating the pronouns. (I have stressed this point in the fragment by choosing different sets of variables for masculine, feminine and neuter pronouns.) If a language has natural gender agreement, like English, this is not serious. In such languages, the natural gender of the object(s) referred to by the antecedent of a bound pronoun determines the gender of the pronoun.

There are languages, however, (German, Romanic languages) that have grammatical gender agreement. 'La sentinelle' (the sentry) has feminine gender, regardless of the fact that the word may refer to a male individual; and any pronoun that has this NP as antecedent must have feminine gender. This information must be available to filter out unwanted anaphoric links, but it is not available on the level of semantics. (The above point is also made in Landman & Moerdijk (1983a), in connection with Partee & Bach's implementation of Cooper-storage.)

Cooper replies - in (1983), chapter VII - by pointing out a series of problems for a purely syntactic treatment of gender agreement. He provides some convincing examples of the ways in which the natural sex of entities referred to influences the anaphoric possibilities of pronouns. His argument misses the point, however. The position at stake is not whether there is a semantic influence on gender agreement (in English, but also in languages that have grammatical gender agreement), but the much more extreme position that an account of gender agreement that exclusively operates on the semantic level is possible, not only for English, but for languages with grammatical gender agreement as well.

In their discussion of the framework of Partee & Bach (1981), Landman & Moerdijk (1983a) raise the point of the dispensability of the logical language in a storage-approach. As soon as reference is made to the set of free variables in a certain EL- or IL-translation, the principle of the dispensability of the logical language appears to be violated. I have referred to free variables in IV.1.2 in the condition on rule FR3 that imposes an anaphora constraint on the mini-fragment. Partee & Bach refer to free variables by introducing a so-called Local Pronoun Store (LPST). The LPST is a collection of indices of free variables that is used to frame certain anaphoric constraints that Partee & Bach impose on their fragment.

Does the fact that reference is made to a property of formulas of the logical language imply that the level of EL- or IL-translations has become indispensable? If we are unwilling to enrich our notion of *interpretation*, the answer is 'yes'. If we have no qualms about introducing something extra in the already richly populated realms of EL- and IL-models, however, then the logical-language-property "containing an occurrence of the free variable x_i" can easily be transposed to the level of interpretation.

Cooper (1983) combines a storage device with direct interpretation. The ploy here is a definition of an *interpretation* as a pair consisting of a *denotation*$_C$ and a *store*, where a *denotation*$_C$ is a function from infinite sequences of individuals to the model-theoretic objects that we used to call denotations, and a *store* is a set of denotations$_C$ (denotations in Cooper's sense). Bound-variable pronouns refer to functions that, for a given sequence *s* of individuals, pick out (the set of sets that contain) the individual that occupies a given position in *s*.

Cooper interprets a 'place-holder' for a stored NP as a function that maps each sequence *s* of individuals to the set of all sets that contain the i-th element of the sequence, where i is a natural number that marks the stored NP.

A sentence that, as a result of storing an NP with mark i, contains a place holder, will be interpreted as (the characteristic function of) a set A of sequences of individuals, where membership of A depends on the i-th objects of the sequences.

A stored NP with mark i is interpreted as a function F_i from sets of sets of sequences to sets of sets of sequences, where, for each set of sequences A,

$$F_i(A) = \{ s \mid \{ a \mid s\,[a/i] \in A \} \in [\![NP]\!] \}.$$

Here s [a/i] is the result of replacing the i-th individual in s by the individual a, and $[\![NP]\!]$ is the old-style generalized quantifier denotation of NP.

It is clear that this makes the new-style interpretation of a stored NP a *binder* function for the place-holder interpretation: whether a sequence s is a member of A may depend on its i-th object; whether a sequence s is a member of $F_i(A)$ does not depend on its i-th object, but depends instead on the GQ-denotation $[\![\text{NP}]\!]$ of the stored NP.

In fact, the infinite sequences of individuals operate rather like assignments to individual variables. An assignment g that maps variable x_i to object a performs exactly the same job in a fragment with an intermediate level of EL- or IL-translations as a sequence of objects s that has object a in its i-th position in a fragment with direct interpretation.

Assignments are like mermaids; mixed creatures that are neither wholly living in the land of syntactic structures nor quite at home in the sea of semantics. The crucial rôle they play in the truth-definition for predicate logic is fully accepted. Assignments are essential in the standard semantics of predicate logic for a compositional treatment (cf. I.1.4). It would not be reasonable to forbid the employment of a similar device in the semantics of natural language.

Every step from propositional logic via predicate logic to modal predicate logic has involved an enrichment of the notion of interpretation. Montague grammarians that are not prepared to accept a further enrichment should explain why Montague's notion of interpretation is so 'natural' that enrichments of it should be ruled out of court.

With the qualms about compositionality out of the way, several problems remain. In the first place it should be noted that there is a problem that cannot be solved easily in the storage-approach: the treatment of donkey-pronouns. Montague's original difficulties with sentences in which they occur (cf. III.5) are inherited by the storage-approach to quantification. Donkey-pronouns will be covered by the referential anaphoric mechanism to which we will turn in chapter V.

Now let us take a closer look at the problem of gender-agreement and the problem of the non-syntactic nature of conditions on the syntactic rules (anaphora constraints). These problems can be solved by enriching syntax structures just enough for calling the gender-agreement mechanism and the constraints on anaphora 'syntactic', by introducing an NP-indexing mechanism. The rule that stores an NP-translation now has a visible syntactic effect: if the NP-translation is stored for index i, the NP gets feature [i] in the syntactic structure. The NP-retrieval rule applies to S-structures containing an NP-structure with an index feature. Application of the rule deletes the feature.

The LIFO constraint that was discussed in IV.1.1 can now be implemented by imposing the condition on application of NP-retrieval that no NP-node properly dominating the NP-node to be retrieved carry an index feature. This means that stored NP-translations need not have index-sets, as in IV.1.1; the enriched syntactic structures contain all necessary information.

Next, index-features on bound pronouns are needed. These indices can either be 'base-generated' (as in PTQ), or introduced by the indexing mechanism at a later stage, provided that at some stage each pronoun has as its index-feature the index of the individual variable used in its translation. Assuming that members from three disjoint sets of indices are available as indices of the variables in the translations of masculine, feminine and neuter pronouns, respectively, let the rule for NP-storage be restricted to employ indices from one of these three sets, according to the syntactic gender feature of the NP to be stored. This solves the problem of gender agreement. Anaphora-constraints can now be imposed without reference to properties of the translation language, for the relevant EL-features have been transposed to the syntax.

I will not modify the syntax of the mini-fragment to incorporate the above ideas. Instead, my ambition is to present a synthesis between Montague Grammar and Transformational Grammar that is more elegant and also much closer to the spirit of May's and Higginbotham's ideas on Logical Form. In the next section the incorporation of a level of Logical Form in Montague Grammar will be discussed in general terms.

IV.2 The Synthesis of MG and TGG

The enrichment of syntactic structure with additional information about quantifier scopes and anaphoric links that takes place in the LF-component of a TGG grammar serves to remove semantic ambiguities. The resulting 'enriched structures' (or, equivalently, the pairs consisting of a syntactic structure and the information needed for scope/anaphora fixing in the structure) determine interpretation; provided, of course, that lexical ambiguities have been resolved already. 'Enriched' structures are at a level somewhere between syntactic structures and the model-theoretic objects that interpret them.

In Montague Grammar, quantifier scope ordering and anaphoric disambiguation typically takes place at an earlier stage: during the derivation of the syntactic structure. One might say that in Montague Grammar interpretation is determined by a pair consisting of a well-formed syntactic expression (a string or a labelled bracketing) plus the derivational history of that expression. It is not difficult, however, to modify the Montague framework and postpone the fixing of scopes and anaphoric links (NP-storage is one way of doing this, in fact). Derivation trees as they are used in classical Montague Grammar are not suited to play the rôle of LF-structures. They encode a process that has taken place <u>in the course of constructing</u> a certain syntactic expression. Logical Forms in TGG are the result of a process that occurs <u>after</u> a syntactic expression has been constructed.

We will introduce a level in Montague Grammar of 'enriched syntactic structures', serving to disambiguate the syntactic structures they are derived from, with respect to quantifier scopes and bound anaphora. We need a name for these "intermediate structures" at the level between syntactic constituency structure and semantic interpretation. I propose to call these intermediate structures, that I will be careful to distinguish both from the level of structures of surface syntax and from that of modeltheoretic objects, "Extended Syntax Structures" or "Logical Forms". The motive behind the choice of the latter poetic but somewhat outworn epithet is my wish to rehabilitate the label in Montegovian circles by applying it to something that is acceptable to both Montague-grammarians and TGG-theorists.

What about the received idea among Montague-grammarians that the concept of 'Logical Form' is alien to the enterprise of Montague Grammar? The Montague-theorists who deny that 'Logical Forms' can occur in Montague Grammar, except as dispensable ornaments, do not talk about 'Logical Forms' in my sense. Instead, they mean by 'Logical Forms' the expressions of a logical language (EL, IL, ...) that are used in Montague Grammar as shorthand for modeltheoretic objects. Studies that compare Montague Grammar and TG Grammar usually rephrase the question of the dispensability of a level of Logical Form (in TG-grammar and Montague Grammar alike) as the problem of the dispensability of a level of translation to IL or a comparable logical language. In Partee & Bach (1981; 447) the TGG-level of 'Logical Form' is equated with the level of IL-translations in Montague Grammar without further ado. The authors state that the hypothesis that an intermediate level of translation into a logical language is dispensable "runs counter to most earlier and much current work in semantics by linguists, where the usual assumption is that the output of semantic interpretation is 'semantic representation' [...]". Landman & Moerdijk (1983; 92) make the same equation: they assert that it follows from the compositionality principle that there is no level of 'Logical Form' in Montague Grammar.

Of course, I agree that the level of translations in a logical language is dispensable in Montague Grammar. I do not agree with the equation of 'Logical Form' and 'Logical Translation', however. LF-structures in my sense (and my stipulation is of course intended as an explication of the notion as it is current in TGG-circles) are not interpretations, nor do they serve as shorthand for interpretations. Rather, they are representations derived from syntactic structures meant to provide information about certain kinds of disambigation of these structures.

I continue with a short digression on Logical Forms. Is the level of Logical Forms in my specific sense also the level that is appropriate for the formulation of <u>inference-patterns</u>, for the definition of a notion of synonymy, etc. ? Answer: this might well be the case. At the very least it is possible to define an equivalence relation on the set of Logical Forms that holds between LFs with the same interpretation. This fact alone does not make LFs into a part of the modeltheoretic apparatus, by the way, for by the same token the level of derivation-trees in classical Montague Grammar would be a part of the model-theory.

Do Logical Forms always look like 'enriched syntactic structures'? It depends. In the framework of MG+ that will be defined in IV.3, the LF-structures retain all information about syntactic structure. In general, this need not be the case, however. Syntactic structure may get lost in the transition process from syntactic structures to LF-structures. A case where this happens is the level of Discourse Representation Structures in Kamp (1981), viewed as an LF-level. It is essential that the information that is relevant for interpretation is maintained; semantically irrelevant features may get lost.

What is the philosophical status of the in-between level of Logical Forms? This question invites philosophical speculation about 'mental representation' (cf. e.g. the introductory section in Kamp (1981)). One might assume that a level of Logical Forms will turn up in computer implementations of natural language fragments and speculate about the relation between this level of computer implementation and what happens in the human brain. In my view these speculations are just that: mere speculations. As long as there is no agreement about the formal properties of Logical Forms, such philosophical investigations start from very flimsy premisses. This philosophical activity will remain risky unless it acquires a basis of theories of Logical Form that are both detailed and formally precise. I will also evade another question: 'Is Logical Form a part of syntax?' If this is asked against the background of a theory about the mental reality of syntactic structures, it is connected with the previous question. I have no doubt that ultimately, when we are at the stage where research in syntax will tell us something about how the human mind functions, the pursuit of these questions will prove to be of paramount importance. Still, we should keep in mind that the concept 'syntactic structure of natural language' is as yet so diffuse that questions about its demarcation are a matter of stipulation rather than argument.

Finally, what is the aim of introducing a level of Logical Form structures? In order to achieve a synthesis between the TGG and the Montague frameworks, we need a clear distinction between syntax proper and the semantically motivated devices for scope ordering and anaphora-resolution. Introducing a level of LF-structures in Montague Grammar enables us to draw this distinction. The LF-structures provide a starting point for interpretation; they may serve as a starting point for drawing inferences as well (in this they may function as a logical language, after all).

Still, we must bear in mind that, despite the superficial resemblance between the LF-structures in TGG and formulas of first order predicate logic, the LF-component in TGG cannot be taken to be the TGG counterpart to the IL-formulas in Montague Grammar. There is a crucial difference between LF-structures and IL- (or EL-) formulas. In Montague Grammar an IL-formula that translates a well-formed syntactic expression can always be replaced by a an equivalent formula: 'the' translation of an expression is not a formula, but an equivalence class of formulas. No such thing holds for LF-structures: every LF-structure is syntactically tied to a grammatical sentence. One might call the LF-structures that have the same interpretation 'equivalent', but one must bear in mind that the substitution of one LF-structure for another, equivalent one might sever the 'syntactic' tie that binds the original Logical Form to a grammatical sentence. Similarly, if one defines an equivalence relation on derivation-trees in Montague Grammar in this same manner, equivalent trees need not derive the same syntactic expressions: the derivation trees for 'John is a fool' and 'There is someone called John and he is a fool' may well be equivalent, but they derive different expressions.

IV.3 MG+: Montague Grammar with an LF-component

IV.3.0 Introduction

My aim in this section is to introduce a framework for the description of English that is both rich enough syntactically to embody the most important syntactic constraints on scopes and anaphora that have been proposed in the TGG syntactic studies discussed in II above, while at the same time providing a rigorous Montague-style semantics. I will call the framework that results from adding an LF-component to Montague Grammar 'MG+'. In IV.3.2, the mini-fragment from IV.1.1 will be taken as a point of departure for the formulation of a fragment of MG+. Directions for extending this fragment will be given in IV.3.5.

IV.3.1 Sketch of the Framework

Derivations as they are generated by PTQ are not suited to play the role of LF structures. Structured derivations, as they are generated in structured PTQ, a variant where the syntactic strings are replaced by labelled structures are hardly better. Such derivations represent a process that has taken place _before_ the syntactic structure that they derive is construed, not a subsequent process, as does the LF level of a TG grammar. Moreover, in PTQ the result of the derivation process for a sentence may contain indexed pronouns, whereas the surface syntactic structures that are the input of the process of LF-construction in TGG do not contain any indexed Noun Phrases.

I propose to incorporate a clear-cut distinction in Montague grammar between a level of surface syntax and a level of 'extended syntax' (that plays the part performed by Logical Form in TGG). Extended syntax is to be construed on the basis of surface syntax. At the level of surface syntax no scope and anaphora disambiguation has as yet taken place. Interpretation is to be based on the output of the level of extended syntax. Thus the architecture of MG+ looks like this (IL is replaced by EL because I will disregard intensions):

```
 --------      ---------      ------------      -----------
|surface | --> |extended | --> |EL-         | --> | EL-       |
| syntax |     |  syntax |     | formulas   |     |  models   |
 --------      ---------      ------------      -----------
```

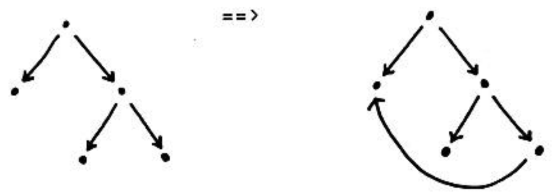
At the level of surface syntax, structure-trees are generated (or admitted). The rules of surface syntax have corresponding translation instructions, but there are certain lexical elements in surface syntax for which there is no translation (vid. personal and reflexive pronouns). The well-formed structures of category S produced by surface syntax serve as input to the component of extended syntax: from a sentence-structure of surface syntax a new <u>final</u> sentence structure in an extended language is derived in a finite number of applications of an 'Extraction Rule'. The Extraction Rule is the key rule of extended syntax. it extracts NPs out of sentential structures and provides personal and reflexive pronouns with indices. A sentential structure is <u>final</u> iff it lacks index-less personal and reflexive pronouns. Each final S-structure of the extended syntax induces an EL-translation. Finally, the EL-formulas are interpreted.

The principal difference between the derivation trees in PTQ and the final sentential structures in MG+ is the way in which they are constructed. Derivation trees in (structured) PTQ are the result of a 'bottom-up' process: well-formed expressions are put together to form more complex well-formed expressions. Final S-structures in MG+ result from a 'top-down' process: the anaphoric links between NPs and the order of precedence of the NPs (and thus the scope of NP-interpretations) in a syntactic structure of category S is gradually fixed.

The advantages of this top-down design are many. In the first place the design ensures that the surface scope order of operators is known beforehand: surface syntactic scope order is given by the sentence-structure that is the input of extended syntax. As a consequence it is easy to keep track of the permutations of surface operator order that are the result of the step by step process of disambiguation. Thus applications of the Extraction Rule that violate some constraint on scope permutation can easily be blocked.

Furthermore, constraints on quantifier scope that are based on structural properties of the sentence under consideration can be incorporated. During the process of derivation of final sentential structures, all information about surface syntactic structure that could be needed is present in the input. The constraints on anaphoric links that are based on the surface syntactic structure of the sentence under consideration can also be incorporated easily.

Finally, note that the top-down design provides the margin that is needed for the formulation of structural constraints on the establishment of anaphoric links. The incorporation of an anaphoric link changes a tree-structure into an acyclic graph, e.g.:



This acyclic graph structure cannot be established in a bottom-to-top interpretation process, for in a bottom-to-top approach the interpretation of an anaphor must be fixed before there is room to link it to its antecedent (cf. also Van Benthem (1983a)). In MG+ anaphoric links are established by introducing indices, and the indexing-mechanism works top-to-bottom.

The distinction between surface syntax and enriched syntax makes it possible to comply with the well-formedness constraint, be it only at the level of surface syntax. I call this version of the well-formedness constraint the 'weak well-formedness constraint' (WWC) and I adopt the following formulation of it:

(WWC) Do not use syntactic expressions in the derivation of a sentence in surface syntax that are not constituent parts of well-formed surface expressions.

The weak well-formedness constraint must be distinguished from the 'strong well-formedness constaint' with which I will mean the following:

(SWC) (i) WWC

(ii) Do not use syntactic expressions in the disambiguation trees for a sentence that are not constituent parts of well-formed surface expressions.

SWC imposes the well-formedness constraint both on the level of surface syntax and on that of extended syntax. It boils down to WWC plus a prohibition on the use of expressions in disambiguation trees that are not well-formed expressions of surface syntax; i.e. it forbids the introduction in the extended syntax of expressions that do not belong to surface syntax.

The fragment to be presented in this chapter does not comply with the SWC. I do not believe that this is a serious defect. If one wants to give an account of anaphoric links and quantifier scopes by means of a binding mechanism, then some indexing mechanism that links operators and variables will have to be present at some level. WWC forbids indices in surface syntax. The discussion in IV.1.3 has revealed the disadvantages of a complete shift of anaphoric linking and scope-assignment to the semantics. Therefore the level of extended syntax is the only place left for indexing, and it is unreasonable to ban indices from this level.

MG+ observes the Principle of Compositionality of Meaning: the semantics of final sentential structures is defined recursively in terms of their (extended) syntax. The compositionality principle does not apply to the structures of surface syntax, as these structures are not yet disambiguated. In this respect there is no difference with (structured) PTQ, where the compositionality principle does not apply to - ambiguous - structured descriptions, but only to - disambiguated - derivation trees.

IV.3.2 Again: A Mini-Fragment

The syntax of the mini-fragment that follows closely resembles that of the mini-fragment in IV.1.1. The storage device is replaced by a rule for mapping structures of surface syntax to LF-structures. For purposes of illustration I have extended the fragment with reflexive pronouns and relative clauses, thus creating at least a minimum of descriptive interest and expressive possibilities.

The format of the lexical entries is as in the mini-fragment in IV.1.1. There is one peculiarity: personal and reflexive pronouns do not have a translation in the lexicon. (These translations will be provided at LF-level.) For the treatment of relative clauses, the grammar has a base-generated WH-dummy _e_ that occupies the relativized NP-position. This dummy behaves like a trace; in its translation the distinguished variable _h_ occurs.

The lexicon

Lexical entries are as in the previous mini-fragment, except the entries for the pronouns. The pronoun-entries lack a translation component. They have a special feature [pro] , present until the stage where it is known what variable should be used in the pronoun-translation. Further, they are marked for gender, number, person. They are also marked for case: for simplicity, the distinction between the objective [+obj] and subjective [-obj] cases of the pronouns is again made by giving them separate entries in the lexicon. The pronoun-entries are as follows:

<he, NP, [m, 3, sg, -obj, pro], -- >
<him, NP, [m, 3, sg, +obj, pro], -- >
<she, NP, [f, 3, sg, -obj, pro], -- >
<her, NP, [f, 3, sg, +obj, pro], -- >
<it, NP, [n, 3, sg, pro], -- >

The reflexive pronouns also lack translations. Instead of the feature [pro], they have the special feature [self]. I will suppose that they have case feature [+obj].

<himself, NP, [m, 3, sg, +obj, self], -- >
<herself, NP, [f, 3, sg, +obj, self], -- >
<itself, NP, [n, 3, sg, +obj, self], -- >

It will prove expedient to provide the WH-dummy with a feature for gender. Therefore we give e the following three entries:

<e, NP, [m, 3, sg, WH], $\lambda P[P(h)]$ >
<e, NP, [f, 3, sg, WH], $\lambda P[P(h)]$ >
<e, NP, [n, 3, sg, WH], $\lambda P[P(h)]$ >

Again we impose the following general constraint on admissible nodes: the combination of two nodes A and B in a new node is forbidden if A and B have incompatible features. (This takes care of subject - verb number agreement in an extension of the fragment that incorporates plural NPs.) For a neat account of morphological features as functions cf. Landman & Moerdijk (1983b).

Further, we need the following special constraints in connection with relative clause formation: (1) if two nodes A and B are combined in a new node, then at most one of them may have the feature [WH]. (This constraint prevents expressions like 'e hates e' from being generated.); (2) the [WH]-feature should always percolate until it reaches S-level, but not beyond that; (3) PPs should not be formed with NPs that have the [WH]-feature (this is needed to prevent the formation of expressions like 'that a man in e loved'); (4) Finally, VP-conjunction should be forbidden if one of the conjuncts has feature [WH] (i.e. 'that loves e and kisses Mary' should be ruled out). If we take care of all this, we have a reasonable implementation of relative clause-formation. In the rules below, I will not again mention these specific feature conditions in connection with relative clause formation. (These feature complications could be circumvented by adopting a GPSG-like metarule-approach to relative clause formation; cf. Gazdar (1981).)

Rules of grammar

The rule schema for the formation of basic structures is as in the previous mini-fragment (except for the quantifier store part). The rules for the formation of complex structures are FR1 - FR6, minus their quantifier store parts, and with conditions added to get the right constraints on relative clause formation. Again, detailed feature information is omitted where it is not strictly relevant.

FR1 NP := SPEC CN

0' = 1'(2')

FR2 VP := TV NP

0' = 1'(2')

Condition: 2 does not have feature [-obj]

FR3 S := NP VP

0' = 1'(2')

Condition: 1 does not have feature [+obj].

FR4 PP := PREP NP

0' = 1'(2')

Condition: 2 does not have feature [-obj].

FR5 CN := CN PP

0' = 2'(1')

Condition: 1 immediately dominates a lexical item.

FR6 $VP := VP \quad PP$

$0' = 2'(1')$

FR7 $\bar{S} := \underline{\text{that}} \quad S$

$0' = 2'$

FR8 $\underset{[\alpha]}{RC} := \underset{[WH]}{\bar{S}}$

where $[\alpha]$ is the gender feature of the relevant [WH]-dummy NP in 1.

$$0' = \lambda Q \, \lambda x \, [\lambda h[1'](x) \; \& \; Q(x)]$$

Note first that the translation of 1 will contain an unbound occurrence of *h*. (The formulation of the other rules and the WH-feature-constraints on them must ensure that 1 contains *only one* occurrence of the trace *e* that engenders an as yet unbound variable *h*.) This variable *h* is bound by λ-abstraction. The gender feature of the WH-trace percolates to the RC-node, to ensure gender agreement between CN and RC in the next rule. This is needed because we will allow the WH-trace to act as antecedent for pronouns and reflexives (cf. IV.3.3). Observe that in the translation part of the rule FR8, the variable h bound by the λ-operator cannot be replaced by any other variable of the same type. This means that the translation language is used here as more than a mere shorthand notation for modeltheoretic objects, and that - strictly speaking - the interpretation process is no longer compositional (cf. Janssen (1983)). Of course, there is a simple remedy. Compositionality can be saved by incorporating a special relativized-item-coordinate in the interpretation procedure. (This matter is discussed in more general terms in IV.1.3 above.) Note finally that the translation instruction ensures that RC translates to type <<e,t>,<e,t>>, as it should in our extensional system.

FR9 CN := CN RC

$0' = 2'(1')$

Note that structures like 'man in a park that scares Mary' are syntactically and semantically ambiguous: the syntax distinguishes between '[[man in a park] [that scares Mary]]' and '[man in a [[park] [that scares Mary]]]'.

FR10 VP := VP <u>and</u> VP

$0' = \lambda x[1'(x) \& 3'(x)]$

Some detailed examples of the workings of this fragment are presented in section IV.3.4 below.

What we have now is a fragment of English with gaps in the translation instructions (no structure containing a pronoun or a reflexive can get a translation), and without a mechanism for anaphoric links and wide-scope quantification. At the level of extended syntax or Logical Form, anaphoric (binding) links will be established and wide scope readings will be accounted for. In the course of this process pronouns and reflexives will receive translations.

IV.3.3 Defining an LF-component

The LF-component we are going to define for the mini-fragment will take the form of an extension of the (surface) syntax. We will suppose that the set of structures of extended syntax <u>includes</u> the set of structures of surface syntax. I.e., all rules of surface syntax are rules of extended syntax. At the level of extended syntax, structures are added by means of a derivation rule ER. This 'Extraction Rule' maps S-structures into S-structures. In the process, the feature [pro] and [self] on some pronouns or reflexives in the S-structures may be replaced by a feature-index. The indexed pronouns or reflexives that are the result of this process have an entry in the extended lexicon.

The extension of the lexicon

An infinite number of lexical items is added. For every index i, the following are in the lexicon of the extended syntax:

<he, NP, [i, m, 3, sg, -obj], $\lambda P[P(x_i)]$ >
<him, NP, [i, m, 3, sg, +obj], $\lambda P[P(x_i)]$ >
<himself, NP, [i, m, 3, sg, +obj], $\lambda P[P(x_i)]$ >
<she, NP, [i, f, 3, sg, -obj], $\lambda P[P(x_i)]$ >
<her, NP, [i, f, 3, sg, +obj], $\lambda P[P(x_i)]$ >
<herself, NP, [i, f, 3, sg, +obj], $\lambda P[P(x_i)]$ >
<it, NP, [i, n, 3, sg], $\lambda P[P(x_i)]$ >
<itself, NP, [i, n, 3, sg, +obj], $\lambda P[P(x_i)]$ >

Further, we add denumerably many instances of a new dummy-NP for 'traces' of an extracted NP. For every index i we have the following trace in the lexicon:

<<u>e</u>, NP, [i, sg], $\lambda P[P(x_i)]$ >

Basic structures of extended syntax are: all basic structures of surface syntax plus the basic structures that can be formed by applying BR to the added lexical items.

[i] is an index feature. If one wants to treat binding phenomena syntactically, it is impossible to avoid indices in the syntax altogether. I will occasionally write the index-features as subscripts. Note, by the way, that the indices on pronouns in PTQ are features as well, even if Montague-grammarians favouring strong constraints on admissible features do not call them so.

Observe that none of the lexical items that have been added has the feature [pro] or [self]. This is important for the working of the rule ER of extended syntax to which we now turn.

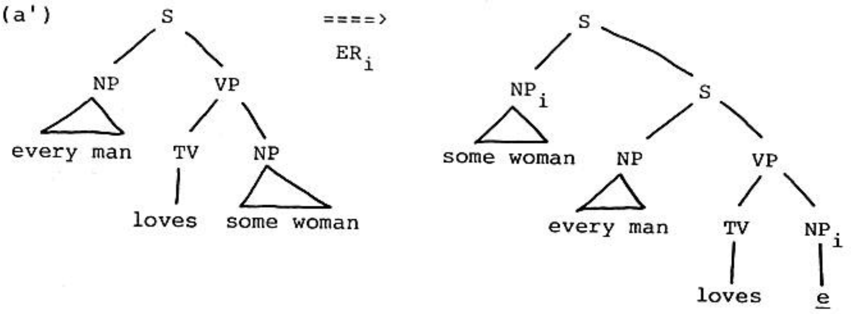
NP-extraction

At the level of extended syntax, a rule of NP-extraction, ER, or rather, a family of rules ER_i, for every natural number i, is added to the rules of syntax. ER_i extracts an NP from its surface-syntactic position, and replaces it with the dummy-structure $[_{NP}\ \underline{e}\ ]_i$. The rule ER_i also has an effect on the NP that is extracted. In case this is a non-indexed full NP, a feature [i] is added that does not effect the translation. In case it is a pronoun that has feature [pro], this feature is replaced with the index-feature [i]. As a result, the extracted pronoun becomes a basic structure of extended syntax that has a corresponding translation by virtue of the extension of the lexicon. ER_i does not apply to NPs that already have an index feature, nor to reflexives (NPs with feature [self]). We will see that it does apply to WH-traces (NPs with feature [WH]), however.

In its simplest application, ER is used to establish scope reversals; cf. the following example:

(a) Every man loves some woman.

(a')



ER can also be used for deictic pronouns:

(b) He walks

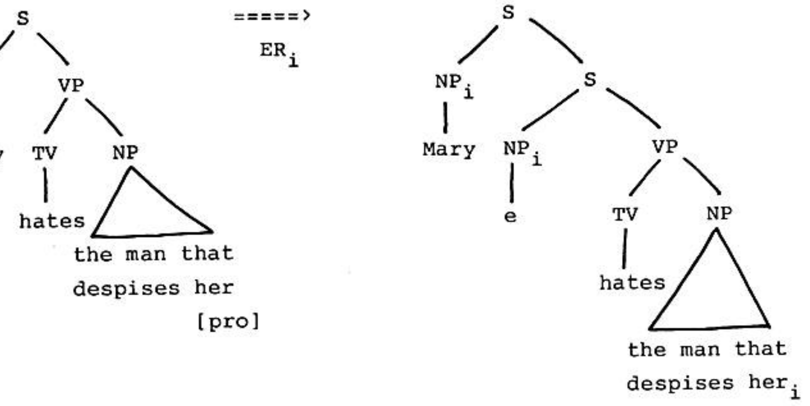
(b')

The result of the application of ER to the pronoun <u>he</u> is that the feature [pro] is replaced with an index feature [i]; the pronominal NP-structure receives a translation in which a variable x_i occurs that is mapped to an appropriate individual by a context-assignment.

Next, ER can be used for establishing anaphoric links between an antecedent NP and an appropriate set of pronouns and reflexives. The antecedent will get extracted and receive an index-feature. The pronouns and reflexives that are to be its anaphors get the same index feature. Example:

(c) <u>Mary</u> hates the man that despises <u>her</u>.

(c')



In surface syntax no anaphoric relations between antecedents and pronouns and reflexives have been established at all: the anaphoric links in (c) and in examples like the following (that are in the fragment) must be established in extended syntax.

(d) Every man that meets a woman that loves him smiles.

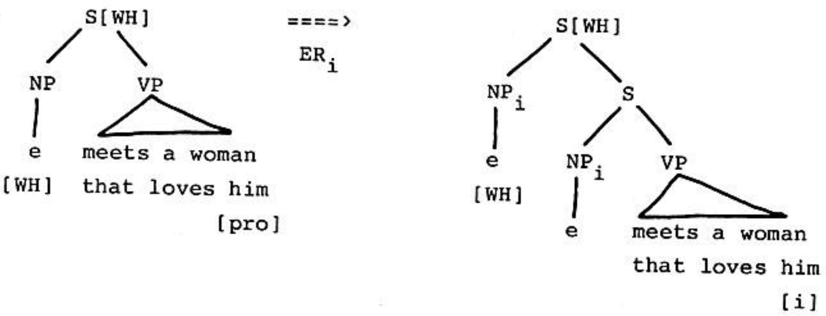
If we change the rule for relative clause formation, and opt for the current TGG structure [$_{NP}$ NP RC] instead of [$_{CN}$ CN RC], then 'every man' can get extracted without further ado. Cf. Janssen (1983, Ch. VIII) for a comparison of these options in a Montague framework. I will not pursue this road here.

In our fragment, as in most standard versions of Montague grammar, relative clauses are CN-modifiers, not NP-modifiers. This means that we must allow structures in which an antecedent NP contains its anaphor:

(e) Every man that meets a woman that loves him smiles.

There are several ways in which this can be achieved. We can formulate ER in such a way that during the extraction of 'every man that meets a woman that loves him' the feature [pro] on 'him' is replaced with the relevant index feature, with the semantic component of ER adapted accordingly. Alternatively, we can allow the following application of ER to the WH-dummy e bound by 'every man' in the embedded structure [_e_ meets a woman that hates _him_] (I thank Gosse Bouma for this suggestion):

(e')



In the formulation of ER that will be given, I adopt the latter alternative.

Example (e) illustrates, by the way, that it is important to mark the WH-dummies for gender. We want to allow the anaphoric link in (e) but rule out anaphoric links as in (f) and (g):

(f) Every man that _e_ meets a woman that loves _her_ smiles.

(g) Every man that _e_ despises _himself_ grunts.

Until now, we have just talked informally about properties of the rule schema ER. For a precise formulation of ER, some definitions of structural notions are needed. Let us suppose that for every syntactic structure C an order of enumeration of the nodes (or: substructures) of C is fixed. So we can speak of a given occurrence of node (substructure) A in C. If we wish to be very explicit, we can talk about node A with occurrence number _k_ in C (for some k).

Now let A, B and C refer to structure occurrences (or to their top-nodes). A and B are NP-occurrences. First we define what it means to be the 'closest' or 'minimal' c-commanding NP of a certain node in a certain structure.

Df. A is the _closest_ c-commanding NP of B in C iff A c-commands B in C, and there is no NP A' such that A c-commands A', and

A' commands B in C.

Next, we want to be able to talk about the closest c-commanding NP from a given set of NP-occurrences.

Df. A is the closest c-commanding NP of B in C with respect to a set D iff A $\in$ D, A c-commands B in C, and there is no NP A' in D such that A c-commands A' and A' c-commands B in C.

We characterize the positions where a reflexive B can be bound by an antecedent-NP A because A is 'close enough'.

Df. B is in the reflexive domain of A in structure C iff

(i) A c-commands B

(ii) A and B have the same gender and number (or in terms of the feature mechanism of the fragment: A and B do not have different gender and number features)

(iii) A does not c-command an S-node that dominates B in C.

(h) is an example of a sentence in the fragment where B is in the reflexive domain of A; (i) is an example where B is not in the reflexive domain of A.

(h) [Every man $]_A$ hates [himself $]_B$.

(i) [Every man $]_A$ hates a woman that $[_S$ e despises [him $]_B$].

Condition (iii) in the definition of 'reflexive domain' is a very simple rendering (sufficient for the fragment as it is) of what in terms of Government-Binding theory would be described as 'B is in the minimal governing category of A'.

Next we elucidate the circumstances under which a pronoun is in the right structural position to be an anaphor bound by a given NP-antecedent.

Df. B is in the pronominal domain of A in structure C iff

(i) A c-commands B

(ii) A and B have the same gender and number

(iii) B is not in the reflexive **domain** of A in C.

Now at last we are in a position to define when a personal pronoun or a reflexive can get bound by an antecedent-NP.

Df. B is in the anaphoric domain of A in structure C iff
 (i) B carries the feature [pro] and is in the pronominal domain of A in C, or
 (ii) B carries the feature [self] and is in the reflexive domain of A in C.

In the following examples B is in the anaphoric domain of A:

(j) [John $]_A$ hates the man that [e despises [him $]_B$].

(k) [John $]_A$ hates [himself $]_B$.

We turn to the key definition that we need for the account of bound anaphora. The definition may seem a bit complicated, but the underlying idea is simple. An ana-set for a given structure C lists a possibility of anaphoric linking between an antecedent NP and a number of pronominal and reflexive NPs in structure C. The ana-sets in the present mini-fragment contain at most two elements, but in general we can have ana-sets with arbitrarily many elements. Cf. the following example (not in the mini-fragment, but cf. IV.3.5 for details on the relevant extension):

(l) John believes that he despises himself.

The possible anaphoric connections are as follows:

(l') John believes that he despises himself.

(l") John believes that he despises himself.

In (l') the relevant ana-set is {he, himself}, in (l") it is {John, he, himself}. The ana-set {John, himself} should be forbidden. (This way to refer to ana-sets is shorthand, of course. To be precise, one would have to list the NP-structures, with their occurrence numbers.)

In the next example the anaphoric possibilities are different from those in (l).

(m) John believes that he likes him.

Here the ana-sets {he, him} and {John, he, him} should be ruled out, but {John, he} and {John, him} are allowed.

The definition of ana-set is recursive:

Df. Set D of NP-structure occurrences is an ana-set in structure C:

(i) If A is an NP-occurrence in structure C that does not have the feature [self], then {A} is an ana-set in C.

(ii) If D is an ana-set in C, and B is an NP-occurrence in C such that B does not c-command any member of D, B has a c-commanding NP in D, and B is in the anaphoric domain of its closest c-commanding NP with respect to D, then D $\cup$ {B} is an ana-set in C.

We can now fix the meaning of 'antecedent of an ana-set'.

Df. A is antecedent of ana-set D in structure C iff A $\in$ D, all members of D - {A} have feature [self] or [pro], and A c-commands every member of D-{A} in C.

Note that it does not follow from the definition alone that every ana-set has a unique antecedent. Pronominal NPs A and B that c-command each other and every other member of an ana-set D might both qualify as antecedents. A check of the formation rules of the fragment reveals that this situation does not occur, however, and thus that antecedents of ana-sets are unique.

The rule schema ER that we are about to define generalizes over a set of rules for extracting the antecedents of ana-sets from a given structure. Syntactically, instance ER_i of ER extracts an NP A that is antecedent of an ana-set D in a sentential structure C (C may be part of a larger sentential structure E; also, the limitation to extraction from <u>sentential</u> structures is not essential). The NP A gets index [i] (if A is a pronoun, A also loses feature [pro]), and is Chomsky-adjoined to C, while all anaphors of C have their feature [pro] or [self] replaced by index-feature [i]. Semantically, A gets wide scope over C, and the members of D - {A} get bound by A.

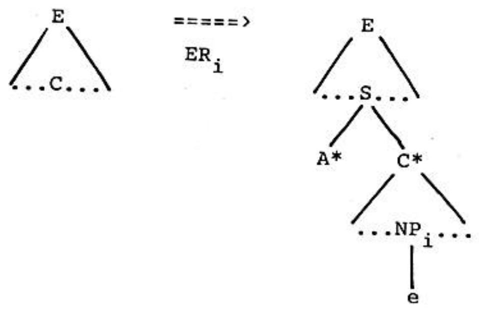
Technically, 'ER' stands for denumerably many rules ER_i, for every natural number i. Every ER_i operates on a quadruple $\langle E, C, D, A\rangle$, where E is a sentential structure, C is a sentential structure that is <u>part</u> of E in the sense that the top node of C is dominated by the top node of E (C need not be a <u>proper</u> part of E, i.e. C and E may be identical: the top node of C need not be <u>properly</u> dominated by the top node of E), D is an ana-set in C, and A is the antecedent in D.

ER_i ("extract NP"):

Df. Let E be a sentential structure, C a sentential substructure of E, D an ana-set in C, and A the antecedent of D. Let A* be the structure that has been obtained from A by adding [i] to the feature set of A, and removing the feature [pro], if it occurs. Let C* be the result of replacing the NP-occurrence A in C by $[_{NP}\ e\ ]_i$, and replacing the feature [pro] or [self] on every element of D - {A} with [i].

$$ER_i(\langle E, C, D, A\rangle) \ = \ E([_S\ A^*\ \ C^*\ ])$$

More pictorially:



Translation instruction for the part $[_S\ A^*\ C^*\ ]$ in the output of ER_i (the rest of the input structure E remains unaffected):

$$[_S\ A^*\ C^*\ ]' = A^{*\prime}\ (\lambda x_i[C^{*\prime}])$$

Conditions on the application of ER_i:

(i) The top-node of C is the minimal S-node that dominates A in C.

(ii) The index feature [i] does not occur in C.

(iii) A does not carry an index feature.

The first condition has as a result that quantification is clause-bounded. (As we have seen in II, this is probably too restrictive. It is of course possible to relax this condition, but one should be careful here. Cf. the comparison with May's theory in IV.3.6.) The second condition is imposed to forbid the 'accidental' co-indexing that may result from applying ER several times for the same index. The third condition, finally, serves to forbid repeated application of ER to the same NP.

The translation instruction for the substructure $[_S\ A^*\ C^*\ ]$ in the output of ER_i is defined, not in terms of C, D and A, but in terms of the syntactic parts of this substructure: A* and C*.

Note that ER_i is formulated as a structure-transformation. The exact format is not essential, though. Without much trouble, ER_i could be reformulated as a metarule in the spirit of Gazdar (1981).

Applications of ER_i to syntactic structures replace NPs featured [pro] or [self] with NPs that do not have these features, and thus remove 'gaps' in the translation instructions. Structures that do not contain translation gaps are ready to be interpreted.

Df. A structure C of extended syntax is a final structure of extended syntax iff C does not contain any nodes with the feature [pro] or [self].

The translation of a final structure is fully determined by its structural description; i.e. final structures are completely disambiguated structures. The principle of compositionality holds for MG+ in the sense that the interpretation of final structures is recursively defined in terms of their syntactic structure.

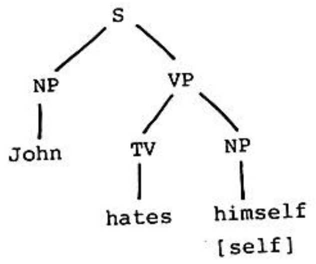
IV.3.4 Some Worked-out Examples

In order to provide a detailed illustration of the functioning of the fragment of MG+, I will work out some examples.

(a) John hates himself

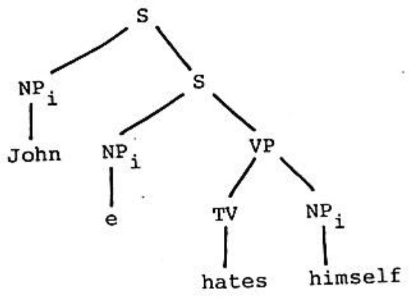
At the level of surface structure, the following tree is admitted by the grammar:

(a')



According to the definition, {John, himself} is an ana-set. An application of ER to this ana-set gives the structure:

(a")



No node in this structure has the feature [pro] or [self], so

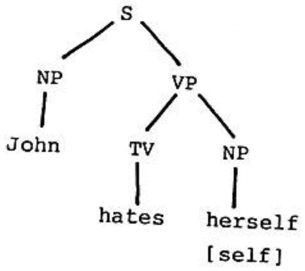
(a") is a final structure of extended syntax. Its translation is defined recursively in terms of its internal structure. The translation of the substructure [e_i hates himself_i] is (after some applications of λ-reduction): $LOVE(x_i, x_i)$.
The translation of the whole structure becomes:

$$\lambda P[P(j)] \; (\lambda x_i[LOVE(x_i, x_i)]),$$

which reduces to: $LOVE(j,j)$.

The surface-syntax also admits the following structure:

(b)

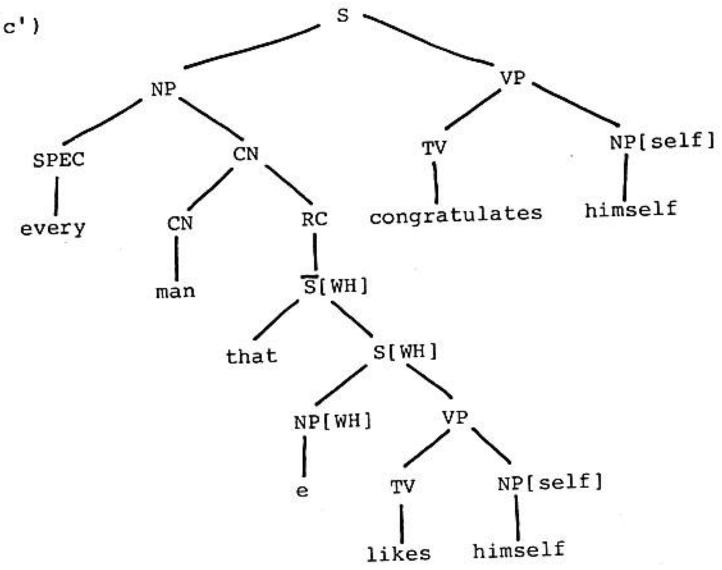


Note, however, that {John, herself} is not an ana-set in (b) (the requirement of gender agreement is not met). This means that it is impossible to apply ER to (b) in such a way that the feature [self] on 'herself' is replaced with an index-feature; i.e. (b) cannot be turned into a <u>final</u> structure of extended syntax, and it therefore cannot receive an interpretation.

(c) Every man that likes himself congratulates himself.

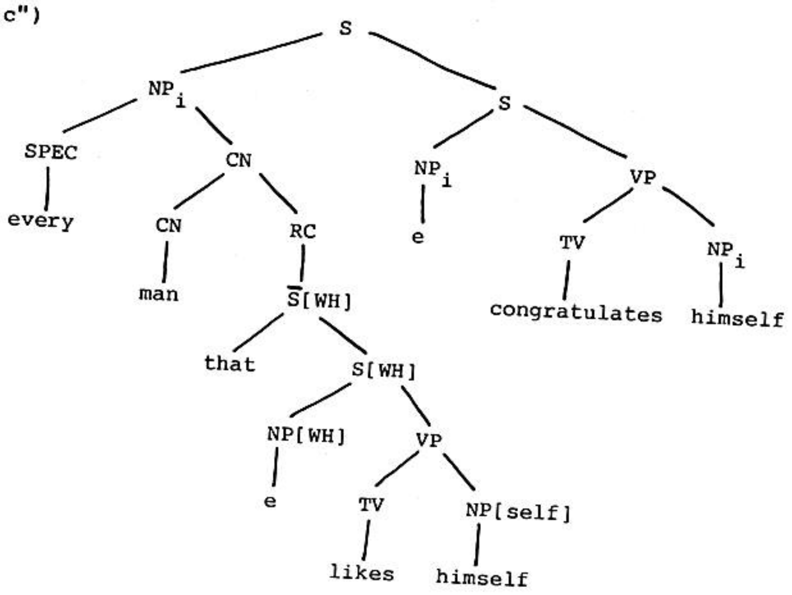
The fragment admits the following surface-structure for this example:

(c')



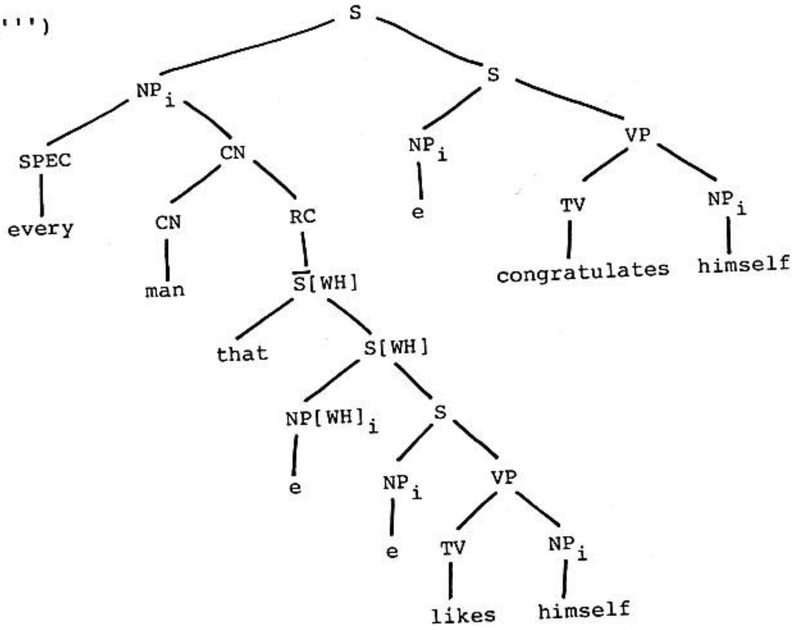
In this structure, {every man that likes himself, himself} is an ana-set. An application of ER_i to this ana-set gives the following result:

(c")



In this structure, the occurrence of *himself* in the relative clause has not yet been bound (or, syntactically, its feature [self] has not yet been replaced with an index). Note that {*e*[WH], himself} is an ana-set in the relative clause (in particular, since *e*[WH] has the gender feature [m], $\underline{e}_i$ and *himself* have the same gender feature). Apply ER to the ana-set {*e*[WH], himself} in the embedded S-structure. It does not make a difference whether the same or a different index is used; I will use the same index:

(c''')



Structure (c''') has no occurrences of [pro] or [self] on any node, so it is a final structure. Here is a detailed account of its translation.

The translation of [e_i congratulates himself$_i$] reduces to:

$$\text{CONGRATULATE}\ (x_i, x_i)$$

The translation of [e_i likes himself$_i$] reduces to:

$$\text{LIKE}\ (x_i, x_i).$$

The translation of [e[WH]$_i$ [e_i likes himself$_i$]] becomes (we suppose that the index-feature on the extracted WH-dummy does not influence the translation):

$$\lambda P[P(h)]\ (\lambda x_i[\text{LIKE}\ (x_i, x_i)])$$

This reduces to:

$$\mathrm{LIKE}(h,h)$$

The S-structure [that $[_S\ e[\mathrm{WH}]_i\ [e_i$ likes himself$_i$]]] has the same translation.

The translation of the relative clause becomes:

$$\lambda Q\ \lambda x\ [\lambda h[\mathrm{LIKE}(h,h)](x)\ \&\ Q(x)]$$

This reduces to:

$$\lambda Q \lambda x[\mathrm{LIKE}(x,x)\ \&\ Q(x)].$$

The translation of the complex CN is:

$$\lambda x[\mathrm{LIKE}(x,x)\ \&\ \mathrm{MAN}(x)]$$

The translation of the extracted subject NP:

$$\lambda Q[/\backslash y((\mathrm{LIKE}(y,y)\ \&\ \mathrm{MAN}(y))\ \text{->}\ Q(y)]$$

Finally, the translation of the whole expression becomes:

$$\backslash Q[/\backslash y((\mathrm{LIKE}(y,y)\ \&\ \mathrm{MAN}(y))\ \text{->}\ Q(y)](\lambda x_i[\mathrm{CONGRATULATE}(x_i,x_i)])$$

This reduces to:

$$/\backslash y((\mathrm{LIKE}(y,y)\ \&\ \mathrm{MAN}(y))\ \text{->}\ \mathrm{CONGRATULATE}(y,y))$$

which is the desired translation.

IV.3.5 Extending the Fragment

It is easy to extend the MG+ fragment: the incorporation of of the theory of plural NPs that was proposed in III.4.4 is rather straightforward. For ease of exposition the singular/plural distinction has been left out of the fragment, however.

Another possible extension, and one that is linguistically very interesting, is the incorporation of so-called raising and equi verbs. I will give a mere sketch. First, an example of a so-called subject-equi verb, and one of a so-called object-equi verb, will be added (I will take 'try' and 'persuade', respectively). I will also add an example of a so-called subject-to-object raising verb: 'believe (that S)'. Further, the syntactically and semantically interesting distinction between 'persuade' and 'promise' will be incorporated.

The following categories must be added: $\overline{VP}$ ('infinitive VP'); $VP/\overline{VP}$ for subject equi verbs, $TV/\overline{VP}$ for object equi verbs and for infinitive-complement 'believe', $VP/\overline{S}$ for that-complement 'believe'; $TV/\overline{S}$ for that-complement 'persuade', and $(VP/\overline{VP})/NP$ for infinitive-complement 'promise'.

$\overline{VP}$ translates to the same type as VP, and the other categories translate accordingly.

The translations in the lexical entries use extensional approximations: we are not primarily interested in intensions, but in ER's effects on the account of anaphoric constraints. Unlike in the traditional Montagovian treatment, the translations of the next lexical entries will not be <u>constants</u>, but logical expressions with a certain internal structure for <u>encoding</u> the control mechanism. (This 'lexicalist' approach to the control problem is not new; cf. e.g. Bartsch (1978).)

$\langle try,\ VP/\overline{VP},\ [\ ],\ \lambda P_{\langle e,t\rangle}\ \lambda x\ [TRY\ (x,P(x))]\ \rangle$

TRY is a constant of type $\langle t,\langle e,t\rangle\rangle$. Recall the convention: '$TRY(a,b)$' is shorthand for '$TRY(b)(a)$'.

$\langle \text{persuade}, \text{TV}/\overline{\text{VP}}, [\ ],$

$\lambda P_{\langle e,t\rangle}\ \lambda \mathbb{P}_{\langle\langle e,t\rangle,t\rangle}\ \lambda x[\ \mathbb{P}(\lambda y\ [\text{PERSUADE}(x,y,P(y))])]\quad \rangle$

PERSUADE is a constant of type $\langle t,\langle e,f(\text{VP})\rangle\rangle$
$= \langle t,\langle e,\langle e,t\rangle\rangle\rangle$.

$\langle \text{believe}, \text{TV}/\overline{\text{VP}}, [\ ], \lambda P\ \lambda \mathbb{P}\ \lambda x\ [\ \mathbb{P}(\lambda y\ [\text{BELIEVE}(x,P(y)])]\quad \rangle$

BELIEVE is a constant of type $\langle t,\langle e,t\rangle\rangle$

$\langle \text{persuade}, \text{TV}/\overline{\text{S}}, [\ ], \lambda p\ \lambda \mathbb{P}\ \lambda x\ [\ \mathbb{P}(\lambda y\ [\text{PERSUADE}(x,y,p)])]\quad \rangle$

PERSUADE is the same constant as above.

$\langle \text{believe}, \text{VP}/\overline{\text{S}}, [\ ], \lambda p\ \lambda x\ [\text{BELIEVE}(x,p)]\quad \rangle$

BELIEVE is the same constant as above.

Note how the implicit type lifting in the lexicon, as discussed in III.6, provides a neat account of the semantic connection between entries that differ only in their category-assignment.

$\langle \text{promise}, (\text{VP}/\overline{\text{VP}})/\text{NP}, \lambda \mathbb{P}\ \lambda P\ \lambda x[\ \mathbb{P}(\lambda y\ [\text{PROMISE}(x,y,P(x)])]\quad \rangle$

PROMISE is a constant of type $\langle t,\langle e,\langle e,t\rangle\rangle\rangle$.

$\langle \text{promise}, (\text{VP}/\overline{\text{S}})/\text{NP}, \lambda \mathbb{P}\ \lambda p\ \lambda x[\ \mathbb{P}(\lambda y\ [\text{PROMISE}(x,y,p)])]\quad \rangle$

PROMISE is the same constant as above.

The extension of the set of syntactic formation rules needed for the incorporation of the lexical entries listed above is obvious from the categorizations. Also needed is an operation of 'rightwrap' (used in Bach (1979,1980) and in Bach & Partee (1981); suggested already in Bennett (1974; 69)).

Rightwrap-transformation:

$[_{VP}\ [_{TV}\ TV/X\ \ X\ ]\ \ NP\ ]\ \ ==>\ [_{VP}\ TV/X\ \ NP\ \ X\ ]$

Here X may be any category.

Rightwrap is an obligatory transformation, needed in a categorial grammar if one wishes to allow 'discontinuous TV-phrases'. Linguistically, the recognition of discontinous TV-phrases as genuine TVs seems important for a neat account of passivization. (Operations similar to this wrapping transformation, although with a more restricted expressive power, are studied extensively in Pollard (1984), which concentrates on concatenation and 'head-wrapping' as an attractive syntactic framework for GPSG.)

It is not quite clear, by the way, that 'rightwrap' is essential for the syntax of control in VP complements. Objections to a 'discontinuous TV' analysis of verbs like *persuade* can be found in Bartsch (1978). Bartsch argues that especially in the case of German it is not the structure of the matrix verb but the context of use that fixes the control relations, and proposes not to handle these cases by making category distinctions. Instead, a categorial rule schema suitable for handling free word order is adopted, and a different account of passivization is provided.

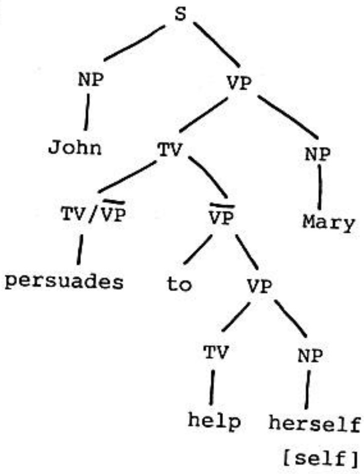
The issue of the need for rightwrap will not be pursued any further here, as passivization is no concern of mine. Still, interestingly, it turns out that the discontinuous TV-analysis plus the definition of c-command in terms of "pre-wrap syntactic structure" yields a bonus for the account of anaphoric constraints. Cf. the following examples.

(a) John persuades Mary to help herself

(b) *John promises Mary to help herself

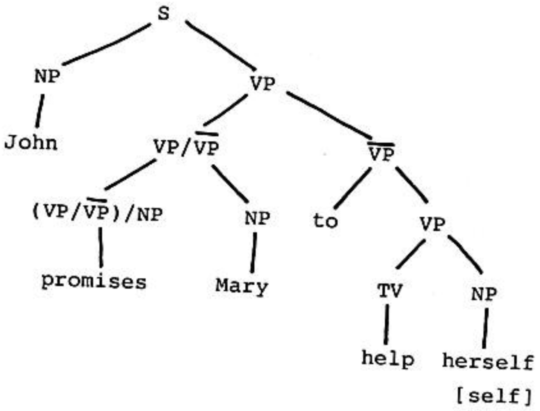
This acceptability-contrast is correctly predicted by the difference in pre-wrap syntactic structure:

(a')



In (a'), 'Mary' c-commands the reflexive 'herself'. There is no intervening S-node, and there is agreement in gender and number, so {Mary, herself} is an ana-set. ER can be applied to this ana-set, and a final structure of extended syntax results with the right interpretation, as the reader can verify.

(b')



In structure (b'), 'Mary' does not c-command the occurrence of the reflexive pronoun, and therefore {Mary, herself} is not an ana-set. There is no way to apply ER in such a manner that the feature [self] on the reflexive gets removed, so (b') does not give rise to a final structure of extended syntax.

Given a wrapped structure, there is always a unique way to unwrap it (the reason is that the grammar uses structural descriptions, not mere strings). This is important, for it seems that we must assume that ER, although it takes wrapped structures as its input, is sensitive to structural features of the unwrapped versions of these structures.

The reader is invited to check that examples like the following have the expected anaphoric possibilities, with the appropriate readings:

(c) John tries to kill himself.

(d) John believes Mary to despise herself.

(e) John believes Mary to despise him.

(f) John believes that Mary despises herself.

etc.

IV.3.6 Strength and Limitations of the MG+ Framework

Again it is easy to incorporate Robert May's theory of scope in the fragment. Give the NPs with specifier 'some', 'no', and 'every' the feature [+q], and, as before, all we have to do to get the predictions of May's theory is to add the Q-constraint, which in the framework of MG+ has the following form:

Q-constraint: NPs with feature [+q] must be extracted.

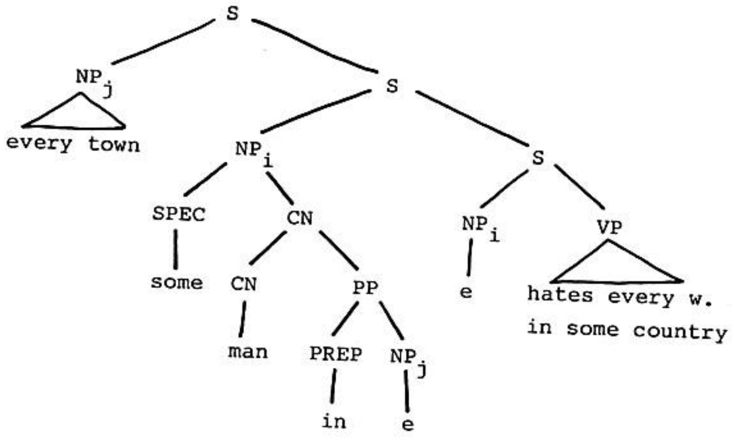
Consider again example (a) that is admitted by the fragment of MG+:

(a) Some man in every town hates every woman in some country.

The q-constraint forces us to extract the following NPs (they all have the feature [+q]): 'some man in every town', 'every town', 'every woman in some country', and 'some country'.

Now suppose that we start with the extraction of 'some man in every town', using index i. Next, we extract 'every town', with index j. The resulting structure is (a'):

(a')



Recall the condition on the extraction process by means of ER: the S-structure from which an NP is extracted must be the minimal S-structure that dominates the NP. Suppose therefore, that we perform the extraction process in the opposite order, first extracting 'every town', for index j, and then 'some man in e_j', for index i. Because of the condition that the extraction site be the minimal dominating S-node, the result is identical to (a'). (This example shows that we should be careful if we want to relax the requirement that 'quantification is clause-bounded'.)

In the interpretation of (a') the quantifier corresponding to the 'every' of 'every town' has scope over the quantifier corresponding to 'some' of 'some man in e'. The same reasoning applies to the quantifiers in the direct object: the 'some' of 'some country' turns out to have scope over the 'every' of 'every woman in e'. These results conform exactly to May's theory.

The constraint that quantification be clause-bounded has been built into the rule ER (condition (i) on ER), so, like in May's system, no NP can get scope beyond the minimal S-structure to which it belongs.

It should not be thought, however, that ER is nothing but a Montagovian reformulation of May's rule QR. ER is rather akin in spirit to a move-NP transformation like QR in a TGG-framework, but ER accomplishes a lot more than QR. ER can be used for everything that QR does; besides, ER accounts for the most important constraints on reflexivization, for all bound readings of pronouns, and for the most important constraints on bound anaphora (in terms of the notion of c-command). All these constraints have been built into the rule.

There is also a natural way to incorporate Kroch's constraints on scopes in the MG+ framework (cf. Kroch (1974,145-6) for an exact formulation of these). Kroch's constraints are formulated as constraints on possible permutations of logical operators in sentences, starting with the order of logical operators in surface structure, plus a set of filters to rule out certain scope-order results of these permutations.

Because a given final structure (of extended syntax) S' can always be traced back to a surface syntactic structure S that S' disambiguates (again, the reason is that the syntax uses structural descriptions instead of mere strings), the permutation p of operators (scope-bearing NPs) involved in the transition from S to S' is given. Using a well-known theorem that every permutation can be written - though not always uniquely - as a product of transpositions (interchanges of 'neighbours'), we can state the following:

> Permutation p is in accordance with Kroch's constraints iff
>
> (i) there is a sequence $\langle t_1, \ldots, t_m \rangle$ of operator-transpositions such that $t_1 \circ \ldots \circ t_m = p$, and each t_i is a transposition permitted by Kroch's constraints, and
>
> (ii) the final operator sequence resulting from p is permitted by Kroch's output filters.

Although the examples discussed above indicate that ER is quite a powerful device, ER does not give an account of all constraints on anaphora. In the first place, constraints on possible anaphoric links between full (i.e. non-pronominal) NPs forbidding the link indicated by the underlinings in (b), are not covered.

(b) *John likes John.

This is not a major flaw, however. In view of our discussion in II.4.1, it seems reasonable to suppose that the unacceptability of (b) can be accounted for by a pragmatic mechanism.

Not only full NPs pose problems, however. ER applies to ana-sets, and the antecedent in an ana-set always c-commands all other elements of the set. The semantics of ER uses variable-binding. Therefore, the account that ER gives of anaphoric links covers only the binding-links inside c-command domains.

In many cases, however, an anaphoric link is established between two NPs A and B, one of which is a pronoun, although neither c-commands the other (cf. the examples in I.2.4). We might try to modify ER so as to let it apply to ana-sets in a relaxed sense, in which the antecedent need not c-command its anaphors. This strategy will not do, for in many cases where there is an anaphoric link without c-command, the link is not a binding link. We are reminded of the conclusion we drew from chapter II: in addition to a bound-anaphora mechanism, we need a 'referential' anaphoric mechanism.

The rule ER that we have formulated fits most of the requirements that could reasonably be imposed on a bound-anaphora device. This mechanism must be supplemented with a refential anaphoric device that, unlike the bound-anaphora rule, is not confined to the sentence level. Anaphora theories that operate on the text level will be investigated in the next chapter.

Finally, let me briefly compare the MG+ framework with the proposals in Bach & Partee (1981). The extension that was sketched in IV.3.5 makes the MG+ fragment comparable in scope to the fragment presented there. The main differences are the following. The NP storage mechanism used by Bach & Partee is replaced with an LF-rule ER. The distinction between 'object-controlled' and 'subject-controlled' reflexives made by Bach & Partee has been avoided in my approach. My account of raising and equi phenomena makes use of 'lexical semantics'; this feature enables me to avoid the complexities of the 'subject-controlled' and 'object-controlled' dummy-NPs that Bach & Partee employ. Wherever Bach & Partee use INFS-structures with dummy-subjects that have an obligatory controller outside the structure, I assume a simple VP-complement, and I relegate the semantics of control to the lexicon.

Bach & Partee investigate the incorporation of VP-'deletion' phenomena in their framework. They arrive at the tentative conclusion that information about indices of free variables present in the translation of the VP serving as antecedent is indispensable for the account. Of course, the indexed structures of extended syntax in MG+ provide all the necessary information: and hence the conditions for felicitous deletion from Sag (1976) can be reformulated to fit the extended syntax of MG+. Our detailed account of the latter procedure has not been included here, for lack of space (but cf. V.4 below).

IV.4 Conclusion

In this chapter I have investigated possibilities for a synthesis between the frameworks of TGG and MG. The technique of NP-storage, the most widely discussed of the attempts at such a synthesis, has been reviewed in detail.

Next, I have attempted to demonstrate that a level of Logical Form (or Extended Syntax) can be added to Montague Grammar in a natural way, and that such an addition permits us to incorporate a number of important constraints regarding scopes, anaphora and reflexivization by the elegant method of capturing them in terms of (extended) syntactic structure.

CHAPTER V

LOGICAL FORM BEYOND THE SENTENCE LEVEL

V.0 Introduction

As we have seen in chapter IV, the binding mechanism that handles scopes and anaphora on the sentence level has to be supplemented by a second anaphora mechanism. Anaphoric links can cross sentence-boundaries. An obvious next move in the construction of an adequate syntax for English is the introduction of a cross-sentential anaphoric mechanism.

Two theories designed to handle inter-sentential anaphors that have outgrown the programmatic stage are those of Jaakko Hintikka and Hans Kamp (Cf. Hintikka (1979), Hintikka & Carlson (1979), and Kamp (1981)). In Van Benthem & Van Eijck (1981), a critical exposition of Hintikka's theory and a proposal for formalization of this theory have been offered. This formalization, which uses formal representations for Hintikka's semantic games, called 'H-trees', has been employed to compare the theories of Hintikka and Kamp, and it has been shown that there are many points of convergence. For details of the Hintikka-Kamp comparison I refer to this paper. As Kamp's theory is the more explicit one, it will be my point of departure in this chapter. My aim is to show how the theory can be extended and modified to fit the linguistic and logical requirements that we have come across in the previous chapters.

First the existing theories of discourse representation will be put in a proper perspective: in V.1 some general remarks will be made about the treatment of discourse phenomena, and about the extent to which existing theories are able to cope with these phenomena.

In V.2 Kamp's theory of Discourse Representation is introduced. Formal definitions of key notions are explained, and, if necessary, extended and modified. Rules for the construction of

Discourse Representation Structures (DRSs) will be proposed that make use of structural notions defined in IV.3 in connection with the MG+ fragment. It will be shown that the resulting theory is an extension of the theory of MG+ (it adds a referential anaphora mechanism to MG+), and at the same time an extension of the Kamp (1981) theory (it adds a bound-anaphora mechanism to the Kamp theory, it treats reflexives, and it handles wide scope readings).

In V.3, the status of the level of DRS-construction will be discussed, and central aspects of Kamp's truth definition will be elucidated. It is pointed out that that the semantics of the theory in Kamp (1981) is classical, in the sense that it is very closely connected with the semantics for first order predicate logic.

A sketch of a theory of VP- and S-anaphora in terms of DRS-construction will be provided in V.4: it turns out that DR-theory is eminently suited to handle phenomena that, in the EST of Transformational Generative Grammar, are taken care of by the Logical Form component. In V.5 the incorporation of the singular/plural distinction in DR-theory will be sketched.

V.1 The Formal Treatment of Discourse Phenomena

These days, interest in the analysis of discourse phenomena is growing rapidly. Most contributions to the subject are still on an informal level, however. To see that a full fledged formal theory of discourse is not yet available, let us briefly consider a list of topics that such a theory should cover.

In the first place, a formal theory of discourse should include an account of so-called discourse anaphora, like those exemplified in the following text.

(a) A man entered the shop. He asked for the manager. He ...

This first topic is the focus of interest in Kamp (1981). A very similar theory - indeed, the differences seem to be mainly terminological - is proposed in Heim (1982). The theories proposed in Hintikka (1979), Hintikka & Carlson (1979) also provide an account, while the theory of Barwise & Perry (1983) can be extended to cover these and similar cases of intersentential anaphora.

Note, however, that - roughly speaking, of course - each of these theories treats a sequence of sentences constituting a discourse as merely a long conjunction of sentences. The step from sentence analysis to discourse analysis is made in fact by adding an infinity of rules (one for every natural number n) to sentence syntax:

$$T \quad := \quad S_1 \quad \ldots. \quad S_n$$

$$0' \quad = \quad 1' \;\&\; \ldots. \;\&\; n'$$

It should be kept in mind that this is indeed a very modest step beyond sentence syntax.

A next topic that should be treated in a full fledged formal theory of discourse is the use of shifts in tense and aspect to structure a piece of discourse (cf. the topic of consecutio temporum in Latin school grammar). Consider the following example:

(b) Bill entered the shop. He asked for the manager, who had to be fetched from a bar nextdoor, and turned out to be dead drunk. Meanwhile, Bill had worked himself up to a rage...

It is clear that if the consecutio temporum in this text is to be taken into account, a semantic treatment as a mere conjunction is not adequate. An attempt to extend the formal theory of discourse representation to cover these tense/aspect phenomena on the text level can be found in Kamp & Rohrer (1983). (Cf. also Partee (1984) for discussion.)

A next step to be taken is the incorporation of an account of the 'pushing' and 'popping' of subject matter, a very salient characteristic of narrative structure. Such an extension presupposes a formal account of consecutio temporum, for shifts of tense and aspect are among the means employed to regulate the process of pushing and popping. Here is an example of the phenomenon that I have in mind:

(c) Suzan has been very ill for quite a while [...] Matters having been like this for some time, aunt Mary came over suddenly. She decided to stay in a place called [...] Now, these days, hotels are not what they used to be. [...] Just imagine: before the war, we once stayed in a magnificent place in Paris, and [...] Nowadays, such old-fashioned hospitality [...] Aunt Mary, however, did not complain at all. [...] Anyway, Suzan [...]

In this example the main story of the narrative structure is temporarily halted, and a substory is begun. Because the yarn of the main story is taken up again later, we may say that this story has been pushed to a return stack. The same thing happens to the substory about aunt Mary, and to the digression about modern hotels. The last-in, first-out ordering of the return stack reveals itself in the way in which these items pop up again later in the course of the narrative.

The narrative structure of this example could be schematized in 'mock programming language style' as follows:

```
(c') MAIN STORY "Suzan"
       PUSH MAIN STORY "Suzan"; SUB-STORY "Aunt Mary"
          PUSH SUB-STORY "Aunt Mary"; DIGRESSION "Modern hotels"
               PUSH DIGRESSION "Modern hotels"; ANECDOTE "In Paris"
          POP DIGRESSION "Modern hotels"
       POP SUB-STORY "Aunt Mary"
     POP MAIN STORY "Suzan"
```

The example and the schema are a bit misleading in several respects. In the first place, different narrative yarns may have equal status as story lines, so we would have to distinguish MAIN STORY 1, MAIN STORY 2, etc. Also, in actual discourse the process of pushing and popping usually takes place in a highly irregular way. (Indeed, some people's oral style would benefit greatly from a course in "goto-less narration", one feels.)

Nevertheless, an attempt at formalization of these popping and pushing phenomena should be made; this surely will give rise to interesting questions about the possible interconnection between the different components of the discourse structure: Which anaphoric cross-references are possible? What rôles do tense and aspect shifts play in the popping and pushing? Are there any discourse-elements that act as 'flags' to indicate that a move to a 'subroutine' occurs?

These rather vague and general remarks are all I have to contribute to this third aspect of discourse analysis. For some interesting proposals in this area, cf. Polanyi & Scha (1984). I mention the topic only to make clear that the 'discourse representation theory' that we will be concerned with here, is still in a rather early stage of development.

Also, the current theories of discourse are confined to the analysis of monologues. A further step is to blend formal work on question-answer analysis (cf. Groenendijk & Stokhof (1984) and the references given there) with formal theories of discourse representation in an account of the interaction between two or more agents engaged in a discourse of information-exchange.

V.2 Discourse Representation Theory

V.2.0 What is DR-theory?

The cornerstone of Hans Kamp's theory of Discourse Representation (cf. Kamp (1981)) is a formal method for constructing 'representations' for texts, i.e. for sequences of sentences, each of which is generated by a formal rule system of sentence syntax. The sentence syntax is 'minimal' in the sense that it does not account for scope-disambiguation and anaphoric links. Thus, in example (a), a link between antecedent and pronoun as indicated by the underlinings will only get established at the level of 'representation' construction.

(a) Bill likes a girl that admires him.

In this example, where the text consists of just one sentence, the construction of a representation may be considered as an enrichment of sentence syntax. Kamp calls the 'representations' at the text level provided by his theory 'Discourse Representation Structures' or 'DRSs'.

Presently, the theory is confined to the construction of DRSs for monologues, and it focusses on the resolution of anaphoric ambiguities on the across-sentential level. (I will restrict attention to the simplest version of the theory, in which tense/aspect is not yet taken into account.)

The discourse-account of anaphora may be extended to cover cases of donkey-pronouns, examples of which were mentioned in I.2.4. Indeed, Kamp hails the fact that his theory seems to provide a general account of both 'bound' and 'referential' anaphors as one of its major virtues (but cf. V.2.2 and V.4 below).

The key to the treatment of anaphora at DRS construction level is the introduction of a set of elements of discourse syntax called 'discourse referents' or 'reference markers'. The former tag has an unfortunate semantic taint, suggesting, wrongly, that the envisaged DRS-elements are entities in a model of some sort. Therefore, I will stick to the latter one. Reference markers are introduced by the rules of DRS-construction as they apply to NPs. Their rôle in the account of anaphora is simply this: whenever two NPs are to be interpreted as anaphorically linked, a statement that equates the relevant reference markers is added to the DRS. A careful formulation of the truth definition for DRSs takes care of the semantics.

An informal example may serve to make this general picture clear. A DRS for example (a), with the anaphoric link indicated by the underlinings, is (a'):

(a')

x y z

Bill likes a girl that admires him
x = Bill
x likes a girl that admires him
girl(y)
x likes y
y admires him
z = x
y admires z

In this simple case the DRS consists of a 'box' containing a set of reference markers (vid. {x,y,z}) and a set of statements in a language that is an extension of the language of the fragment of English for which the DRSs are constructed (because in these statements reference markers may occur instead of NPs, the equality sign may be used, and statements that combine a basic CN and a reference marker, like 'girl(y)', may occur).

It is important to note that the process of DRS-construction for sequences of sentences belonging to the fragment is completely specified in a set of DRS-construction rules. The start-instruction simply is: place the sequence of sentences you want to build a DRS for in a box, and start applying the DRS-construction rules to the first sentence in the sequence.

There is one and only one DRS-rule applying to the example-sentence 'Bill likes a girl that admires him'. In this sentence the proper name 'Bill' has syntactically largest scope, in the sense that the final syntactic construction step has been the combination of the proper name with the rest of the sentence. The DRS-construction recipe demands an application of the rule for proper names. This rule instructs you (1) to introduce a reference marker 'x' for the proper name 'Bill', and (2) to add the statements 'x = Bill' and 'x likes a girl that admires him' to the set of statements in the box. Next, apply DRS-construction rules to these new statements. 'x = Bill' is 'atomic', so no rule applies to it. What DRS-rule applies to 'x likes a girl that admires him' depends again on the NP that has syntactically largest scope. The reference marker 'x' not being a genuine NP, this is the NP 'a girl that admires him', and a DRS-rule for indefinite descriptions is applied. And so on, until all statements have been decomposed to atomic statements.

Of course, the application of the DRS-rules is not completely mechanical. As the construction of a DRS is supposed to fix anaphoric links, every time a pronoun is encountered in the construction process, there is a certain margin for arbitrary choice. E.g., the DRS (a') establishes a link between Bill and him, but a DRS in which him is linked to an appropriate NP in previous discourse is also possible. One only has to replace 'z' in the statement 'z = x' with the appropriate reference marker. In view of this latitude in the DRS-rules, one might say that a text (sequence of sentences) determines a set of DRSs; if one disregards the alphabetic variation caused by the choice of markers, the set of DRSs determined by a given text will be finite.

Deictic uses of pronouns are not covered in Kamp (1981), but they can easily be incorporated. They create more options for the interpretation of pronouns, and may of course cause the set of DRSs determined by a given text to become infinite.

Example (a) is an extremely simple case: its DRS consists of only one box. In general, DRSs may consist of several boxes, ordered by a relation of 'subordinance'. If then clauses and universal NPs give rise to 'DRS-splits': the introduction of subordinate pairs of boxes. The fragment of Kamp (1981) does not cover negation, but a rule for negation would also give rise to a DRS-split. Cf. the rules in V.2.2 for details.

Consider example (b) and DRS (b') for an illustration of a DRS consisting of several boxes:

(b) Every boy loves a girl

```
(b')  --------------------------------
     | Every boy loves a girl         |
      --------------------------------

      -------------    ---------------
     |     x       |  |     y         |
     |             |  |               |
     |  boy (x)    |  | x loves a girl|
     |             |  |  girl (y)     |
     |             |  |  x loves y    |
      -------------    ---------------
```

The construction rule that applies to the sentence in the main box of the DRS (sentence (b)) is the rule for NPs of the form 'every CN'. This rule gives rise to a DRS-split: a pair of boxes subordinate to the main box is introduced; a reference marker 'x' appears in the left subordinate box; 'boy(x)' is placed in this box, and 'x loves a girl' is placed in the right subordinate box. The next rule applies to the NP 'a girl' in 'x loves a girl', in exactly the same way as it applied to 'a girl' in example (a).

Sentence (a) is existential, whereas (b) is universal. This logical difference is accounted for in the truth definition for DRSs. The 'universal force' of DRS (b') is guaranteed by the DRS-interpretation rules. These rules ensure that a DRS-pair like the one in (b') is true in a model M iff every function that maps the markers occurring in its lefthand member to appropriate individuals in M can be extended to a function that fulfils the conditions imposed by the righthand member of the pair, i.e. it maps new markers to appropriate individuals in M, and it validates the atomic expressions occurring in the pair. A more precise formulation of this will be given in V.2.1.

The general framework of the theory is as follows:

(1)		(2)		(3)
Discourse formation	===>	Discourse Representation Structure (DRS) construction	===>	Interpretation in a model
↑		↑		↑
Sentence syntax		DRS construction rules		truthful embedding

The process of DRS-construction is implemented by a list of DRS-construction rules, the application of which transforms discourses into Discourse Representation Structures. The DRS-construction rules process a discourse sentence by sentence. If the discourse consists of sentences $S_1, \ldots, S_n$, then a DRS for sentences $S_1, \ldots, S_k$ ($k \leq n$) is constructed by applying DRS-rules to S_k that extend a "complete" DRS for $S_1, .., S_{k-1}$ into a "complete" DRS for $S_1, \ldots, S_k$.

Kamp (1981) gives five construction rules, one for proper names, one for indefinite NPs, one for pronouns, one for conditional expressions (syntactic constructions of the form "if .., then .. "), and one for universal expressions (expressions in which a universal NP is marked by its syntactic position as the element that the next construction rule must apply to). In V.2.2 I will propose revised formulations for these rules, and add some new ones as well. A further extension and revision will be given in V.5.

The DRS-construction rules introduce "reference markers", formal individuals that may serve as antecedents for bound and unbound pronouns alike. The rules disambiguate discourses as to anaphoric connections. Kamp's main reason for postponing the establishment of anaphoric links to the level of DRS-construction is his wish to cover intersentential anaphora in a unified account that also handles bound pronouns and 'donkey' pronouns.

V.2.1 Formal Definitions Modified and Extended

We now turn to the formal definitions of key concepts used in the Kamp (1981) framework. Most of these will be presented in a slightly modified and extended form.

First, a syntax for a simple fragment of English is presented. The language of this fragment is called L_o. The syntax of L_o resembles that of the mini-fragments in IV.1.1 and IV.3.2. I will not repeat the definition of L_o here. Suffice it to say that the set of basic lexical items of L_o consists of proper names, common nouns, intransitive verbs and transitive verbs, that the fragment contains non-indexed pronouns and rules for forming NPs of the forms 'every CN' and 'a CN', a rule for forming sentences of the form 'if A then B' and a rule for forming relative clauses.

At the next level Discourse Representation Structures (DRSs) are defined for strings of L_o-sentences. In the DRSs, <u>discourse referents</u> or <u>reference markers</u> are introduced; these figure as additional basic terms of the language of the fragment. V is the set of all reference markers. $L_o(X)$ is the language that results from adding the subset X of V to the set of basic terms of L_o. $L_o'(X)$ is the result of adding sentences of the form 'u=<u>a</u>' (where u is a reference marker in X and <u>a</u> is a proper name), 'u=v' (where u and v are reference markers in X), and 'B(u)' (where u is a reference marker in X and B is a common noun of L_o) to $L_o(X)$. Expressions of $L_o'(X)$ figure as building blocks in the DRSs.

At a final stage, a truth definition for complete DRSs is given, in terms of truthful embeddings for the reference markers occurring in the DRSs.

The fragment of Kamp (1981) does not include sentential or VP-negation. To incorporate these, I propose to extend the language L_o as follows. For every basic VP or TV <u>A</u> of L_o, add the VP or TV -<u>A</u> to the language. Further, add the relation sign '≠' to the language. Correct interpretations for the expressions in which these signs occur will be provided by the extended truth definition, to be given below.

If A is a basic VP or TV, I consider both A and -A as atomic predicates. Also, both '=' and '≠' are atomic predicates, in the sense that they may figure in the atomic formulas of $L_o(X)$'. Let At(X) denote the set of atomic formulas of $L_o(X)$', thus understood. The terms that occur in atomic formulas of $L_o(X)$' are either members of X or proper names. (The DRS construction rules will ensure that in a complete DRS a proper name a that figures in the discourse will occur in an expression 'x = a', where x is a member of X.)

An L_o-discourse is a string of sentences of L_o. A set of DRS-construction rules for L_o-discourses is a set of rules that decompose the L_o-sentences and build a DRS for a particular L_o-discourse, fixing anaphoric links in the process. A formal definition of DRSs will be given below. Intuitively, a DRS is a partially ordered set of DRs ("boxes"), where a DR is a pair consisting of a finite subset U of V and a finite set of sentences of L_o'(U). Some of the DRS-construction rules merely extend a given DR, other rules ('branching rules') introduce a new DRS-pair in "subordinate" position. A complete DRS for a discourse consisting of L_o-expressions is a DRS in which every DR is maximal (every DR-extending construction rule applicable to an expression in a DR has been applied, and every applicable branching rule has been applied once).

Here is one of Kamp's key examples of one-sentence discourses, and a DRS for that example:

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

```
(a') -----------------------------------------
    |                                         |
    | every farmer who owns a donkey beats it |
    |                                         |
     -----------------------------------------
     ------------------      ----------------
    |   u   v          |    |                |
    |                  |    |                |
    | farmer(u)        |    |   u beats it   |
    | u owns a donkey  |    |                |
    | donkey(v)        |    |                |
    | u owns v         |    |   u beats v    |
     ------------------      ----------------
```

(a') is a complete DRS according to Kamp's definition. Kamp calls the upper box the principal DR of the DRS. The bottom left and right boxes are DRs subordinate to the principal DR, and the bottom right DR is also subordinate to the bottom left DR.

If one strips Kamp's complete DRSs of all non-atomic expressions, the format of the 'stripped' DRs and DRSs can be defined in a simple way. Although the set of reference markers for a given DR in a DRS can be recovered from the members of V that occur in the formulas in the DRS, it is more perspicuous to keep them in. It is also convenient to include the set of reference markers of the superordinate boxes in every box.

This alternative format for DRSs is illustrated in (a"); a precise definition for it will be provided below.

```
(a") --------------------------------
    |                                |
     --------------------------------
     --------------    -------------
    |   u   v      |  | u   v       |
    |              |  |             |
    | farmer(u)    |  |             |
    | donkey(v)    |  | u beats v   |
    | u owns v     |  |             |
     --------------    -------------
```

For an illustration of the fact that the process of DRS-construction can reveal a connection in meaning between (anaphorically disambiguated) sentences, consider example (b).

(b) If a farmer owns a donkey, he beats it.

Kamp's DRS-construction rule for _if then_-constructions ensures that a DRS for (b) can be given that is identical to (a") or that is an alfabetic variant of (a").

DRSs that are alfabetic variants of each other may be regarded as _synonymous_ DRSs: it follows from the truth definition for DRSs (to be given below) that they will be true in the same models. The fact that there is a clear notion of _synonymy_ for DRSs means that it is possible, in principle, to define a notion of logical entailment on the DRS-level, and to develop a theory of reasoning in terms of DRSs.

Concerning the formal definitions of DRS-notions, to which we now turn, a general remark is in order. Although it is easy to grasp the principles that underly DRS-construction, it is tedious to provide a rigorous definition of the construction process. In this, DR-theory resembles methods for the construction of semantic tableaux (cf. e.g. Beth (1955)): to give the reader an idea of how the method works is much easier than to provide a formal definition. Nevertheless, formalization is particularly important in connection with DR-theory: the empirical claims concerning anaphora depend on formal properties of the structures to be defined.

Df. At(X) is the set of atomic formulas of $L_o'(X)$.

In fact this is not fully precise; the full syntactic characterization of 'atomic formula' is omitted here for convenience. All possible forms that atomic formulas can take are enumerated in the definition of _verification_ of an atomic formula (see below).

Df. If $B \subseteq At(X)$, then RM(B) is the set of reference markers occurring in B.

Next, we give a precise definition of the 'boxes'.

Df. $DR_{At(X)}$, the set of Discourse Representations for At(X), is the set of all pairs $\langle A_0, A_1\rangle$ such that A_1 is a finite subset of At(X), $A_0 \supseteq RM(A_1)$, and A_0 is finite.

Df. The <u>universe</u> of a DR $\langle A_0, A_1\rangle$ is its first component A_0.

My definition of DRSs will differ from Kamp's at several points: it is a definition of 'stripped' DRSs, and it takes the universe of any DR A to be included in the universes of the DRs B subordinate to A. The first modification makes it possible to work with atomic expressions instead of their occurrences. We will see below that the latter modification results in a considerable simplification of the truth definition.

Df. $DRS_{At(X)}$, the set of DRSs associated with the set At(X) of atomic formulas of $L_o'(X)$, is a set of triples $\langle A_0, A_1, A_2\rangle$, that is defined recursively as follows:

(1) $\langle A_0,A_1,A_2\rangle \in DRS_{At(X)}$, if $\langle A_0,A_1\rangle$ is a member of $DR_{At(X)}$, and A_2 is a finite set of pairs of members of $DRS_{At(X)}$ such that for every pair $\langle B,C\rangle \in A_2$ it holds that $A_0 \subseteq B_0 \subseteq C_0$;

(2) Nothing else is in $DRS_{At(X)}$.

Note that the most trivial case of a DRS is the triple $\langle \emptyset, \emptyset, \emptyset\rangle$. The case where $A_0 = \emptyset$ and $A_1 \neq \emptyset$ is excluded by the demand that A_0 include the set of reference markers of A_1 (cf. the definition of $DR_{At(X)}$). The case where $A_0 = A_1 = \emptyset \neq A_2$ may occur; similarly for the case where $A_2 = \emptyset$.

It is convenient to define proto-DRs and proto-DRSs as well:

Df. A proto-DR is like a DR, except for the fact that non-atomic formulas may occur in it.

Similarly for a proto-DRS. Sometimes I will tacitly extend definitions that apply to DRs and DRSs to proto-DRs and proto-DRSs.

In the next definition, we need to distinguish between different occurrences of the same DRS. Suppose that for any given DRS A an enumeration is fixed of the members of A_2. The definition employs these enumerations.

Df. SUB(A), the set of occurrences of sub-DRSs in a DRS A, is recursively defined as follows:

(1) $\langle A,0\rangle$ is a member of SUB(A);

(2) if $\langle B,C\rangle \in A_2$, and $\langle B,C\rangle$ occupies position m in the enumeration of the members of A_2, then:
for any member $\langle D,n\rangle$ of SUB(B), $\langle D,n+2m+1\rangle$ is a member of SUB(A), and for any member $\langle E,k\rangle$ of SUB(C), $\langle E,k+2m+1\rangle$ is a member of SUB(A);

(3) Nothing else is in SUB(A).

Df. The relation of *immediate superordinance* between two DRS-occurrences $\langle B,m\rangle$ and $\langle B',n\rangle \in$ SUB(A) (notation: $\langle B,m\rangle$ S $\langle B',n\rangle$) holds iff $\langle B',C\rangle \in B_2$, for some C such that $\langle C,n+1\rangle \in$ SUB(A), or $n = m+1$ and $\bigvee$ $\langle C,k\rangle$ $\in$ SUB(A) such that $\langle B,B'\rangle \in C_2$.

It follows from this definition that every member of SUB(A) - $\{\langle A,0\rangle\}$ has a *unique* immediately superordinate DRS-occurence in SUB(A).

Df. For any DRS $A = \langle A_0, A_1, A_2\rangle$, pr(A), the *principal* DR of A, is the pair $\langle A_0,A_1\rangle$.

Df. For any DRS A, DR(A), the *set of DR-occurrences* in a DRS A, is the set $\{ \langle pr(B),n \rangle \mid \langle B,n \rangle \in SUB(A) \}$.

The relation of immediate superondinance can also be defined between members of DR(A):

Df. The relation of *immediate DR-superordinance* between two DR-occurrences $\langle\langle B_0,B_1\rangle,m\rangle$, $\langle\langle B'_0,B'_1\rangle,n\rangle \in DR(A)$ (notation: $\langle\langle B_0,B_1\rangle,m\rangle \; \underline{S} \; \langle\langle B'_0,B'_1\rangle,n\rangle$) holds iff $\langle B,m\rangle \; S \; \langle B',n\rangle$.

Again, any member of DR(A) - $\{\langle pr(A),0\rangle\}$ has a unique DR-occurrence in DR(A) that is its immediate superordinate.

Next, we define the relations of superordinance and DR-superordinance S^* and $\underline{S}^*$:

Df. S^* is the transitive closure of S.

Df. $\underline{S}^*$ is the transitive closure of $\underline{S}$.

Basically, $\underline{S}^*$ is the converse of Kamp's relation of subordinance; for any DRS A, $\underline{S}^*$ partially orders DR(A) and S^* is a partial ordering of SUB(A).

Next, we turn to matters of interpretation.

Df. A *DRS-model* for the language L_o is a pair $\langle E,F\rangle$, where E is a non-empty set (the domain of individuals of M), and F is an interpretation function that assigns an element of E to each proper name of L_o, a subset of E to each basic CN or basic IV of L_o, and a subset of E x E to each basic TV of L_o.

We define truthful embeddings for DRSs:

Df. f is a truthful embedding for DRS A $\in$ $\text{DRS}_{At(X)}$, in model M (= <E,F>) if

(1) Dom(f) = A_0;

(2) for all $\phi \in A_1$: f verifies ϕ in M;

(3) for all <B,C> $\in A_2$: for every g $\supseteq$ f with dom(g) = B_0 that truthfully embeds B, there is an h $\supseteq$ g with dom(h) = C_0 that truthfully embeds C.

Notice the recursion in this definition, following that for DRSs themselves.

The definition of truthful embedding employs the notion of verification of an atomic expression. Its definition employs the stipulations that are to be expected in a Tarski-style approach to semantics:

Df. f verifies a member ϕ of At(X) in model M = <E,F> (we may presuppose that f is a finite function with domain $\subseteq$ X and range $\subseteq$ E that is defined for the reference markers, say x,y, occurring in ϕ):

Suppose ϕ has the form 'x=y': f verifies ϕ in M iff f(x) = f(y).

Suppose ϕ has the form 'x$\neq$y': f verifies ϕ in M iff f(x) $\neq$ f(y).

Suppose a is a proper name, and ϕ has the form 'x = a': f verifies ϕ in M iff f(x) = F(a).

Suppose A is a basic common noun and ϕ has the form 'x A': f verifies ϕ in M iff f(x) $\in$ F(A).

Suppose A is a basic IV, and ϕ has the form 'x A':
f verifies ϕ in M iff $f(x) \in F(A)$.

Suppose A is a basic IV, and ϕ has the form 'x -A':
f verifies ϕ in M iff $f(x) \notin F(A)$.

Suppose A is a basic TV, and ϕ has the form 'x A y':
f verifies ϕ in M iff $\langle f(x),f(y)\rangle \in F(A)$.

Suppose A is a basic TV, and ϕ has the form 'x -A y':
f verifies ϕ in M iff $\langle f(x),f(y)\rangle \notin F(A)$.

All atomic formulas of $L_o'(X)$ have one of the above forms, so this completes the definition of "f verifies ϕ in M".

Df. DRS A $\in$ $DRS_{At(X)}$ is true in M iff A has a truthful embedding in M.

This is a somewhat streamlined version of the "truthful embeddings" in Kamp (1981).

Finally, we can define DRS-interpretations:

Df. The interpretation of DRS A in model M = $\langle E,F\rangle$ is the set $[\![A]\!]_M$ of truthful embeddings of A in M.

The interpretation for a DRS in a model $\langle E,F\rangle$ is a set of finite functions with domain $\subseteq$ V and range $\subseteq$ E. The interpretation of a DRS that is not true in M is the empty set. If the interpretation of a DRS is not empty, then every member of it represents one way of embedding the DRS in the model under consideration.

V.2.2 DRS Construction Rules

Before I present my version of the DRS-construction rules, a remark should be made about Kamp's claim of providing a 'unified account of anaphora'. While it is certainly true that the DRS-construction level is rich enough to account for both bound and referential anaphors, I will argue that some substantial differences in treatment should remain. The need for this is obscured by the fact that the fragment presented in Kamp (1981) does not cover reflexives (for which an interpretation as bound anaphors is *de rigueur*), and does not have a device for 'VP-deletion'. As we have seen, the interpretation of VP-deletion cases provides a test for the distinction between bound and referential anaphors (cf. II.4.1).

Reflexive pronouns will be incorporated in the theory, and the bound/referential distinction will be made, as follows. I start with the bound-anaphora mechanism at sentence level which was proposed in IV.3 (with some small modifications). Then, the DRS-construction-rule for 'referential' pronouns (i.e. pronouns that do not have an antecedent that acts as a binder at sentence-level) will supplement the anaphoric links for 'discourse anaphora' (including donkey-anaphora). Thus, the DRS-level provides the referential-anaphora mechanism that we need.

In V.4 a DRS-account of VP-deletion (or rather: VP-anaphora) and S-anaphora will be sketched, and it will be shown how this account links up with the bound/referential anaphora distinction.

The Kamp framework must also be extended to cover scope ambiguity of logical operators. Scope-handling in a DRS-framework can be accomplished by a suitable relaxation of the DRS-construction rules (cf. Van Eijck (1984); this paper also provides details about incorporating a 'branching quantification' mechanism in DR-theory). Here, I will rather use the syntactic notions from IV.3.3, defining the DRS-rules for structures of MG+ in the sense of IV.3.3. Of course, the effect of ER may also be incorporated directly in the DRS-construction rules. The present approach has the advantage that it illustrates how the DRS-structures are an *extension* of the Logical Forms at the sentence level (i.e how DRSs are Logical Forms at the discourse level).

Like Kamp, we start with a very simple sentence syntax: the syntax defined in IV.3.2, with some extra rules added for purposes of illustration. FR1 - FR8 are as in IV.3.2, but without their semantic components. Kamp's <u>if then</u>-clauses may be incorporated by adding the following rule:

FR9 S := <u>if</u> S <u>then</u> S

Of course, a semantic component need not be specified: the DRS-construction rules that we are about to define (plus the definition of DRS-interpretation) take over this function.

It is also interesting to incorporate negation in the fragment. Add the following rule:

FR10 S := <u>it</u> <u>is</u> <u>not</u> <u>the</u> <u>case</u> <u>that</u> S

This rule is clumsy, but it will do for purposes of illustration.

Finally, we add rules for sentence-conjunction and sentence-disjunction:

FR11 S := S <u>and</u> S

FR12 S := S <u>or</u> S

The syntax adopted generates structured expressions. In order to incorporate reflexives and wide scope readings, we add the rule ER from IV.3.3 (again, without its semantic component) and assume that DRSs are constructed for structures of MG+ (Logical Forms). Thus, wide scope readings and control of reflexives are accounted for on the level of sentence syntax.

It would be unreasonable to demand that <u>all</u> pronouns be indexed (by applications of ER). The DRS-construction rule that applies to pronouns can account for referential anaphoric links of these pronouns to appropriate antecedents. Bound pronouns are pronouns that have been indexed by an application of ER. These indexed pronouns are taken care of by the DRS-construction rules that apply to their antecedents (cf. the formulations of the rules below).

All reflexives are obligatorily bound at sentence level. This is achieved by letting the input for the DRS-construction rules consist of MG+ structures in which all occurrences of reflexives are indexed (recall that an index-feature on a reflexive signifies that an application of ER has provided them with an antecedent).

Df. Call MG+ S-structures in which all occurrences of reflexives are indexed *appropriate* S-structures of MG+.

Thus, the set of *appropriate* S-structures properly contains the set of *final* S-structures. We will define DRS-construction rules for strings of *appropriate* S-structures of MG+. Note that this is a considerable departure from Kamp (1981), whose sentence-syntax does not establish anaphoric links or wide scopes at all.

Following Kamp, we must define an extended language that admits occurrences of reference markers in NP-positions in sentences of the fragment, statements of the form 'a = x', where *a* is a proper name, and statements of the form 'CN(x)'. We will use this extended language for building DRSs. A minor divergence from Kamp is that we define DRS-rules for structural descriptions, not plain strings. The expressions of the extended language occurring in the DRSs will all be structural descriptions with S as top-node (outermost label). (Think of 'CN(x)' and 'a=x' as '[$_S$ CH(x)]' and '[$_S$ a=x]', respectively.) In referring to these structural descriptions in the DRS-construction rules below, labels and brackets will generally be sacrificed to ease of presentation.

We are now ready to formulate the DRS-rules for sequences of *appropriate* S-structures of the fragment specified above (suitably extended to incorporate reference markers and the statements in which these occur). Kamp's formulation of the DRS-rules ensures that only one such rule will be applicable to any given expression in a DRS. E.g., a sentence with a universal NP as *outermost constituent* will be decomposed by the rule CR(*every*), and only such sentences can be taken care of by this rule. Because wide scopes are accounted for by ER at the level of (extended) sentence syntax, we can remain faithful to this principle. (Alternatively, we might have effected scope reversals by relaxing Kamp's principle somewhat, letting CR(<u>every</u>) apply to any expression containing a universal NP (syntactic restrictions aside).)

The structural descriptions occurring in the DRSs can be distinguished as follows.

Df. Provided that the top node of E does not immediately dominate a reference marker, the <u>nature</u> of expression E is determined by its top branch. In this case the top branch characterizes an expression as a negative sentence, an <u>if then</u>-sentence, a sentence-conjunction, a sentence-disjunction, a proper-name-sentence, an <u>every</u>-sentence, an <u>a/some</u>-sentence, etc. If the top node immediately dominates a reference marker 'z', the nature of E is that of the c-command domain of 'z'.

Which CR is to be applied to an expression will depend on its nature, as specified here. The reason for the exception in the above definition is that CRs have been applied already to the syntactic positions of the reference markers.

Some examples may make this clear:

- $[_S$ if S then S $]$ is an <u>if-then</u> sentence, and CR(<u>if</u>) has to be applied to it;
- $[_S\ [_{NP}$ every CN $]\ [_{VP}$ loves a woman $]]$ is an <u>every</u> sentence, and CR(<u>every</u>) has to be applied to it;
- $[_S$ x $[_{VP}$ [loves] [a woman] $]]$ is an <u>a</u>-sentence (for the reference marker 'x' immediately dominated by 'S' is disregarded); and CR(<u>a</u>) has to be applied to it.

Suppose that we are in the process of building a DRS; i.e we have a proto-DRS $\langle A_0, A_1, A_2 \rangle$, and sentence S occurs in A_1. An approprate CR from the list to be given below must be applied to

S. The CR-applications engender a decomposition of the sentences to which they are applied, as specified in the rules below. The application of suitable CRs will gradually remove all non-atomic expressions from the proto-DRS, and the result is a DRS in the sense of V.2.1.

We first give the list of Construction Rules for expressions with an 'NP-nature': these construction rules will remove an NP-occurrence from the expressions they apply to. There are two cases: the NP-occurrence immediately c-commands an S-structure (in this case ER has been applied to it), or the NP-occurrence does not immediately c-command an S-structure (ER has not been applied to it). For convenience, we refer to both kinds of expressions as S([NP]).

Thus S([a girl]) specifies a certain *form* of S-expression. The S-expressions $[_S$ x loves a girl] and $[_S$ [a girl]$_i$ [e$_i$ admires herself$_i$]] both are of this form. The S-expression $[_S$ if $[_S$a girl smiles], then $[_S$ John blushes]] is not. The reason: the latter expression is an *if-then*-expression, not an *a*-expression, and the CR that applies to it does not process the occurrence of '[a girl]'.

In a context where 'S([NP])' has been mentioned, I will use 'S([u])' for the result of substituting reference marker 'u' for the occurrence of 'NP' that determines the nature of the expression, in case NP does not immediately dominate an S-structure, and for the result of (1) removing the relevant occurrence of 'NP' and the S-node that dominates it, and (2) substituting 'u' for every pronoun and/or reflexive that has the same index as this NP-occurrence, otherwise.

Some examples:

- Suppose '$[_S$ x loves a girl]' has been mentioned. This expression is of the form 'S([a girl])'.
  Now 'S([u])' is: $[_S$ x loves u].

- Let S([every girl]) be:
  $[_S$ $[_{NP}$ every girl]$_i$ $[_S$ e$_i$ admires herself$_i$]]
  Then 'S([u])' is: $[_S$ u $[_{VP}$ admires u]].

One more general remark. In view of the decision in V.2.1 to let the universes of the DRs ('boxes') be 'inherited' in all subordinate DRs ('boxes'), the instruction "add a reference marker to the universe of DR A" must everywhere in the following rule be read as: "add a reference marker to the universe of A <u>and to the universes of all DRs subordinate to A</u>".

We start with the rule for proper-name-sentences, i.e. the CR that applies to sentences of the form S([PN]). Using the conventions above, it can be stated as follows:

CR(<u>PN</u>): Remove 'S([PN])' from the member A_1 of the proto-DRS A in which it occurs, select a reference marker u that does not occur in A_0, add the marker u to the universe of the principal DR of the proto-DRS, add 'PN = u' to the set of expressions of the principal DR, and add 'S([u])' to A_1.

This rule is basically as in Kamp (1981), to which the reader is referred for a motivation.

We turn to the rule for <u>every</u>-phrases. This rule will apply to sentences of the form S($[_{NP}$ every $[_{CN}$ X that Y]]). We let 'Y([u])' be the result of substituting 'u' for the relevant [+WH] trace and for pronouns and reflexives bearing the same index as that [+WH] trace (with the same convention as above) in sentence 'Y'. (In case the relative clause is absent, no 'Y([u])' will be introduced.)

CR(<u>every</u>): Remove 'S([every [X that Y]])' from the member A_1 of the proto-DRS A in which it occurs, select a reference marker u that does not occur in A_0, and add a pair <B,C> to A_2, where B = $\langle A_0 \cup \{u\}, \{X(u), Y([u])\}, \emptyset\rangle$, and C = $\langle A_0 \cup \{u\}, \{S([u])\}, \emptyset\rangle$.

The DRS-construction rule for some/a-expressions:

CR(some/a): Remove 'S([some/a [X that Y]])' from the set A_1 of the proto-DRS A in which it occurs, select a new reference marker u, add the reference marker u to A_0, and add the expressions 'X(u)', 'Y([u])', and 'S([u])' to A_1.

CR(no) will be given below, after the rule for sentence negation CR(NEG) has been given, for this rule is a combination of CR(NEG) and CR(some/a).

CR(the), the rule for definite descriptions, calls for a modification of the DRS-format. Moreover, several uses of definite descriptions should (and can) be distinguished. The reader is referred to Van Eijck (1984) for details. (Cf. also V.5.)

We turn to the DRS-construction rule for pronominal sentences. Let 'S([pro])' denote a sentence in which a pronoun-occurrence is in outermost position.

CR(pro): Remove 'S([pro])' from the set A_1 in the proto-DRS A in which it occurs, select a new reference marker u, find a suitable reference marker x from A_0, add the reference marker u to A_0, and add the expressions 'S([u])' and 'u=x' to A_1.

The expression 'u=x' establishes an anaphoric link with the NP that is represented by reference marker 'x' (i.e.: the NP that has given rise to the introduction of 'x' in the DRS). Note that the anaphoric links that are established by CR(pro) are different from the anaphoric links resulting from the fact that an antecedent-NP and its anaphoric pronouns (and/or reflexives) were members of an ana-set with the same indices. In the former case the antecedent and the anaphor are represented by different referent markers (and these markers are linked by an identity statement); in the latter case the antecedent and the anaphor are represented by the same marker. In V.4 this difference will be exploited in an account of VP-anaphora.

Note that there is no separate DRS-construction rule for reflexive pronouns. Reflexives are obligatorily bound, so they are replaced by reference markers during application of the CR for their antecedents.

CR(pro) must still be extended to accommodate 'deictic' pronouns. Roughly, what is needed is an 'anchoring' of deictic pronouns in the world (in the model). The concept of 'anchoring' was developed by Barwise & Perry (cf. Barwise & Perry (1983)), but it suits DR-theory very well. In the context of DR-theory, an anchor can be taken to be a (finite) partial function from the set of reference markers to the set of individuals in the model. Let f_0 be such an anchor. To construct an anchored DRS A, proceed as before, only start out with $\mathrm{dom}(f_0)$ as the universe of the principal DR of A. Deictic pronouns are handled now by letting CR(pro) link them to a reference marker from the set $\mathrm{dom}(f_0)$.

Here is the rule for negation:

CR(NEG): Remove '[it is not the case that ϕ]' from the set A_1 of the proto-DRS A in which it occurs. Select a reference marker u that does not occur in A_0. Add the DRS-pair $\langle B,C\rangle$ to A_2, where $B = \langle A_0, \{\phi\}, \emptyset\rangle$ and $C = \langle A_0 \cup \{u\}, \{u \neq u\}, \emptyset\rangle$

Thus, a trick has been used to fit the treatment of negation into the DRS-format as defined in V.2.1. '$\neg\phi$' is paraphrased as: '$(\phi \rightarrow \bot)$', where '$\bot$' denotes an expression that is false in any situation (the Falsum). The rôle of the Falsum in this rule for negation is played by '$u \neq u$'.

In the box-representations of DRSs it will be convenient to abbreviate a DRS-pair $\langle B,C\rangle$ resulting from an application of the construction rule for negation as NEG(B), where NEG(B) is the DRS B marked with a sign for negation. To give an example: we take DRS (a) to be an abbreviation for DRS-pair (b).

```
(a)   -----------------
     |NEG x  y  z      |
     |                 |
     |    xRy          |
     |    ySz          |
      -----------------
```

```
(b)   ----------------     ---------------
     |   x  y  z      |   | x  y  z  u    |
     |                |   |               |
     |    xRy         |   |    u≠u        |
     |    ySz         |   |               |
      ----------------     ---------------
```

The rule for *no*-sentences uses the same idea:

CR(*no*): Remove 'S([no [X that Y]])' from the set A_1 of the proto-DRS A in which it occurs, select two new reference markers *u* and *v*, and add the pair ‹B,C› to A_2,
where B = ‹A_0 U {u}, {X(u),Y([u]),S([u])}, ∅›, and
C = ‹A_0 U {u,v}, {u≠u}, ∅›.

The result can again be abbreviated with a NEG-DRS:

```
(c)   -----------------
     | ~~no woman walks~~  |
      -----------------
      -----------------
     | NEG     x       |
     |                 |
     |  woman (x)      |
     |  walk (x)       |
      -----------------
```

Next, we turn to the rule for *and*:

CR(<u>and</u>): Remove '[$_S$ S_1 <u>and</u> S_2]' from the set A_1 of the proto-DRS A in which it occurs and replace it by the elements 'S_1' and 'S_2'.

As it stands, CR(<u>and</u>) is not quite right. Consider the following examples:

(d) A girl smiled and she was happy.

(e) She was happy and a girl smiled.

These sentences have different anaphoric possibilities, one feels: in (d) an anaphoric link is possible, in (e) this is not the case. Recall that, according to the theory of sentence syntax that we have adopted, an anaphoric link between two NPs neither of which c-commands the other cannot be established at the sentence level: ER cannot be used to establish a binding link between the two NPs.

The difference in anaphoric possibilities must therefore be accounted for on the DRS-level, but it is clear that rule CR(<u>and</u>) obliterates the structural distinction between the two examples.

It seems that, in order to get the right anaphoric predictions, conjoined sentences must be decomposed in left-right order (Hintikka & Carlson (1979) call this the 'Progression Principle'). This principle can be implemented by modifying the rule as follows: only S_1 is added to A_1, and S_2 is made the first member of the sequence of sentences that constitutes the part of discourse still to be processed.

The DRS-construction-rule for <u>if then</u>-sentences:

CR(<u>if</u>): Remove '[$_S$ if S1, then S2]' from the member A_1 of the proto-DRS A in which it occurs, and add <B,C> to A_2, where B = $\langle A_0, \{S_1\}, \emptyset\rangle$ and C = $\langle A_0, \{S_2\}, \emptyset\rangle$.

Given this rule and the rule for negation, the rule for <u>or</u>-sentences can employ the paraphrase of [$_S$ S_1 <u>or</u> S_2] as: [$_S$ <u>if</u>

not S_1, *then* S_2] :

CR(*or*): Remove '$[_S$ S_1 *or* S_2]' from the set A_1 of the proto-DRS A in which it occurs. Put $\langle B,C \rangle$ in A_2, where B = $\langle A_0$,{$[_S$*it is not the case that* S1]},$\emptyset\rangle$, and C = $\langle A_0$,{S2},$\emptyset\rangle$.

Incidentally, there is a problem with disjunction in the DR-framework. Consider sentence (f):

(f) Either John doesn't own *a car* or he washes *it*.

The problem with our formulation of the DRS-rule for disjunction is that the reference marker introduced for the pronoun *it* cannot get linked to the reference marker introduced for *a car*. The reason is this. The pronoun must get linked to a reference marker that already occurs in the universe of the DR in which it gets processed. But the reference marker for *a car* will make its first appearance in a box that is *not* identical or superordinate to the box in which *it* gets processed. A proto-DRS for (f) would be (g):

(g)
```
        ---------------------------
       |      x                    |
       |                           |
       |   x = John                |
        ---------------------------
  ----------------       ------------------
 |     x          |     |        x         |
 |                |     |                  |
 |                |     |   x washes it    |
  ----------------       ------------------
  ----------------
 |NEG   x         |
  ----------------
  ----------------
 |NEG             |
 |     x   y      |
 |                |
 | car (y)        |
 | x owns y       |
  ----------------
```

The appropriate reference marker for <u>it</u> is 'y', but this marker is not accessible, for it is not in the universe of the box where <u>it</u> is processed.

In this particular case the solution is obvious: a DRS with the same truth conditions but without the anaphora-problem would be the following:

```
(h)   -------------------------
     |          x               |
     |                          |
     |       x = John           |
      -------------------------
  -------------       ---------------
 | x    y      |     |  x     y      |
 |             |     |               |
 | car (y)     |     | ~~x washes it~~ |
 | x owns y    |     | x washes y    |
  -------------       ---------------
```

In order to get this DRS, the rule for disjunction must be restated. Stipulate that in case 'S_1' is a sentence of the form 'NEG(S_k)' (i.e. if the next rule that would have been applied to S_1 would have been the rule for negation), then '$[_S$ <u>it</u> <u>is</u> <u>not</u> <u>the</u> <u>case</u> <u>that</u> $S_1]$' = 'NEG(NEG(S_k))' = 'S_k'.

This concludes the list of construction rules for DRSs, for the time being. In V.5 the rules will be reconsidered.

From the recursive definition of 'interpretation' for DRSs in V.2.2 it follows that DR-theory is compositional in the sense that the interpretation of a DRS is defined recursively in terms of the interpretations of its parts. Any recursive truth-definition implicitly uses a form of composition. Kamp (1981) provides a recursive definition of truth, so there is absolutely no need to worry about compositionality in the DRS-framework. Still, it is instructive to be explicit about the <u>way</u> in which a DRS is composed out of "parts" that determine its interpretation.

I will take the parts of a DRS $A = \langle A_0, A_1, A_2\rangle$ to be a set of 'atomic' DRSs plus a set of DRS-pairs. The members of the DRS-pairs need not be atomic: they may in turn consist of several components each. Nothing is wrong with this, for the DRSs that occur inside a component of a DRS A will be less complex than A. (Essentially the same phenomenon can be observed in the recursive definition of the DRSs themselves.)

Df. COMP(A), the set of <u>components</u> of an DRS $A = \langle A_0, A_1, A_2\rangle$, is the set: $\{\langle A_0, \{\phi\}, \emptyset\rangle \mid \phi \text{ is a member of } A_1\} \cup A_2$.

Note that for any DRS A, COMP(A) is finite.

Now the interpretation of a DRS is a function of the interpretations of its components; i.e. DR-theory satisfies the principle of compositionality. This proposition is nothing but a restatement of the truth-definition in terms that elucidate the underlying compositionality principle:

<u>Proposition 1</u>: For any DRS A, and any model M,

$$\begin{aligned}[\![A]\!]_M = {} & \bigcap\{[\![D]\!]_M \mid D \in \text{COMP(A) and D is a DRS}\} \\ & \cap \bigcap\{f \mid \langle B,C\rangle \in \text{COMP}(A)\ \&\ \text{dom}(f) = A_0\ \& \\ & \qquad /\backslash g \supseteq f\ (g \in [\![B]\!]_M \to \backslash/ h \supseteq g\text{: } h \in [\![C]\!]_M)\}\end{aligned}$$

Next, when DRSs are considered as expressions of a logical language, the expressive power of the latter is exactly the same as that of the first order predicate logical language PL with individual variables, individual constants, unary and binary predicate symbols, and the binary predicate '='. It should be noted that this result does not imply that the theory has been weighed and found wanting, or something of the kind. Rather, it puts the DRSs in a proper perspective: DRSs are simply not intended as expressions of a logical language that in any sense 'rivals' predicate logic (or EL or IL, for that matter). DRSs are part of a disambiguation device at the text level, just like the expressions of extended syntax in MG+ are a disambiguation device at the sentence level.

We proceed in two steps. First, we show how DRSs for PL-formulas are to be constructed; next, we give a translation mechanism from DRSs to PL-formulas.

Proposition 2: For every formula χ of PL there exists a DRS A such that A can be truthfully embedded in a model M iff χ is satisfiable in M.

Proof: We may suppose that the set of reference markers V coincides with the set of individual variables of PL. (Otherwise, fix a bijection.) A DRS for the language PL is like a DRS for the language $L_0'(X)$, except for the fact that "atomic formula of $L_0'(X)$ " is replaced everywhere in the definitions by "atomic formula of PL".

We define DRS-construction rules for PL-formulas. Let χ be an PL-formula. Let χ^* be an equivalent PL-formula in '&', '$\neg$' and '/\'.

The construction process for the DRS A that corresponds to χ^* is as follows. Construct the proto-DRS A = $\langle A_0, \{\chi^*\}, \emptyset \rangle$, where A_0 consists of the set of all variables (= reference markers) that have a free occurrence in χ^*. Apply the following DRS-construction rules to A:

CR(&): Suppose PL-formula ζ of the form ϕ & ψ occurs in the second member B_1 of the proto-sub-DRS B of the proto-DRS A. Remove ζ from B_1, and add the elements ϕ, ψ to B_1.

CR($\neg$): Suppose PL-formula ζ of the form $\neg\phi$ occurs in the second member B_1 of the proto-sub-DRS B of the proto-DRS A. Remove ζ from B_1, and add $\langle B_0, \{\phi\}, \emptyset\rangle, \langle B_0 \cup \{u\}, \{u{\neq}u\}, \emptyset\rangle\rangle$ to B_2, where u is an element of $\mathcal{V}$ that does not occur in C_0 for any proto-DR C in DR(A).

CR(/\): Suppose PL-formula ζ of the form /\x $\phi(x)$ occurs in the second member B_1 of the proto-sub-DRS B of the proto-DRS A. Remove ζ from B_1, and add $\langle B_0 \cup \{u\}, \emptyset, \emptyset\rangle, \langle B_0 \cup \{u\}, \{\phi[u/x]\}, \emptyset\rangle\rangle$ to B_2, where u is an element of $\mathcal{V}$ that does not occur in A_0, and $\phi[u/x]$ is the result of replacing all occurrences of x in ϕ by occurrences of u.

It is easily verified that applying the above rules to A and to the proto-DRSs that result from applications of the rules, yields, at the stage where no further rules apply, a DRS for PL. A simple induction establishes the fact that χ is satisfiable in M iff the DRS for χ^* has a truthful embedding in M. QED.

Here is an example that will elucidate the above recipe, providing a DRS for the following formula:

(a) (Px -> \/y $\neg$Rxy)

An equivalent formula in '/\', '$\neg$', and '&', is (b):

(b) $\neg$(Px & /\y Rxy)

Formula (b) contains free occurrences of the variable x, so we start with a proto-DRS that has {x} as its universe:

```
(c)   ------------------------------
     |             x                |
     |                              |
     |    ¬ (Px  & /\y Rxy )        |
      ------------------------------
```

The only rule that applies to this proto-DRS is CR(¬); using this rule has the following result (I use overstrike to indicate formulas that have been removed from the proto-DRS):

```
(d)   ------------------------------
     |             x                |
     |                              |
     |    ¬ ~~(Px  & /\y Rxy )~~        |
      ------------------------------
 --------------------      -------------------
|     x    u         |    |     x    u        |
|                    |    |                   |
|  Px & /\y Rxy      |    |     u ≠ u         |
 --------------------      -------------------
```

To this new proto-DRS, only the rule CR(&) applies. The result:

```
(e)   ------------------------------
     |             x                |
     |                              |
     |    ¬ ~~(Px  & /\y (Rxy))~~       |
      ------------------------------
 --------------------      -------------------
|     x    u         |    |     x    u        |
|                    |    |                   |
|  ~~Px & /\y Rxy~~      |    |     u ≠ u         |
|     Px             |     -------------------
|   /\y Rxy          |
 --------------------
```

Again only one rule is applicable to (e), vid. CR(/\), which yields (f), the DRS translating formula (b).

```
(f)    -------------------------------
       |            x                |
       |                             |
       |   - (Px  & ⋀y Rxy )         |
       -------------------------------

 --------------------          ------------------
|     x    u         |        |    x    u        |
|                    |        |                  |
| Px & ⋀y Rxy        |        |    u ≠ u         |
|    Px              |         ------------------
|   ⋀y Rxy           |
 --------------------

 ---------     ---------
| x u v   |   | x u v   |
|         |   |         |
|         |   |  Rxv    |
 ---------     ---------
```

The reader may check that the the DRS will be true in any model of (b) and vice versa.

The example makes clear that DRSs strongly resemble <u>construction trees</u> for PL-formulas. Evidently, the reverse construction is also possible:

<u>Proposition 3</u>: For every DRS A there exists a PL-formula χ such that, for any model M, A has a truthful embedding in M iff χ is satisfiable in M.

<u>Proof</u>: We may consider the basic CNs, IVs and TVs, the negations of the basic IVs and TVs, and the expressions '=' and '≠' of the language $L_o'(X)$, as predicates of PL, and the proper names of $L_o'(X)$ as constants of FPL. Likewise, we may consider the members of X as elements of the set of PL-variables. It follows from these assumptions that, given a DRS A = $\langle A_0, A_1, A_2 \rangle$, every member of A_1 is a PL-formula.

Given a DRS A, we provide translations for the components of A, the elements of COMP(A). COMP(A) will be finite, and every member of COMP(A) is of the form $\langle A_0, \{\phi\}, \emptyset\rangle$ or $\langle B,C\rangle$, where B and C are DRSs.

The translation TR(A) for a DRS of the form $\langle A_0, \{\phi\}, \emptyset\rangle$ is simply ϕ.

If $\langle B,C\rangle$ is a DRS-pair, we may suppose that TR(B) and TR(C) have already been constructed. Let TR(B) be ϕ and let TR(C) be ψ. Now the translation of $\langle A_0, \emptyset, \{\langle B,C\rangle\}\rangle$ is:

$/\backslash x_1..x_n$ (ϕ -> $\backslash/ y_1..y_m$ ψ),

where $\{x_1,\ldots,x_n\}$ is $B_0 - A_0$ and $\{y_1,\ldots,y_m\}$ is $C_0 - B_0$.

The translation of A is the (finite) conjunction of the translations of its atomic-DRS components and of the translations of the DRSs $\langle A_0, \emptyset, \{\langle B,C\rangle\}\rangle$ corresponding to its DRS-pair components. A simple induction establishes the fact that the resulting translation is satisfiable in a model M iff the DRS from which it is derived has a truthful embedding in M. QED.

It is clear from the proof that there is a difference between ordinary material conditionals in PL and the DRS-pairs that represent conditionals in DR-theory: the latter may involve universal and existential quantification, as indicated by the translation instruction. (Kamp has noted - indirect personal communication - that the generalized conditionals of DR-theory may give rise to a generalized rule of Modus Ponens.)

Here is an example of a DRS-translation, according to the recipe of proposition 3:

(g) Some farmer beats every donkey that he owns.

The DRS for (g):

```
(h)   --------------------------
     |        x                 |
     |                          |
     |     farmer(x)            |
      --------------------------
 -------------      ----------------
|  x    y     |   |   x     y       |
|             |   |                 |
| donkey(y)   |   |   x beats y     |
| x owns y    |   |                 |
 -------------      ----------------
```

The translation:

(i) Fx & /\y ((Dy & xOy) -> xBy)

The translation procedure makes it possible to enrich the Kamp framework with a level of logical translations. If logical translations are used, the truth definition in terms of truthful embeddings is replaced with the standard Tarskian truth definition for formulas of predicate logic. Clearly, the method of direct interpretation by means of truthful embeddings and the method of using a level of PL-translations for DRSs plus the standard truth definition for PL are equivalent.

Propositions 2 and 3 make clear that the DRS-language and the language of PL are very closely connected. It lies near, therefore, to suppose that the DRSs constitute a logical language with the same function as the logical languages employed in the Montague-framework. Still, there is an important difference between DRS-construction rules for a natural language fragment containing ambiguous pronouns and the DRS-construction rules employed in proposition 2. PL-formulas are already fully disambiguated, so their DRS-construction-rules do not have to perform any real work. DRS-construction-rules for natural language discourse, on the other hand, do perform a real job: they provide the additional syntactic information that disambiguates the discourse. Thus, the DRS-level is not comparable to the level of an eliminable logical language that translates structures that are already fully disambiguated. Rather, the DRS-level is very similar to the level of LF in the framework of transformational generative grammar, to the level of disambiguation trees in Montague Grammar, and to the level of extended syntax in the MG+ framework of chapter IV. The level of logical translations in MG is optional, but the level of extended syntax in MG+ or that of DRSs in DR-theory is not.

It is therefore reasonable to regard the level of Discourse Representation Structures as a level of Logical Form, like the extended syntax in the MG+ fragment of the previous chapter. In a sense, DRSs perform the function of a logical language: they encode the semantic information necessary for interpretation. Unlike the formulas of a translation language in a traditional Montague framework, however, they are also <u>syntactically</u> connected to sentences (or sequences of sentences): a series of applications of <u>syntactic</u> DRS-construction rules has gradually disambiguated the discourse, by fixing anaphoric links.

There have been attempts to view the level of DRS-construction as a part of semantics, by considering the DRSs as a logical language comparable to Montague's IL. (For this 'Montegovian' perspective on DR-theory cf. e.g. Zeevat (1984).)

My objection is that in this perspective the potential ambiguity of the discourses stares one in the face. The principle of compositionality of meaning demands that the logical translation language be eliminable, and for this to be possible a drastic revision of the sentence syntax component of the DR-framework is essential. Such a revision is quite unnecessary if one is willing to consider the DRS-level as a legitimate <u>extension</u> of syntax.

V.4 The DR-account of VP- and S-anaphora: A Sketch

This section contains a sketch of a theory of VP- and S-anaphora in the DR-framework. The reason for such a focus is that crucial linguistic evidence in connection with the bound/referential anaphora distinction can be found in the area of VP- and S-deletion phenomena. Cf. the examples discussed in II.4.1, involving the distinction between pronominal anaphors that are 'strictly' identical to their antecedents, and pronominal anaphors that are 'sloppily' identical to their antecedents.

In DR-theory, it is natural to reanalyze cases of VP- and S-deletion as cases of VP- and S-anaphora, by means of the introduction of appropriate new types of reference markers. An extension of DR-theory in this direction will constitute a test for the way in which the theory accounts for the bound/referential anaphora distinction: recall that cases of 'sloppy' identity are supposed to be connected with a bound anaphora mechanism, cases of 'strict' identity with a referential anaphora mechanism.

We start with S-anaphora. Consider the following mini-discourse:

(a) Bill says that he will win. John says so too.

I will assume that embedded clauses like 'that he will win' give rise to embedded DRSs (or in-frame DRSs), and that 'so' is an S-anaphor, to be linked at the DRS-construction level with an appropriate in-frame DRS. Thus: the embedded DRSs should give rise to reference markers of a new kind, 'S-markers' (as opposed to 'individual reference markers'), that are available for anaphoric S-links.

Later on, I will also introduce VP-markers. Technically, this proliferation of new markers can be avoided. For the anaphoric mechanism for that-clauses or VPs to work properly, it is enough to specify the 'set of descendants' of the appropriate that-clause or VP in the DRS. Thus, introducing special markers only serves for more perspicuous presentation.

S-markers represent embedded sentences. It will prove useful to indicate the individual reference marker that represents the subject of the attitude verb in an S-marker. (For an informal discussion of the truth conditions for in-frame DRSs cf. chapter VI. Cf. also Van Eijck (in prep).)

For reasons that will become clear shortly, we will assume that in an (S-)anaphoric link to a DRS-marker 'K[u]', where 'u' represents the subject of the relevant attitude verb, the marker representing the subject of the S-anaphor will get substituted for the marker 'u'. (The examples below will make this clear.)

Under these assumptions a possible representation for the first sentence of (a) would look something like (b):

(b)

u K[_/u]

~~Bill$_i$ says that he$_i$ will win~~
Bill = u
~~u says that u will win~~
u says K[u]

K[u]

u

(that) u will win

We have made use of a reference marker K of a new kind: K is a marker for an <u>in-frame</u> DRS (an S-marker). The individual marker for the <u>subject</u> of the propositional attitude verb that gives rise to S-marker K is indicated between brackets; hence: 'K[u]'. The assumption that an anaphoric link to this S-marker is possible under substitution of a new marker for 'u' is indicated by the notation 'K[_/u]'. One might compare 'K[_/u]' to a <u>parametrized procedure</u> in a programming language; like such a procedure, the S-marker can be <u>called</u> (linked to an S-anaphor), under substitution of a suitable value for the parameter 'u'.

Given this additional apparatus, S-anaphora can be accounted for by a mechanism that makes use of S-markers. Representation (b) for the first sentence of (a) can be extended to a representation for the two sentences in (a) by treating <u>so</u> in 'John says so too' as an anaphor linked to 'K[_/u]':

(c)

u K[_/u] w

~~Bill~~$_{\cancel{i}}$ says ~~that he~~$_{\cancel{i}}$ ~~will win~~
Bill = u
~~u~~ says ~~that u will win~~
u says K[u]

~~John~~ says ~~so (too)~~
John = w
w says ~~so~~
w says K[w/u]

K[u]

u w

(that) u will win

In DRS (c) the ambiguity of the discourse is resolved: the second sentence of the discourse is taken in the sense of 'John says that John will win'. Note that the way in which 'so' is replaced with a reference marker is analogous to the way in which CR(<u>pro</u>) replaces pronoun-occurrences with (individual) reference markers.

One might think the DR-approach to S-anaphora to boil down to the same thing as an approach that uses syntactic peculiarities of the lambda-expression translating the antecedent of an S-anaphor, say in a Montagovian framework. The difference is this: in Montague-grammar, it is a fundamental tenet that the logical language be eliminable. Therefore, there is no <u>syntactic</u> connection between the natural language expression that is to serve as antecedent of an S- or VP-anaphor and the lambda-expression that translates it. An approach that invokes syntactic features of the logical translation language blurs the distinction between syntax and semantics. A DR-approach that uses features of the part of the DRS that has already been built does not: as in the case of pronominal anaphora, S- and VP-anaphora resolution may depend on features of the DRS-syntax.

To get the DRS for the reading of discourse (a) in which 'John says so too' is taken in the sense 'John says that Bill will win', the distinction between <u>bound</u> anaphora and <u>referential</u> anaphora in 'Bill says that he will win' is crucial. For the second possible reading one has to assume that in the first sentence of the discourse 'he' is <u>not</u> linked to 'Bill' by an application of ER at S-level, but by an application of CR(<u>pro</u>). This results in a slightly different DRS:

(d)

u K[_/u] w

~~Bill~~ says ~~that~~ he ~~will win~~	~~John~~ says ~~so (too)~~
Bill = u	John = w
~~u~~ says ~~that~~ he ~~will win~~	w says ~~so~~
u says K[u]	w says K[w/u]

K[u]

u v w

~~(that)~~ he ~~will win~~
v = u
v will win

It is clear that in order to ensure that this DRS gets the reading in which 'John says so' is interpreted as 'John says that Bill will win', one has to make use of the formal distinction between (d) and (c) resulting from the difference in treatment between bound and referential anaphora. The only difference between (c) and (d) is the presence of the extra marker 'v' in an identity statement 'v = u' and in the atomic statement 'v will win' in (d).

The following stipulation exploits the formal difference between bound and referential anaphora:

Df. If 'K[u]' is an S-marker, and 'w' is an individual reference marker, then 'K[w/u]' stands for the result of substitution of 'w' for 'u' in all statements occurring in the DRS marked 'K[u]', *except in atomic identity statements*.

This exception for atomic identity statements is reasonable, for these statements do not, strictly speaking, represent parts of L_o sentences, but they provide "auxiliary" anaphoric links.

The definition ensures that in (c) 'K[w/u]' refers to the DRS (e), in (d) to the DRS (f):

```
(e)  ----------------          (f)  ----------------
    | v   w          |             | u  v  w          |
    |                |             |                  |
    | w will win     |             | v = u            |
     ----------------              | v will win       |
                                    ----------------
```

Recall that 'w' represents 'John' and 'u' 'Bill'. Thus (d) will be true iff John asserts that Bill will win. The difference between the bound and the referential reading of the first sentence of the discourse engenders the distinction between the DRSs, and the two readings of discourse (a) are accounted for.

Now consider mini-discourse (g):

(g) Every boy says that he will win. John says so too.

Processing of the first sentence will result in an embedded DRS with marker 'K[u]' for 'he will win', where 'u' is the reference marker representing the subject 'everyone' of the propositional attitude verb. Evidently, the embedded DRS must be accessible later on in the discourse. Therefore, K[_/u] must be placed in the principal DR (thus, the CR for embedded sentences is rather like the CR for proper names).

Here we encounter a problem. Note that 'u' is *not* a member of the universe of the principal DR, for this reference marker is introduced in a subordinate DR by CR(*every*). According to the definition for the meaning of 'K[w/u]', it may be that the "loading" of 'K[_/u]' with the value 'w' will result in an S-marker referring to a DRS in which 'u' still occurs, viz. in an atomic identity statement. In the principal DR, however, the link between 'u' and its antecedent is lost (for this antecedent is represented by 'u' at a subordinate level).

In view of this problem, it seems reasonable to assume the following principle.

<u>Constraint on S-marking</u>

> 'K[_/u]' may be linked to an S-anaphor at a given DR-level A if either 'u' does not occur in any atomic identity statements in 'K[u]' (in which case 'u' will be absent from all statements in 'K[w/u]', for any w ≠ u), or 'u' is a member of the universe of A.

The constraint emphasizes the similarity between S-markers and proper names. An S-marker 'K[w/u]' can be seen as a "proper name" for a proposition, at all DR-levels where 'K[u]' could be used to represent the proposition that it represents at the DR-level where it actually occurs.

In fact, there is no reason to suppose that an anaphoric mechanism as sketched here is restricted to VPs or embedded S-clauses. The DR-perspective suggests that - in principle, at least - anaphoric reference is possible to any sentence-element that is represented by an identifiable "DRS-part". This matter will not be pursued here, however.

Given the constraint on S-marking, a DRS for the first sentence of (g) could look like this:

```
(h)  -----------------------------------------
    | K[_/u]                                   |
    |                                          |
    | ~~every boy_i~~ says ~~that he_i will win~~    |
     -----------------------------------------

     -------       ----------------------------
    |  u    |     | u                           |
    |       |     |                             |
    | boy(u)|     | ~~u~~ says ~~that u will win~~      |
     -------      | u says K[u]                 |
                  |                             |
                  | K[u]  --------------------  |
                  |      |  u                 | |
                  |      |                    | |
                  |      | (that) u will win  | |
                  |       --------------------  |
                   ----------------------------
```

In DRS (h) <u>he</u> is taken to be bound by <u>every</u> <u>boy</u>.

Whether the link between 'every boy' and 'he' is the result of an application of ER at the level of extended sentence syntax (as in (h)), or of an application of CR(<u>pro</u>) at the DRS-construction level is of course immaterial for the interpretation of the DRS. It does matter, however, for the S-anaphor in the second sentence of (g). If 'he' is linked to the marker representing 'every boy' by an application of CR(<u>pro</u>), then an atomic identity statement, say 'v = u', is introduced, and as a result a marker K[_/u] cannot be available in the principal DR. This corresponds with the fact that a 'referential' reading of the S-anaphor is blocked.

Now, if 'he' is linked to 'every boy' by ER, then 'K[_/u]' will be available in the principal DR, and 'John says so too' will give rise to the atomic condition 'w says K[w/u]', where 'John' is represented by 'w' and 'so' by 'K[w/u]'. This will ensure that the discourse is unambiguously interpreted as: John says about himself that he will win.

Alternatively, suppose that <u>he</u> in 'Everyone says that he will win' is taken to refer to some previously mentioned individual, say mr. X. Then he will be linked to a marker 'x' for mr. X which belongs to the universe of the principal DR. No atomic identity statement containing 'u' will be present in the DRS 'K[u]' representing the that-complement sentence. Again, the second sentence of the discourse will give rise to a condition 'w says K[w/u]', but now the embedded DRS K[u] will be such that the interpretation of the condition is: John agrees with everyone else that mr. X will be the winner.

Next, consider an example in which a reflexive occurs:

(i) John says that he despises himself. Bill says so too.

Suppose that the first sentence of (i) is taken in the sense where John talks about himself. Then the link between 'he' and 'himself' must be provided by ER at the level of extended sentence syntax, for we suppose that the DRS-construction rules take appropriate S-structures as input. A DRS for the first sentence of (i) could be:

(j)

> u K[_/u]
>
> ~~John~~ says ~~that he$_i$ despises himself$_i$~~
> John = u
> ~~u~~ says ~~that he$_i$ despises himself$_i$~~
> u says K[u]
>
> K[u]
>
>> u v
>>
>> (that) ~~he$_i$ despises himself$_i$~~
>> v = u
>> v despises v

Again, the DRS for the first sentence of (i) determines the interpretation of the second sentence of (i). In (j), the anaphoric link between 'John' and 'he' is a referential link (for it is the result of an application of CR(<u>pro</u>), not of ER). Therefore, if 'so' in the second sentence of (i) is anaphorically linked to the that-clause in the first sentence by 'K[w/u]' (where 'w' represents 'Bill'), the reading where Bill agrees that John despises himself will result. In case ER has provided the link between 'John' and 'he', we get the reading where Bill makes an assertion about himself. Note that there is no way to interpret the second sentence of the discourse as conveying the message that Bill despises John. This result is intuitively correct.

If we replace the first sentence of (i) by a universal sentence, and we take 'he' to be bound by the universal NP, the ambiguity disappears:

(k) Every man says that he despises himself. Bill says so too.

The explanation is the same as in the case of (g).

It is clear from the examples that the mechanism sketched here makes it possible to distinguish between 'strict' and 'sloppy' identity in the way that is needed for the account of S-anaphora and VP-anaphora (cf. II.4.1).

We now turn to the account of <u>VP-anaphora</u>. The story is analogous to what was sketched above. Consider the following example.

(l) John despises himself. Bill does too.

Intuitively, what we need as antecedent for the VP-anaphor 'does' in the second sentence of the discourse, is the "part" of the DRS representing the VP 'despises himself' in the first sentence. In this particular case the relevant part of the DRS will consist of a single atomic statement 'u despises u', where 'u' represents the subject 'John'. We do not need the whole clause, but only the predicate. This can be achieved by introducing a VP-marker 'P[_/u]' for the part of the DRS representing the VP of the first sentence, and processing 'w does (too)' (where 'w' represents 'Bill') as 'w P[_/u]', i.e. 'P[w/u]'. Thus, the VP <u>does</u> is interpreted as an anaphor that gets linked to the VP <u>despises himself</u> by means of the VP-marker 'D[_/u]'. The complete DRS for (l) now becomes:

```
(m)  -----------------------------------
    | u   P[_/u]   w                     |
    |                                    |
    | ~~John_i despises himself_i~~      |
    | John = u                           |
    |                                    |
    | P[u] ---------------               |
    |      | u despises u  |             |
    |       ---------------              |
    |                                    |
    | ~~Bill does (too)~~                |
    | Bill = w                           |
    | w P[_/u]                           |
     -----------------------------------
```

The construction accounts for the fact that (l) is not ambiguous. Likewise, the following discourse will turn out not to be ambiguous.

(n) Every man despises himself. Bill does too.

We will assume that VP-markers 'P[_/u]', like S-markers, will be available in any DR of a DRS, provided either that 'u' does occur in the universe of this DR, or that 'u' does not occur in identity statements in 'P[u]'. (The definition of 'substitution' for VP-marker is the same as for S-markers.)

Thus, the processing of 'Bill does too' in the DRS for (n) will work out as in (g) and (k). Just as in the case of S-anaphora, this sketch explains certain ambiguities that turn on the distinction between 'strict' and 'sloppy' identity. It is clear that the DR-perspective predicts strong analogies between VP- and S-anaphora, a prediction that is borne out by the linguistic evidence. Consider example (o).

(o) John believes that Mary loves him. Bill does too.

There are two possibilities for the DRS-representation of the first sentence in (o), on the assumption that there is an anaphoric link between 'John' and 'him'. Either we can take 'John' and 'him' to be co-indexed by ER at S-level, or we may suppose that the link is provided by an application of CR(<u>pro</u>) to 'him' that links the pronoun to the reference marker representing 'John'. The DRSs are (p) and (q), respectively.

```
(p)   ----------------------------------------------
     | u   P[_/u]   v                               |
     |                                              |
     | ~~John_i believes that Mary loves him_i~~    |
     | John = u                                     |
     | ~~u believes that Mary loves u~~             |
     |                                              |
     | P[u] ------------------------------------    |
     |      | u believes K[u]                   |   |
     |      |                                   |   |
     |      |   K[u] -------------------------  |   |
     |      |        | u  v                   | |   |
     |      |        |                        | |   |
     |      |        | (that) ~~Mary loves u~~| |   |
     |      |        |        Mary = v        | |   |
     |      |        |        v loves u       | |   |
     |      |         ------------------------  |   |
     |       -----------------------------------    |
      ----------------------------------------------
```

(q)

```
 ---------------------------------------------
| u   P[_/u]  v                                |
|                                              |
| ~~John believes that Mary loves him~~        |
| John = u                                     |
| ~~u believes that Mary loves him~~           |
|                                              |
| P[u] ---------------------------------       |
|      | u believes K[u]                 |     |
|      |                                 |     |
|      |   K[u] ------------------------ |     |
|      |        | u   v   w            | |     |
|      |        |                      | |     |
|      |        | (that) ~~Mary loves him~~ | |     |
|      |        |        Mary = v      | |     |
|      |        |        v loves him   | |     |
|      |        |        w = u         | |     |
|      |        |        v loves w     | |     |
|      |         ----------------------  |     |
|       ---------------------------------      |
 ---------------------------------------------
```

Extension of (p) for 'Bill does too' will result in the reading where Bill believes that Mary loves Bill; (q) is the basis for an extension that will get interpreted as: Bill believes that Mary loves John.

Likewise, the account predicts that only a sloppy identity reading is possible for the VP-anaphor in (r):

(r) Every boy believes that Mary loves him. Bill does too.

With this sketch of a DR-approach to VP- and S-anaphora, I have tried to show that all the features of the traditional 'deletion' approach to the linguistic phenomena treated in this section (cf. Sag (1976)) can be incorporated in the DR-perspective. Moreover, a questionable feature of the traditional approach has been avoided. The rule for VP-deletion in Sag (1976) is stated in terms of structures of Logical Form, but beyond the fact that these Logical Forms are supposed to employ lambda-abstraction, they are not explicitly characterized. In particular, nothing is said or done to prevent identification of Logical Forms with expressions of a logical translation language, e.g. in a Montagovian framework. Under such an identification, the translation language is made to perform a function that it was not intended to perform. What was intended as merely a convenient means for talking about modeltheoretic objects, becomes an integral part of the syntax of natural language.

In the DR-approach, there is no such confusion of syntax and semantics: the DRS-construction rules are an extension of syntax at the cross-sentential level, and the theory of VP- and S-anaphora is phrased in terms of such rules. The effect of lambda-abstraction is achieved by permitting anaphoric links to VP- and S-markers with parameters for individual reference markers. Thus, the section gives additional weight to the view that DRSs are eminently suited for the rôle of Logical Forms.

V.5 DR-theory and the Singular/Plural Distinction

V.5.0 Introduction

In III a proposal for the syntactic and semantic treatment of plurality in Montague grammar has been made. Incorporating this proposal in the theory of logical form based on Montague grammar that was proposed in IV is straightforward. If one wants to extend DR-theory to a theory of logical form at the cross-sentential level that extends a theory of logical form as sketched in IV, then it is necessary to formulate DRS-construction rules for plural NPs. A proposal for the treatment of plurality in DR-theory can be found in Van Eijck (1983). In this section the issues raised there will be taken up again, but in some cases the reader will be referred to the paper.

What makes the issue of anaphoric links involving plural pronouns so difficult is the fact that 'they' and 'them' admit of such a plethora of anaphoric possibilities. Indeed, at first sight it seems that almost anything goes as regards anaphoric antecedents for plural pronouns. Any theory of anaphora that incorporates the singular/plural distinction must steer clear of the danger of allowing too many anaphoric possibilities and explaining nothing at all on one hand, and the peril of being too restrictive and therefore open to all kinds of linguistic counterexamples on the other. I am well aware of these dangers, and I do not contend that I have been completely successful at avoiding both of them. Nevertheless, I believe that the sketch of a version of 'plural DR-theory' provided below is a useful first step.

V.5.1 Plural DR-theory

The main problem with plural DR-theory is that it must account for many more anaphoric links than singular DR-theory. Consider the following contrasts:

(a) Pedro owns no donkey. *He beats it.

(b) Pedro owns no donkey. Still, he beats them.

(c) No arrow has hit the target. *It must have been crooked.

(d) No arrow has hit the target. They must have been crooked.

These examples indicate that plural pronouns, but not singular pronouns, can be used to refer to contextually relevant classes introduced by CNs.

Thus, admitting plural pronouns compels us to deal with new kinds of anaphora. Here is an illustration of three different kinds of anaphoric links one has to take into account if one takes plural anaphors into consideration. In each of the three examples the antecedent is singular. The anaphor may be (1) singular and 'bound' by the antecedent, as in (e), (2) plural and picking up its reference from the NP-antecedent, as in (f), or (3) plural and picking up its reference from the CN inside its antecedent, as in (g) (cf. Van Eijck (1983) for more details and examples, and for terminology):

(e) Many a farmer said that he was angry.

(f) Many a farmer came to the fair. They had a jolly good time. [The plural pronoun refers to the set of all farmers that came to the fair.]

(g) Many a farmer complained that they had been fooled by the government. [A complaint about the fooling of all farmers, not only of the farmers that complained, is voiced.]

In (e) we have a case of bound NP-anaphora, in (f) a case of unbound NP-anaphora (i.e., in the terminology of Evans (1980),"E-type" NP-anaphora). I propose to call the kind of anaphora in (g) "CN-anaphora".

The examples illustrate that, as soon as plural pronouns are admitted, the DRS-rules for singular NPs must be adjusted (and DRS-rules for plural NPs must be added). The examples point the direction for a treatment of plural anaphora in DR-theory. We distinguish between two kinds of reference markers:

- singular markers: x, y, etc.

- plural markers: X, Y, etc.

Because of examples like (f) and (g), where a plural pronoun is used to pick up a reference to a singular NP or to the CN inside a singular NP, we need plural markers in the DRS-rules for singular NPs as well as in the rules for plural NPs. Note that the extension of DR-theory with plural markers will destroy the correspondence between DR-theory and first order predicate logic mentioned in V.3.

We will suppose that CNs and plural NPs give rise to plural markers. Thus, every plural NP gives rise to two plural markers, one for the NP itself, and one to represent the CN. In view of the fact that anaphoric reference to CNs does not seem to depend on the depth of embedding of the antecedent CN, we will suppose that CN-markers are always added to the principal DR of a DRS. In this way the fact that the anaphoric behaviour of CNs resembles that of proper names is reflected in the DRS-construction rules.

Here is an example of the DRS-construction rule for the plural NP 'some CN[pl]'. Instead of giving a formal version of the rule, I will - for ease of presentation - merely give a paradigm application from which the rule itself can easily be reconstructed. The paradigm sentence is 'Some men talk'. This example gets the following DRS (some new notational conventions are introduced which will be explained below):

(h)

X Y

~~some men talk~~
(iX: men (X))
some (X,Y)
Y talk

In this example-DRS, X is the plural marker representing the CN 'men', and Y is the plural marker representing the whole NP 'some men'. '(iX: men (X))' is an example of a new kind of expression to be added to the DRS-language, and 'some (X,Y)' is an example of a new kind of atomic formula.

To see that both reference markers are indeed necessary, consider the difference between (i) and (j):

(i) Some men talk. They are boring.

(j) Some men talk sweetly. But they all are chauvinist pigs anyway.

If (i) is construed with an anaphoric link between the two sentences, the most obvious reading of the second sentence is: the talking men referred to in the first sentence are boring. This reading can be got by linking the plural pronoun to the reference marker representing the NP (Y in example-DRS (h)). If (j) is read with an anaphoric link, the most obvious interpretation of the second sentence is: 'all men are chauvinist pigs'. Here the plural pronoun must be linked to the CN-marker (X in the example-DRS).

In order to ensure the right interpretation for the example DRS (h), a truthful embedding f for the DRS in a model <E,F> should map X to the set of all men - i.e. to the set F(men) - and Y to a set consisting of a non-empty subset of the set of all men. This can be achieved by providing the right definitions for the verification of '(iX: men (X))' and 'some (X,Y)'. We stipulate that the expression '(iX: men (X))' is verified by a function f iff f(X) fulfils the condition 'men (X)', and f(X) is the maximal set that fulfils this condition. We stipulate further that f verifies 'some (X,Y)' iff $f(Y) \subseteq f(X)$ and $f(Y) \neq \emptyset$. It is easily checked that this gives the desired result for example (h).

To get the right treatment of plurality in connection with VP-interpretation, we take the same road as in chapter III: we suppose that every VP is interpreted as a set of sets. Thus, in a model <E,F> for plural DR-theory, every basic IV of the language is mapped to a subset of P(E), every basic TV as a subset of P(E) x P(E). The definition of verification for 'Y talk' now becomes: f verifies 'Y talk' in <E,F> iff $f(Y) \in F(talk)$.

This slightly altered way of interpreting VPs necessitates an obvious change in the definition of verification for singular reference markers: if y is a singular marker, then f verifies 'y talks' in model <E,F> for plural DR-theory iff $\{f(y)\} \in F(talk)$. Similarly for the other atomic formulas involving basic IVs or TVs and singular reference markers.

One might also adopt either plurality disambiguation at the VP level or plurality disambiguation at the NP level, as discussed in III.4.4.

Under the first option, one introduces features [d], [u] and [c] (for 'distributive', 'unspecific', and 'collective', respectively) on basic plural IVs and on basic plural TVs with a singular marker in direct object position, and similar features for the direct object positions of basic TVs occupied by plural reference marker. The right interpretations are ensured by providing the obvious stipulations for verification of the resulting atomic formulas. One example: f verifies 'X IV[d]' in model <E,F> iff for every $e \in f(X)$, $\{e\} \in F(IV)$.

Under the second option, the relevant features are given to occurrences of the plural reference markers: one assumes that plural markers may have the feature [d] for 'distributive', [u] for 'unspecific' or [c] for 'collective'. Now the definitions of verification for atomic formulas in which these features occur on plural reference markers must be adapted. (For further discussion of this issue cf. III.4.4 above, and Van Eijck (1983).)

What we will need anyway is a feature [d] on plural reference markers representing the CNs of <u>singular</u> NPs, to ensure the obligatory distributive interpretation. An example:

(k) Every man that can lift a piano brags about his strength.

It seems that, to account for one of the readings of the following text, a CN-marker representing the set of men that can lift a piano must be available:

(l) Every man that can lift a piano brags about his strength.
They usually are no good at anything else, though.

If one introduces a plural marker X for the set of men that can lift a piano, then one must force the distributive reading of 'X can lift a piano': a mapping of X to a set of individuals who can lift a piano <u>together</u> should not count as a verifation of this expression.

A DRS for a slightly simplified variant of (k) could be the following (a plural CN-marker is introduced, and the feature [d] is used to force the distributive reading of this marker; the treatment of 'every' remains unchanged):

```
(k') -------------------------------------
    |    X                               |
    |                                    |
    |  ~~every man that lifts a piano brags~~  |
    |  (iX: man(X), X[d] lifts a piano )  |
     -------------------------------------
     ----------------   ------------------
    | X  x           || |  X  x          |
    |                || |                |
    | man x          || |  x brags       |
    | x lifts a piano|   ------------------
     ----------------
```

In this DRS, processing the CN 'man that lifts a piano' has resulted in the expression '(iX: man(X), X[d] lifts a piano)' that is to be interpreted as the set of men that lift a piano. The feature [d] in 'X[d] lifts a piano' must lead to a distributive interpretation.

The example makes clear, by the way, that an 'expression' of the form '(iX: ...)' need not be atomic in the sense that no more DRS-construction rules apply to it. Strictly speaking, '(iX:...)' is not an expression at all, but a format for expressions of the extended language. In case '(iX:...)' derives from a basic CN without a relative clause, the colon is followed by a single expression, and this expression is an atomic formula. In case '(iX:...)' derives from a basic CN plus a relative clause (as in example (k')), the colon is followed by two expressions, one of them representing the basic CN, the other the relative clause. In example (k') the expression 'X[d] lifts a piano' represents the relative clause, and it is not atomic.

In view of these considerations, the rule for the interpretation of the format '(iX:...)' must be stated with some care. The definition of verification must be extended to non-atomic expressions of the extended language used in the DRSs. In the context of a completely constructed DRS, every non-atomic expression S determines a set of occurrences of atomic expressions and DRS-pairs that, in a sense that can easily be made more precise, derive from this occurrence of S. A function f verifies an occurrence of a non-atomic expression S iff f can be extended to a truthful embedding for this set. A function f verifies (iX:...) iff f can be extended to a truthful embedding for the set A of atomic formulas and DRS-pairs deriving from the expressions following the colon in '(iX: ...)', and no function f' that is like f except for the fact that $f'(X) \supsetneq f(X)$ is a truthful embedding for this set A.

To return to example (k'): 'X[d] lifts a piano' is not atomic. It must be processed further. Again introducing a new kind of atomic formula, we assume that the occurrence of 'X[d]' in this expression gives rise to a DR-split, as follows:

(k")

~~X[d] lifts a piano~~

X x

x in X

X x

x lifts a piano

The definition of verification for the atomic expression 'x in X' is as follows: function f verifies 'x in X' in model <E,F> iff f(x) ∈ f(X).

Combined with the definition of truthful embedding for DRS-pairs, this has as a result that f verifies 'X[d] lifts a piano' iff for every member e of the set f(X), {e} is a member of the interpretation of 'lifts a piano'. This is indeed the desired distributive interpretation.

The new notational conventions make it possible to rephrase the DRS-construction rules for 'every' and 'some[sg]' in a way that stresses the similarities with the rule for 'some[pl]'. Here are some sample DRSs:

(1)

X Y

~~every man talks~~
(iX: man (X))
every (X,Y)
Y[d] talks

The DR-split is not effected by the determiner 'every' any more, but by the marker Y with the feature [d]. The verification condition for 'every (X,Y)' : f verifies 'every (X,Y)' in <E,F> iff f(X) = f(Y) [i.e. f(Y) ⊆ f(X) and f(X) ⊆ f(Y)].

This rule for 'every' results in the following DRS for example (k):

(k''')

X Y

~~every man that lifts a piano brags~~
(iX: man(X), X[d] lifts a piano)
every (X,Y)
Y[d] brags

Note that additional revisions are necessary now to ensure that the anaphoric link in 'Every man that lifts a piano drops it' is still accounted for. This point will be discussed below.

Here is a sample DRS to illustrate the rule for singular 'some'. Note the similarities with the rule for plural 'some', as illustrated in example (h) above.

(m)

X y

~~some man talks~~
(iX: man (X))
some (X,y)
y talks

f verifies 'some (X,y)' in <E,F> iff f(y) $\in$ f(X).

The rule for 'all' is very similar to the revised rule for 'every':

(n)

X Y

~~all men talk~~
(iX: men (X))
all (X,Y)
Y talk

f verifies 'all (X,Y)' in <E,F> iff f(X) = f(Y). Note that the only difference with the rule for 'every' is the fact that the marker in 'Y talk' does not have the feature [d]. This accounts for the contrast between (o) and (p) (cf. the discussion of the constraint on the interpretation of 'quarrel' in III.4.4 above):

(o) All men quarrel.

(p) *Every man quarrels.

The general picture emerging from these rule-examples is as follows. Every Common Noun gives rise to a plural marker and to a format for a sub-DRS serving to characterize the set that is to be the image of this marker under a truthful embedding. Every NP-specifier gives rise to an atomic formula in which a CN reference marker and an NP reference marker occur, and of which the verification conditions depend on the nature of the specifier.

Now consider example (q):

(q) Many a farmer who owns a donkey beats it.

The most straightforward incorporation of NPs like 'many a CN' would be by means of a DRS-rule similar to Kamp's original rule for 'every CN', but with different embedding conditions. Example (q) would then get DRS (q').

```
(q')  -----------------------------------------
      | Many a farmer who owns a donkey beats it |
      -----------------------------------------
      ------------          -----------
      |  x   y     | => M |   x     y  |
      |            |      |            |
      | farmer(x)  |      |            |
      | donkey (y) |      | x beats y  |
      | x owns y   |       -----------
      ------------
```

Here '=> M' indicates that there are <u>many</u> embeddings of the lefthand box that also verify the righthand box.

This approach will not do. Consider a situation in which there are twenty farmers. One of them is rich and cruel: he owns fifty donkeys and he ill-treats all of them. The other farmers each have one donkey and they treat it well. Intuitively, sentence (q) should turn out false in this situation, but in the proposed approach it does not: there are 50 farmer-donkey pairs that fulfil the conditions of DRS (q'), and just 19 that verify the lefthand but not the righthand box.

I will return to (q) later. In the spirit of the reformulation proposals above, a rule for 'many' that does not encounter this logical problem may be provided:

```
(r)   ----------------------------
      |    X        Y              |
      |                            |
      |  many a farmer works       |
      |  (iX: farmers (X))         |
      |  many (X,Y)                |
      |  Y[d] works                |
      ----------------------------
```

Again, X is a CN-marker, and Y is an NP-marker. As above, a truthful embedding for the DRS will map X to the CN-set (the set of all farmers). The verifying condition for 'many(X,Y)': f verifies 'many (X,Y)' iff f(Y) consists of many of the f(X)s. The feature [d] on Y enforces the distributive reading needed for all singular specifiers. The rule for plural 'many' is as in (r), except for the fact that the feature [d] need not be present.

The difference in the rules for singular 'many a CN' and plural 'many CNs' explains the following contrasts:

(s) Many soldiers surround the town

(t) * Many a soldier surrounds the town

Plural reference markers with feature [d] must be processed further: they give rise to DRS-splits. DRS (r) must be completed as follows:

```
(r')  -----------------------------
     |    X       Y                 |
     |                              |
     |   ~~many a farmer works~~        |
     |   (iX: farmers (X))          |
     |   many (X,Y)                 |
     |   ~~Y[d] works~~                 |
      -----------------------------

      --------------    -------------
     |  X  Y  y     |  |  X  Y  y    |
     |              |  |             |
     |  y in Y      |  |  y works    |
      --------------    -------------
```

The embedding conditions for the subordinate DRS-pair in (r'): every function f with f(y) $\in$ f(Y) satisfies the condition that f(y) is a worker.

We now return to example (q). Given the above stipulations, a DRS for (q) must look like this:

```
(q")     ----------------------------------
        |    X        Y                      |
        |                                    |
        | (iX: farmers (X)   ;               |
        |        ~~X[d] own a donkey~~        |
        |                                    |
        |    --------   ----------           |
        |   | X Y x  | |  X Y u   |          |
        |   |        | |          |          |
        |   | x in X | | donkey(u)|          |
        |    --------  | x own u  |          |
        |               ----------     )     |
        |                                    |
        |   many (X,Y)                       |
        |   ~~Y[d] beat it~~                   |
         ----------------------------------
             --------     -----------
            | X Y y  |   |   X Y y   |
            |        |   |           |
            | y in Y |   | y beat it |
             --------     -----------
```

Here the first subordinate DRS-pair represents "X[d] own a donkey". The other pair represents "Y[d] beat it".

The problem with this DRS is the following: we cannot process the pronoun it, for the reference marker u to which this pronoun must intuitively be linked is not in an accessible position. Still, it is clear that if the CN reference marker X fulfils the condition expressed in the first subordinate DRS-pair, then the NP reference marker Y will fulfil that condition too. Therefore the righthand member of the second subordinate DRS-pair may be extended with the atomic formulas in the right-hand member of the first DRS-pair, substituting y for x, and the appropriate marker for it becomes available:

```
(q''')  --------------------------------
       |      X        Y                  |
       |                                  |
       | (iX: farmers (X)   ;             |
       |         ~~X{d} own a donkey~~    |
       |                                  |
       |    --------   ----------         |
       |   | X Y x  | |  X Y u   |        |
       |   |        | |          |        |
       |   | x in X | | donkey(u)|        |
       |    --------  | x own u  |        |
       |               ----------     )   |
       |                                  |
       |    many (X,Y)                    |
       |    ~~Y{d} beat it~~              |
        ----------------------------------
            --------    ------------
           | X Y y  |  |   X Y y u  |
           |        |  |            |
           | y in Y |  | donkey u   |
            --------   | y own u    |
                       | y ~~beat it~~  |
                       | y beat u   |
                        ------------
```

(q''') will have the right truth-conditions.

The same adjustment will be needed in the alternative treatment of 'every', in order to account for the anaphoric link in 'Every farmer who owns a donkey beats it'. The DRS for this example will now be like (q'''), with 'many (X,Y)' replaced by 'every (X,Y)'. Thus, the uniformity in the rule-format for plural DR-theory is bought at the cost of a complication in the anaphoric link mechanism.

V.5.2 Plural DR-theory and Generalized Quantifiers

All examples of NP-specifiers that we have considered in plural DR-theory until now have denotations that are - in terms of their properties as generalized quantifiers - right monotone increasing. For convenience the definition, that has been given in III.5, is repeated here.

Df. An NP-specifier denotation D is right monotone increasing iff DAB and $B' \supseteq B$ implies DAB'.

There is also a natural counterpart to this:

Df. An NP-specifier denotation D is right monotone decreasing iff DAB and $B \supseteq B'$ implies DAB'.

As is easily seen, 'every', 'all', 'some' and 'many' are right monotone increasing. It is particularly easy to check the truth-conditions of expressions containing NPs with right monotone increasing specifiers, because so-called 'witness sets' may be used (cf. Barwise & Cooper (1981)).

Df. A set W is a witness set for $\llbracket [_{NP} \text{SPEC CN}] \rrbracket$ iff $W \subseteq \llbracket \text{CN} \rrbracket$ and $W \in \llbracket \text{NP} \rrbracket$.

Witness sets W for NPs with right monotone increasing specifiers have the property that $X \in \llbracket \text{NP} \rrbracket$ iff $\bigvee W\ W \subseteq X$.

Thus, a sentence of the form $[_S[_{NP} \text{SPEC CN}]\ \text{VP}]$, where SPEC is right monotone increasing, is true iff

$$\bigvee W\!: W \subseteq \llbracket \text{CN} \rrbracket \ \&\ W \in \llbracket [_{NP} \text{SPEC CN}] \rrbracket \ \&\ W \subseteq \llbracket \text{VP} \rrbracket.$$

If we switch from VP-denotations of type <e,t> to denotations of type <<e,t>,t> in order to account for the singular-plural distinction, as we have done in plural DR-theory, the same specification of the truth conditions holds under a distributive interpretation of a sentence $[_S[_{NP} \text{SPEC CN}]\ \text{VP}]$. Under a collective interpretation we get the following: if SPEC is right monotone increasing, then $[[_{NP}$ SPEC CN] VP] is true iff

$$\backslash/\ W{:}\ W \subseteq [\![CN]\!]\ \&\ W \in [\![[_{NP}\ SPEC\ CN]]\!]\ \&\ W \in [\![VP]\!].$$

The case of unspecific predication calls for a similar adjustment. But in any case, the truth conditions of the sentence can be framed in terms of witness sets, with the witness sets acting as 'positive instances' of the NP-denotation. In the format for DRS-rules in plural DR-theory, use has been made of this fact. The plural NP-markers figuring in the rules are all intended to be mapped to witness sets.

It is easy to provide DRS-rules for other right monotone increasing NP-specifiers, like the numerals. Example: for the treatment of '(at least) two men walk' one needs an atomic condition 'two (X,Y)', with the stipulation that function f verifies the condition if f(Y) contains at least two of the f(X)s. Rules for definite descriptions are slightly more complicated: here one must employ the '(iY: ...)' format. Example: 'the two men walk' gives '(iY: X=Y; two(X,Y))', where 'X' is the CN-marker for men.

<u>Right</u> <u>monotone</u> <u>decreasing</u> NP-specifiers, e.g. 'no', 'no three', 'neither' and 'few' (in the sense of 'not many'), may be treated as <u>negated</u> increasing specifiers. Thus, plural 'no' is read as 'not some[pl]'. Here is a sample DRS:

```
(a)  ----------------
    | X              |
    |                |
    | ~~no men walk~~ |
    | (iX: men(X))   |
     ----------------
     ----------------
    | NEG      Y     |
    |                |
    | some (X,Y)     |
    | Y walk         |
     ----------------
```

Similarly for the other examples. The negation has as a result that the NP-markers introduced by DRS-rules for decreasing specifiers will be in subordinate position. This effectively prevents across-sentential NP-anaphora in these cases.

Finally, for specifiers that are neither right increasing nor right decreasing, like 'exactly three', both a 'positive' and a 'negative' verifying condition is needed. In other words: they must be treated as an implicit conjunction of an increasing specifier and a decreasing one. 'Exactly three men walk' can be paraphrased as: 'three men walk but no four men walk'. Such a treatment predicts, rightly, that the NP-markers introduced by the rules for these specifiers are accessible for across-sentential NP-anaphora.

This concludes my discussion of plural DR-theory. It will be clear that a lot of work remains to be done. A flaw of the DRS-rules as they are formulated here is that they do not decompose complex NP-specifiers. A reformulation of the rules that makes it possible to treat 'the two' by first applying the rule for 'the' and next that for 'two' would be most welcome.

V.6 Conclusion

After a global discussion of theories of syntactic and semantic analysis that extend beyond the sentence level, we have taken Hans Kamp's proposal for a theory of Discourse Representation as a point of departure for a theory of Logical Form beyond the sentence level.

The exposition of Kamp's theory has given rise to several modifications and extensions. Formal properties of Discourse Representation Structures have been investigated, and their relation to formulas of first order predicate logic has been discussed.

Next, it has been argued that DRSs have the right properties to serve a number of purposes that in Transformational Generative Grammar are relegated to the Logical Form component of the grammar. Notably, it has been shown that a theory of VP- and S-anaphora can be formulated at the DRS-level.

Finally, an extension of the theory incorporating the singular/plural distinction has been formulated.

VI CONCLUSION AND FURTHER DIRECTIONS

VI.1 <u>What has been achieved?</u>

The aim of chapter V has been to extend Kamp's theory of discourse representation to a theory of logical form beyond the sentence level fitting all the requirements that we have come across in previous chapters. We have added wide scope readings for NPs, reflexives, and the singular-plural distinction. Also, we have indicated how the constraints on possible anaphoric binding-links from the MG+ fragment in IV, can be incorporated in a DR-theory. Finally, as I hope to have shown in the example of the DR-account of VP and S-anaphora, the level of discourse representation structures seems indeed suited for tasks that in a TGG-framework are relegated to the level of logical form.

Still, the theory we have ended up with in chapter V leaves certain things to be desired. The first thing that comes to mind is that the formulation of the DRS-rules seems rather <u>ad hoc</u> at times. To mention one example: one would welcome a revision of the theory in which all DRS-rules treating determiners of a certain category have a common format. Something in this area has been achieved in V.5, but one has the feeling that a still more general treatment should be possible. Here, a further attempt at reformulation should be made, e.g. in the direction of a treatment that more clearly reflects the structure proposed for the NP-specifier system in II and III above.

Further, it will be clear that not yet all the ingredients for a theory of logical form at the text-level including but going beyond a logical form theory based on a synthesis of Montague Grammar and TGG, have been presented.

For one thing, the problems of raising and equi that can be elegantly solved in Montague grammar by transposing complexity from the syntax of the raising or equi verb to its logical translation instruction (cf. IV.3.5), are still in need of an adequate DR-treatment. The correct DRS-representation for sentences involving raising or equi phenomena must be provided by the ways in which the DRS-construction rules apply to the raising and equi verbs. In order to get things right here, features for subject or object control should be incorporated in the structures of sentence syntax, and the DRS-construction rules should be reformulated to take these into account.

In this connection it looks promising to formulate DRS-rules for a version of sentence syntax in the spirit of Pollard (1984). Pollard adopts a framework where raising and control features are reflected in the categorization system, and the DRS-rules may employ the additional categorial information. Such a program will not be undertaken here, however, for it constitutes a reseach project on its own.

Another point where DR-theory must be worked out further before parity with the extended Montague framework from chapter IV is achieved, is the interpretation of embedded sentences. DRSs for embedded sentences have been introduced in the previous chapter, but no explicit semantics for in-frame DRSs has been provided. The rest of this chapter will be devoted to a tentative exploration in this area. Two possible extensions for treating embedded sentences (that-complements) will be sketched. First, in VI.2, a possible-world semantics is considered. Next, in VI.3, the connection between DR-theory and Barwise & Perry's Situation Semantics is discussed, and a situational semantics for embedded sentences is proposed.

VI.2 THAT-Complement Constructions: Intensional Treatment

VI.2.0 DRSs for THAT-complement Constructions

My aim in this section and the next is to investigate the problem of treating propositional attitude verbs like 'say that', 'assert that', 'believe that', 'know that' in a DRS-framework. As has already been pointed out in V.4, the overall framework of DRS-theory suggests a treatment in terms of 'embedded DRSs' or '*in-frame* DRSs', as I have called them. The problem is: how should the embedding conditions for in-frame DRSs be stated.

Let us suppose that the lexicon of the language-fragment we start with, L_o, contains, besides proper names, common nouns, intransitive and transitive verbs, propositional attitude verbs like 'know that', 'believe that', 'assert that', of category IV/S. We forget about the plural extension from section V.5 for the moment, and extend the language $L_o(X)$' in a different direction, by adding expressions of the form 'x says that B', where B is a DRS. If 'x says that B' occurs in component A_0 of DRS A, I will say that DRS B is *framed in* DRS A. An example of a DRS for a 'know_that' context (for convenience, I will leave out the DRS-markers from V.4):

(a) John knows that some man walks.

```
(a') -------------------------------------
    |        x                           |
    |                                    |
    |      x = John                      |
    |      x knows  -------------------- |
    |              |  x      y          ||
    |              |                    ||
    |              | (that)  man(y)     ||
    |              |         y walks    ||
    |               -------------------- |
     -------------------------------------
```

The definition of DRSs must be modified to encompass the in-frame DRSs. Call expressions of the form 'x knows that B', where B is a DRS, molecular formulas of $L_o(X)$'. The definition of DRSs is modified by allowing molecular formulas to occur in the second element of a DRS. The definition of the relation of subordinance between DRSs must also be modified: we stipulate that if B is framed in A, then A $\leq$ B (i.e. B is immediately subordinate to A).

Now there are several ways to go for the semantic treatment of in-frame DRSs. An intensional treatment along the lines of Montague grammar will be sketched in the next section.

VI.2.1 An Intensional Treatment of THAT-complements

The proper treatment of propositional attitude verbs, in the Montegovian spirit at least, is intensional. If we want to follow Montague in extending DRS-theory, we need intensional models. A model for 'intensional DRS-theory' is a quadruple

$M = \langle D_e, W, \mathbf{G}, F \rangle$, where

- D_e is the domain of entities (I take D_e to be the same for every world);
- W is a set of possible worlds (I suppress mention of an accessibility relation R on W, for I will suppose R to denote the universal relation on $W \times W$);
- $\mathbf{G}$ is the power set of the set of finite functions with domain $\subseteq V$ (the set of reference markers) and range $\subseteq D_e$;
- F is an interpretation function for the constants of L_o.

L_o (expanded with that-c verbs) has the following constants: proper names, basic IVs, basic CNs, basic TVs and basic IV/Ss. The interpretation function F is such that:

- for every proper name a, $F(\underline{a}) \in D_e$

- for every basic CN A, $F(\underline{A}) \in (P(D_e))^W$

Note that, for any CN A and world w, the members of F(A)(w) are elements of D_e, not elements of $D_e{}^W$. This means that CN is not a proper category for common nouns like 'price' and 'temperature'. These intensional common nouns must be assigned to a different category, ICN, with the following interpretation: for every basic ICN A, $F(\underline{A}) \in (P(D_e{}^W))^W$. ICNs will be disregarded here.

- for every basic IV A, $F(\underline{A}) \in (P(D_e))^W$

- for every basic TV A, $F(\underline{A}) \in (P(D_e \times D_e))^W$

TV is the category of extensional transitive verbs. The interpretation of basic intensional transitive verbs will be defined at the end of the section.

- for every basic IV/S A, $F(\underline{A}) \in (P(D_e \times G^W))^W$

We can now use F to define a function $[\![\ ]\!]_w$ from worlds to DRS-interpretations in those worlds. In view of proposition 1 from V.3 it is enough to define $[\![\ ]\!]_w$ for minimal DRSs, i.e. DRSs of the form $\langle A_0, \{\phi\}, \emptyset\rangle$, where ϕ is an atomic or molecular expression of $L_o(X)'$, or $\langle A_0, \emptyset, \{\langle B,C\rangle\}\rangle$, where $\langle B,C\rangle$ is a pair of DRSs. This extension is straightforward.

For any DRS A, $[\![A]\!]_w$ is a set of finite functions with domain $\subseteq V$ (the set of reference markers) and range $\subseteq D_e$.

Her is an example of a truthful embedding in an intensional model for a DRS containing a propositional attitude verb:

(a)

```
 ----------------------------------------
|   x        y                           |
|                                        |
|  x = John                              |
|  y = Bill                              |
|  x asserts  --------------------       |
|            |         x   y      |      |
|            |                    |      |
|            | (that)  y walks    |      |
|             --------------------       |
|                                        |
 ----------------------------------------
```

f is a truthful embedding for DRS (a) in a model $M = \langle E,W,\mathbf{G},F \rangle$, for world w, iff Dom(f) = {x,y}, f(x) = F(John), f(y) = F(Bill), and $\langle f(x),G \rangle \in$ F(assert)(w), where G is the function with domain W and range $\subseteq \mathbf{G}$ such that for every $w' \in W$,

$$G(w') = \{g \mid g \supseteq f \text{ and } g \in [\![\langle \{x,y\}, \{y \text{ walks}\}, \emptyset \rangle]\!]_{w'}\}.$$

Observe that the function G should map every world w either to the set {f} or to the empty set, according to whether Bill does or does not walk in world w.

One could call the function G a <u>proposition</u> of intensional DRS-semantics: propositions of intensional DRS-semantics are like Montegovian propositions, except for the fact that the truth-values occurring in the latter have been replaced here by sets of finite embedding functions.

In the above example the set of reference markers of the main DRS equals that of the in-frame DRS. In (b), with anaphoric relations as specified by DRS (b'), we have a similar case.

(b) John asserts that he walks.

```
(b')   --------------------------------
      |          x                     |
      |                                |
      |   x = John                     |
      |   x asserts  ----------------  |
      |             |        x       | |
      |             |                | |
      |             |(that) x walks  | |
      |              ----------------  |
       --------------------------------
```

f is a truthful embedding for DRS (b') in model M = $\langle E,W,\mathbf{G},F\rangle$, for world w, iff Dom(f) = {x}, f(x) = F(John), and $\langle f(x),G\rangle \in$ F(assert)(w), where G is a function with domain W and range $\subseteq \mathbf{G}$ such that for every $w' \in W$,

$$G(w') = \{g \mid g \supseteq f \text{ and } g \in [\![\langle \{x\}, \{x \text{ walks}\}, \emptyset\rangle]\!]_{w'}\}.$$

Since every truthful embedding f for DRS (b') maps x to the individual F(John), the function g should map every world w either to the set {f} = $\{\{\langle x, F(John)\rangle\}\}$ or to the empty set (according to whether John does or does not walk in world w).

In both examples the sets of reference markers of the mother-DRS and the in-frame DRS were the same, but of course new reference markers may be introduced at the level of the in-frame DRS. This will be the case in one of the possible DRSs for (c):

(c) John believes that a man walks.

Incidentally, in-frame DRSs can also be employed for the treatment of intensional transitive verbs like 'seek', to which we now briefly turn. Let the category of basic intensional transitive verbs be ITV, and let 'seek', 'conceive' have category ITV. The syntax of L_o is extended to accommodate them in the obvious way. The syntax of $L_o(X)$' is extended with molecular expressions 'x $\underline{A}$ $\underline{B}$', 'x -$\underline{A}$ $\underline{B}$', where x is a reference marker, $\underline{A}$ is a basic ITV, and $\underline{B}$ is an in-frame DRS.

The interpretation function F is expanded to cover basic ITVs as follows:

If $\underline{A}$ is a basic ITV, then $F(\underline{A}) \in (P(D_e \times \mathbf{G}^{W}))^{W}$.

The interpretation function $[\![\ ]\!]_w$ is expanded in the obvious way.

Here are some examples to illustrate the treatment of ITVs by means of intensional embeddings for in-frame DRSs:

(d) John seeks a unicorn.

```
(d') ------------------------------
    |      x                       |
    |                              |
    |    x = John                  |
    |    x seeks   -------------   |
    |             |  x    y     |  |
    |             |             |  |
    |             | unicorn(y)  |  |
    |              -------------   |
    |                              |
     ------------------------------
```

f is a truthful embedding for DRS (d') in a model $M = \langle E,W,\mathbf{G},F\rangle$, for world w, iff $f(x) = F(\text{John})$, and $\langle f(x), G\rangle \in F(\text{seek})(w)$, where G is the function with domain W and range $\subseteq \mathbf{G}$ such that for every $w' \in W$,

$$G(w') = \{g \mid g \supseteq f \text{ and } g \in [\![\langle\{x,y\},\{\text{unicorn}(y)\}, \emptyset\rangle]\!]_{w'}\}.$$

In other words, G is a function that maps every world w' to the set of functions with domain {x,y} that assign John to x and an object that is a unicorn in w' to y.

Another DRS for (d) is also possible:

```
(d")  ------------------------
     |   x        y            |
     |                         |
     |   x = John              |
     |   unicorn (y)           |
     |   x seeks    -------    |
     |             | x    y |  |
     |             |        |  |
     |              -------    |
      ------------------------
```

Precise definitions of the DRS construction rules involved will not be given here, but a rule has been applied to the direct object NP <u>before</u> application of the rule for ITVs can open an in-frame DRS. Therefore the in-frame DRS that appears in the direct object position of 'seek' is a trivial one: it does not impose any conditions at all.

f is a truthful embedding for DRS (d') in a model $M = \langle E,W,\mathbf{G},F\rangle$, for world w, iff $dom(f) = \{x,y\}$, $f(x) = F(John)$, $f(y) \in F(unicorn)(w)$, and $\langle f(x), G\rangle \in F(seek)(w)$, where G is the function with domain W and range $\subseteq \mathbf{G}$, such that for every $w' \in W$, $G(w') = \{f\}$. In other words: G now is a constant function that maps every world w' to the function f such that f(y) picks an object in D_e that is a unicorn in the world of evaluation w. This result is intuitively correct.

The above sketch illustrates that an intensional development of DRS-theory is rather straightforward. Note, however, that the intensional treatment of that-complements in DR-theory suffers from the same ailments as Montague's approach to that-complements. Like Montague-grammar it wrongly predicts logical omniscience (i.e. if ϕ is a necessary truth, then from "John knows that p" it follows that "John knows that p and ϕ"), and it does not give a straightforward account of inferences like "John knows that p and q, ergo John knows that p".

VI.3 THAT-complement constructions: Situational Treatment

In what follows some very sketchy remarks will be made about the connection between DR-theory and the theory of Situation Semantics. For an introduction to Situation Semantics, the reader is referred to Barwise (1981), Barwise & Perry (1981, 1983, 1984), and Barwise (1984). Instead of the full-fledged apparatus used in this series of proposals, I will work with an embryonal version of the theory.

VI.3.0 Situation Semantics Made Simple

Basically, Situation Semantics is a theory of meaning and interpretation for natural language in which partial models replace classical total models. In Barwise & Perry (1983) - henceforth 'S&A' - it is argued that 'going partial' is attractive for a whole number of reasons. For one thing, S&A gives a nice account, in terms of partiality, of the several uses of definite descriptions. Further, it is claimed that a semantics for propositional attitudes in terms of situations (partial models) engenders a notion of 'strong consequence' that can be used to solve the philosophical problem of logical omniscience arising in a possible-world semantics for the attitudes. These and other claims made in S&A will not be discussed here. They are mentioned only to indicate the possible interest of a theory of meaning for DR-theory in terms of partial models.

For our purposes, it is enough to introduce a few basic concepts, suitably simplified.

Df. A <u>circumstance</u> or <u>possible</u> <u>fact</u> is a sequence $\langle r, a_1, \ldots, a_n, pol \rangle$, where r is an n-place relation, $a_1, \ldots, a_n$ are objects, and pol is a truth-value.

Thus, circumstances tell us that a certain relation holds between certain objects, or, alternatively, that the relation does <u>not</u>

hold between the objects.

Df. A situation is a set of circumstances.

Df. A situation s is coherent if (1) no two circumstances in s differ only in their polarity, (2) there is no object a such that <=,a,a,0> ∈ s, (3) there are no distinct objects a, b such that <=,a,b,1> ∈ s.

Df. Two situations s_1 and s_2 are compatible if their union is coherent.

Df. A situation s_1 is part of a situation s_2 iff every circumstance of s_1 is a circumstance of s_2.

Given a classical model M for first-order predicate logic, let M* be the set of all atomic facts about M, in the obvious sense. Then <{M*}, P(M*)> is an example of a situation structure. Note that M* is coherent and every member of P(M*) is coherent, in the sense defined above. All situations occurring in a situation structure are called factual situations of the structure.

In general, situation structures may be a quite a bit more complex than this simple example, but the only complication relevant here is the one that results from the incorporation of special situations called constraints. A situation structure should respect any constraint occurring in it. Below it will be explained what this means.

Situations may be classified by means of situation types.

Df. A situation type is just like a situation, except for the fact that it may contain one or more place-holders for relations, objects, or truth-values.

The place-holders occuring in situation types are called indeterminates. Here is an example of a situation type:

E { <girl, y, 1>, <kiss, y, John, 1> }

In this situation type, y is an indeterminate for objects. The other ingredients: 'girl' is the property of being a girl; 'kiss' is the relation of kissing; 'John' is the individual John. The situation type E can be used to classify the situations in which there is a girl such that the girl kisses John.

A situation s is of a given type E iff, for some substitution of relations, objects or truth-values for the indeterminates in E (i.e. for some anchoring of the indeterminates), the resulting situation E[f] (where f is the anchor) is included in s. Anchors for situation types may be partial: not all indeterminates in a situation type E need be in the domain of the anchor f. If f is a partial anchor for E, E[f] will be a situation type, not a situation.

A crucial concept in situation semantics is that of 'constraint'.

Df. A constraint CO is a situation:
{<involves, E, E', 1>} (E and E' are situation types)

Note that here the situation types E and E' figure as objects in a circumstance. Involves is a primitive relation between situation types and situation types, where these situation types are considered as objects. Situation type E involves type E', with respect to a given situation structure, iff every situation of type E in the structure is part of a situation of type E' in the structure. If a structure behaves as stated in a constraint, we say that the constraint holds in the structure, or that the structure respects the constraint.

Barwise & Perry's standard example of a constraint is "kissing involves touching". This constraint could be formulated as follows: every situation of type {<kiss, x, y, 1>} (where x and y are indeterminates for individual objects) involves a situation of type {<touch, x, y, 1>}. In S&A-notation:

{<involve, {<kiss, x, y, 1>}, {<touch, x, y, 1>}, 1>}

Speaking very roughly, we may say that constraints in Situation Semantics play the rôle of meaning postulates in Montague grammar.

For the connection between tenseless DR-theory and the simplified form of Situation Semantics presented above, I will take my cue from a remark in S&A, p. 284:

> "We think event-types can be used to give a semantic account of discourse, with the formal individuals used to individuate anaphoric connections. Indeed, we think that event-types probably provide the right level of analysis to study the relationship between situation semantics and Kamp's discourse representation structures."

Given this starting point, there are several ways to establish the link between DR-theory and Situation Semantics (cf. Kamp (1983) and Sem (1984) for some suggestions). Kamp (1983), which has been the major inspiration for what follows, makes each pair $\langle A,f\rangle$, where A is a DRS and f a truthful embedding for A in $M = \langle E,F\rangle$, correspond to a (finite) submodel of M. I.e., for every pair $\langle A,f\rangle$ there is a structure $\langle E_S, F_S\rangle$ such that:

(1) $E_S \subseteq E$

(2) F_S agrees with F on the proper names in E_S, and F_S assigns to each CN or IV $\underline{b}$ a pair $\langle F_S+, F_S-\rangle$ of subsets of E_S, and to each TV $\underline{b}$ a pair of subsets of $E_S \times E_S$, such that $F_S+(\underline{b}) \subseteq F(\underline{b})$ and $F_S-(\underline{b}) \cap F(\underline{b}) = \emptyset$.

Let A be a DRS and f a truthful embedding for A in M. Then the associated submodel for $\langle A,f\rangle$ will be the submodel $\langle E_S, F_S\rangle$ with $E_S = \text{range}(f)$ and F_S induced by A_1 (i.e. if "x -A" $\in A_1$, then $f(x) \in F_S-(A)$, etc.).

Kamp takes these finite submodels as his situations. The finite submodels of a model M, however, are not very informative about what goes on in the full model.

Proposition: The associated submodel of a pair $\langle A,f \rangle$ of a DRS A and its truthful embedding f gives only existential information about A.

Proof: Note that the DRS $A' = \langle A_0, A_1, \emptyset \rangle$ will be truthfully embedded by f if $A = \langle A_0, A_1, A_2 \rangle$ is truthfully embedded by f. Also, $\langle A',f \rangle$ and $\langle A,f \rangle$ have the same associated submodel $\langle E_S, F_S \rangle$. But A' is equivalent to a finite conjunction ϕ of (negations of) atomic PL-formulas and ϕ is satisfiable iff its existential closure is true. QED.

This proposition shows that a slightly more complex definition of the 'associated situation' of a pair $\langle A,f \rangle$ is needed. It suggests that we must find a way to encode information involving universal quantification, implication or disjunction in situations. For this, we can employ constraints.

In order to see how the concept 'constraint' from situation semantics is related to DR-theory, we briefly take a closer look at the relation 'involves'. Situation type E involves situation type E' (with respect to a given situation structure) iff every factual situation of type E is part of a factual situation of type E'.

E involves E' can be paraphrased as: for every total anchor f for E, if E[f] is factual, then E[f] is of type E'[f]. Now it need not be the case that f is a total anchor for E', but we can always extend f to a total anchor for E'. This yields the following paraphrase for E involves E':

(a) For every total anchor f for E: if E[f] is factual, then there is an extension g for f, such that g is a total anchor for E', and E'[g] is factual.

The similarity of (a) to Kamp's embedding clause for subordinate DRS-pairs is striking already, but the fact that truthful embeddings for DRS-pairs are defined in terms of extensions of embedding functions must still be taken into account.

What we will actually need to make the connection between Situation Semantics and DR-theory are not constraints, but constraint types.

Df. A constraint type is a situation type
$\{\langle \text{involves}_I, E, E', 1\rangle\}$,
where I is a set of indeterminates for individual objects.

Constraint types are related to constraints as follows. For every anchor f defined for all members of I, $\{\langle \text{involves}_I, E, E', 1\rangle\}[f]$ is the constraint $\{\langle \text{involves}, E[f], E'[f], 1\rangle$. Note that a constraint type may be said to contain an anchor indeterminate.

A situation s is of type $\{\langle \text{involves}_I, E, E', 1\rangle\}$ iff there is an anchor f such that the constraint $\{\langle \text{involves}_I, E, E', 1\rangle\}[f]$, i.e. $\{\langle \text{involves}, E[f], E'[f], 1\rangle\}$, is included in s. This means that the situation structure in which s occurs must respect this constraint, and this in turn entails that the following must hold:

(b) For every anchor g for E[f] such that E[f][g] is factual there is an extension h of g such that E'[f][h] is factual.

As the domains of f and g, and those of f and h, do not overlap, g and h can be viewed as extensions of f, which yields another formulation of (b):

(c) For every extension g of f such that E[g] is factual there is an extension h of g such that E'[h] is factual.

This is exactly the form of the clause for the truthful embedding of DRS-pairs.

To make the connection is simple now. It will do no harm if we suppose the set of indeterminates for individual objects to be identical to the set of reference markers V. We will use the definition of 'DRS' from V.2.1, so a DRS A is a triple $\langle A_0, A_1, A_2\rangle$, where A_0 is a set of reference markers, A_1 is a set of atomic conditions, and A_2 is a set of DRS-pairs.

First, define a function H from atomic conditions to circumstance types (possible facts with objects replaced by indeterminates). For a proper name b, let [b] be the object denoted by b, for a CN, IV or TV b, let [b] be the corresponding property or 2-place relation. Suppose further that ϕ is an atomic condition. Let x,y be members of V (i.e. x,y are reference markers and indeterminates for individual objects). Then H is defined as follows:

If ϕ is $x=\underline{b}$, where b is a name, then $H(\phi) = \langle =, x, [\underline{b}], 1\rangle$

If ϕ is $x=y$, then $H(\phi) = \langle =, x, y, 1\rangle$

If ϕ is $x\neq y$, then $H(\phi) = \langle =, x, y, 0\rangle$

If ϕ is $\underline{A}(x)$, where A is a CN, then $H(\phi) = \langle [\underline{A}], x, 1\rangle$

If ϕ is $x\underline{A}$, where A is an IV, then $H(\phi) = \langle [\underline{A}], x, 1\rangle$

If ϕ is $x\text{-}\underline{A}$, where A is an IV, then $H(\phi) = \langle [\underline{A}], x, 0\rangle$

If ϕ is $x\underline{A}y$, where A is a TV, then $H(\phi) = \langle [\underline{A}], x, y, 1\rangle$

If ϕ is $x\text{-}\underline{A}y$, where A is a TV, then $H(\phi) = \langle [\underline{A}], x, y, 0\rangle$

This completes the definition of H.

Now one can use recursion to define, on the basis of H, a function H* from DRSs to situation types (Intuitively, the situation type H*(A) is constructed out of A by mapping the members of A_1 to appropriate circumstance types, and the members of A_2 to appropriate constraint-types):

> $H^*(A) = H^*(\langle A_0, A_1, A_2\rangle)$ is the smallest situation type E containing the H-image of every member of A_1 and containing, for every member $\langle B,C\rangle$ of A_2, the constraint-type $\langle \text{involves}_{Ao}, H^*(B), H^*(C), 1\rangle$.

As an example of the workings of this definition, consider the DRS for (one of the readings of) sentence (d):

(d) Some farmer beats every donkey that he owns.

```
(d')       -------------
          |      x       |
          |              |
          |  farmer(x)   |
           -------------
    -----------     -----------
   |  x  y      |  |  x  y      |
   |            |  |            |
   | donkey(y)  |  | x beats y  |
   | x owns y   |  |            |
    -----------     -----------
```

Calling the members of the subordinate DRS-pair B and C, respectively, we get the following H*-image for this DRS:

(e) {<farmer,x,1>,<$\text{involves}_{\{x\}}$, H*(B), H*(C),1>}

This works out as (f):

(f) {<farmer,x,1>, <$\text{involves}_{\{x\}}$,
{<donkey,y,1>,<owns,x,y,1>},{<beats,x,y,1>},1> }

Suppose that (d') has a truthful embedding h, and that h maps x to the farmer Pedro. Then we might say that h is a truthful embedding for (d') in view of the following situation (in the technical sense of situation semantics):

(g) {<farmer,Pedro,1>, <involves,
{<donkey,y,1>,<owns,Pedro,y,1>},{<beats,Pedro,y,1>},1> }

More generally:

Df. Given a classical DR-model M = ‹E,F›, a DRS A and a truthful embedding f of A in M, the <u>associated</u> <u>situation</u> of the pair ‹A,f› is the situation H*(A)[f].

Note that the associated situation of a pair ‹A,f›, in the sense of this definition, does provide more information than the associated submodel of ‹A,f› in Kamp's sense. Information involving universal quantification, wide-scope negation, implication or disjunction is now conveyed by means of facts that employ the relation 'involves'.

Finally, note that the mapping H* that we have defined carries the theory of Situation Semantics a bit beyond what is covered in S&A. Notably, Barwise & Perry do not treat quantified NPs and sentence negation in their book. The mapping H* ensures that the treatment of quantification and sentence negation in DRS-theory carries over to Situation Semantics. Both are handled by means of constraints.

Sentence negation is only mentioned in passing in S&A, with a dark hint that it is a difficult topic ("Sentence negation is a complicated matter, not one we take up in any detail here"; o.c. p. 138). Indeed, it has been suggested (cf. Cooper (1984)) that sentence negation constitutes a serious problem for the theory. Our connection between DRS-theory and Situation Semantics reveals that there is no problem at all, provided that one is willing to wide-scope negation by means of constraints. (Narrow scope negation - 'VP-negation' - poses no problem; here 0,1-polarities can be used.)

The sentence "It is not true that a dog barks" gives rise to a DRS with a subordinate DRS-pair, and this pair has as its H* image a constraint ‹involve, E, E',1›, where E is the type of situation in which a barking dog occurs, and E' is an incoherent situation. Thus, the sentence is true in a situation structure in which every situation with a barking dog in it is part of an incoherent situation. In view of the definition of situation structures, this means that the sentence is true in a situation structure iff no factual situation has a barking dog in it. (If this seems too strong, this is because in my simplified account of Situation Semantics <u>locations</u> are left out of the picture.)

VI.3.2 A Situational Treatment of THAT-complements

The connection established above between DR-theory and Situation Semantics leads to a promising alternative for the interpretation of that-complement sentences from VI.2.1. For convenience, attention will be mainly restricted to the attitude verb 'know_that'.

An example of a DRS for a 'know_that' context:

(a) John knows that some man walks.

The DRS:

```
(a') ---------------------------------
    |   x                             |
    |                                 |
    | x = John                        |
    | x knows  ------------------     |
    |         |  x   y           |    |
    |         |                  |    |
    |         | (that) man (y)   |    |
    |         |        y walks   |    |
    |          ------------------     |
     ---------------------------------
```

In order to arrive at an interpretation in situational DR-theory for DRSs like (a'), function H* defined in VI.3.1 is to be extended with a clause for molecular expressions of the form 'x knows (that) B', where B is a DRS.

For such an extension, a primitive property of event types 'realized' is needed. An event type E is <u>realized</u> in a situation structure iff, for some anchor f, E[f] is factual. This property gives rise to constraints of a new form: if E is a situation type, {<realized,E,1>} and {<realized,E,0>} are constraints.

Df. A situation structure SS <u>respects</u> the constraint {<realized,E,1>} iff, for some anchor f, E[f] is factual in

SS; a situation structure SS <u>respects</u> $\{\langle \text{realized}, E, 0\rangle\}$ iff there is no anchor f with E[f] factual in SS.

Again, we can move from constraints to constraint types. If I is a set of indeterminates for individual objects, $\{\langle \text{realized}_I, E, 1\rangle\}$ and $\{\langle \text{realized}_I, E, 0\rangle\}$ are constraint types. The connection between constraints and constraint types is the same as before: situation <u>s</u> realizes $\{\langle \text{realized}_I, E, 1\rangle\}$ iff there is an anchor f with domain I such that $\{\langle \text{realized}, E[f], 1\rangle\}$ is part of <u>s</u>.

The function H from VI.3.1 can now be extended as follows:

> Suppose that, for some DRS B, 'x knows (that) B' occurs in component A_1 of DRS A, and assume that $A_0 \subseteq B_0$.
> Then:
>
> H(x knows (that) B) is the situation type:
> $\{\langle \text{know}, x, \langle \text{realized}_{Ao}, H^*(B), 1\rangle, 1\rangle\}$.
>
> H(x - knows (that) B) is the situation type:
> $\{\langle \text{know}, x, \langle \text{realized}_{Ao}, H^*(B), 1\rangle, 0\rangle\}$.

Thus, H and H* are defined by simultaneous recursion. These stipulations ensure that H*(A) is defined for any DRS in our extended sense.

The function H* will now map DRS (a') to the situation-type (b):

(b) $\{\langle =, \text{John}, x, 1\rangle,$
$\langle \text{know}, x, \langle \text{realized}_{\{x\}}, \{\langle \text{man}, y, 1\rangle, \langle \text{walk}, y, 1\rangle\}, 1\rangle, 1\rangle\}$

In view of the fact that 'x' does not occur in the event type that John knows to be realized, this reduces to:

(b') $\{\langle =, \text{John}, x, 1\rangle,$
$\langle \text{know}, x, \langle \text{realized}, \{\langle \text{man}, y, 1\rangle, \langle \text{walk}, y, 1\rangle\}, 1\rangle, 1\rangle\}$

As the factual situations of every situation structure are coherent, a situation structure in which type (b') is realized will have the following situation in it:

(b") {<know,John,<realized,{<man,y,1>,<walk,y,1>},1>,1>}

In the analysis sketched here, 'know' expresses a relation between individuals and possible facts of a certain, rather abstract, kind. For any situation type E, <realized,E,1> is a circumstance (a possible fact). If someone knows something, the circumstances that figure as objects for 'know' should of course be facts, for knowledge implies truth. This rule of the veridicality of knowledge should be imposed on situation structures by means of an appropriate constraint (see below). Actually, a set of suitable constraints is needed in order to systematically relate situation types to facts about situation types.

How do circumstances and facts come in? Does this sketch for an analysis of that-complement sentences lead to a theory that is not innocent in the sense in which, according to Barwise & Perry, Frege's theory of that-complements is not innocent? Barwise & Perry contend that a theory of the attitudes should interpret embedded clauses as it does main clauses. Frege's reference-sense shift is a betrayal of semantic innocence, in their opinion. The catchword "pre-Fregean semantic innocence" is taken from a remark of Donald Davidson. Let me again quote it (I apologize to the diligent student of Barwise & Perry's work, who doubtless knows it by heart already):

> If we could but recover our pre-Fregean semantic innocence, I think it would be plainly incredible that the words "the earth moves,", uttered after the words "Galileo said that," mean anything different, or refer to anything else, than is their wont when they come in other environments.
>
> Davidson, 1969; quoted in S&A on p. 174

The main problem with the whole issue of semantic innocence is the failure to take the rôle of the subordinating conjunction that into account. (This was first made clear to me by Fred Landman in a lecture on the Fourth Amsterdam Colloquium. Cf. Landman (1984b).) As soon as we are prepared to accept that "that the earth moves" means something different from "the earth moves", we can disagree with Barwise & Perry on the analysis of that-complements, yet remain innocent. I propose to treat the subordinating conjunction that as a fact-former. Note that linguistic evidence for this is provided by locutions like "That the earth moves is an established fact". In the version of situational DR-theory sketched here, DRSs are mapped to situation types by the function H*. But in the case of in-frame DRSs, where a DRS B occurs in combination with 'that', the combination will be mapped to a fact (or rather: a circumstance).

The above proposal is certainly different from the analysis in S&A: in that chapter Barwise & Perry analyze that-complement contexts as expressions standing for relations between subjects and situations: if a knows that ϕ, then ϕ must correctly describe the situations s that are classified by a as epistemic alternatives: situations that are not incompatible with what a knows.

There is a problem of belief and knowledge that is not solved by the S&A-account. Consider the following example:

(c) John knows that a girl loves him.

Suppose (c) is read with narrow scope for 'a girl', an let E be the situation type that classifies John's knowledge. Now, as in the S&A-account E classifies factual situations (i.e. situations in which real individuals occur), John's knowledge will - in some sense - be knowledge about real girls. Thus, John's knowledge is purported to be about girl no. 1, or about girl no. 2, or .... etc.

But (c) states that John has indefinite knowledge (an anonymous female sends him romantic love letters, let us say). To have the indefinite knowledge that some girl has a certain property, is just to know that there is a girl with that property, without believing about any actual objects that one of them is a girl with that property. John's indefinite knowledge is not knowledge about real girls at all, but knowledge about a type of situation. John knows that the situation-type with the rôle of being-a-John-loving-girl in it is realized. The example of indefinite knowledge makes it particularly clear that a piece of knowledge should be construed as a relation to a *fact*.

In my view, if *a* knows that ϕ, then there exists a certain relation between *a* and a *fact*: the fact that the situation type described by ϕ is realized. Such facts are admittedly fairly abstract, and they may have a complicated internal structure, but there is nothing wrong with that: knowing that something is the case may be the outcome of a long and difficult process of reflection, after all.

Some advantages that Barwise & Perry claim for the S&A-theory of the attitudes carry over to my proposal. As in S&A, someone's beliefs may be incoherent without it following from this fact that that person believes everything. Given the fact that John believes that some incoherent type E is realized, there are still many situations not of type E, and John need not believe that these are factual.

Similarly, in general "John knows that ϕ" does not imply "John knows that ϕ and ψ" (where ψ is some necessary truth). The reason is that the constituents of ψ need not figure at all in the type of situation classified by ϕ that John believes to be realized. Although I do not think that this fully solves the problem of logical omniscience, as Barwise & Perry seem to contend, it may be a step towards its solution.

In my analysis the "stock of knowledge" of a person *a* is a set of (possibly highly complex) facts, closed under certain operations, e.g. the operation of conjunction. The formal structure of this set of facts will depend on the choice of constraints for 'know'. Here are some examples of relevant constraints:

CO_1: {<involves,{<realized,E,1>},E,1>}

CO_2: {<involves,{<realized,E,0>},-(E),1>}

-(E) is not a situation type, but a set of situation types (a *schema*), viz. the set that is the *complement* of E. Cf. S&A, 91,..

for details on schemata and complementation. CO_1 and CO_2 may be said to be meaning postulates for 'realized'.

CO_3: $\{\langle involves,\{\langle know,x,\langle realized,E,1\rangle\rangle,1\rangle\},E,1\rangle\}$.

CO_4: $\{\langle involves,\{\langle know,x,\langle realized,E,0\rangle\rangle,1\rangle\},-(E),1\rangle\}$.

CO_3 and CO_4 express the veridicality of knowledge (the fact that knowledge implies truth): if someone knows that p, then p (CO_3), and if someone knows that not-p, then not-p (CO_4).

$$CO_5\text{: } \{\langle involves,\{\langle know,x,\{\langle realized,E,1\rangle, \langle know,x,\{\langle realized,E',1\rangle\},1\rangle\}, \{\langle know,x,\{\langle realized,E+E',1\rangle\},1\rangle\}.$$

E+E' stands for the sum (union) of E and E'. CO_5 expresses that knowing that p and knowing that q implies knowing that p & q.

These are just examples of the kinds of constraints that can be used in an implementation of 'know_that'-DR-theory. There are many open questions in this area. Which constraints should be imposed? What are the relations between the constraints that one might think of in this area? What logic for 'know_that' will result from a certain choice of constraints? How should the relation between 'know_that' and other attitudes be constrained? I will leave this topic for future research.

A bonus of this analysis of someone's knowledge as a set of facts, is that it is very easy to incorporate 'know_whether' complements in the account. Suppose that 'x knows (whether) B' occurs in a DRS A.

H(x knows whether B) is the situation type
$\{\langle know,x,\langle realized_{Ao},H^*(B),POL_1\rangle,1\rangle\}$,

where POL_1 is a truth-value indeterminate.

This stipulation conveys that a situation in which John knows whether Mary loves him must be of the following type:

$$\{\langle \text{know}, \text{John}, \langle \text{realized}, \{\langle \text{love}, \text{Mary}, \text{John}, 1\rangle\}, \text{POL}_1\rangle, 1\rangle\}$$

If a situation structure is such that Mary does indeed love John - i.e. if $\{\langle \text{love}, \text{Mary}, \text{John}, 1\rangle\}$ is factual - then it follows from the veridicality of knowledge that

$$\{\langle \text{know}, \text{John}, \langle \text{realized}, \{\langle \text{love}, \text{Mary}, \text{John}, 1\rangle\}, 1\rangle, 1\rangle\}$$

must also be factual (otherwise the SS would contain an incoherent situation). Similarly, if Mary does not love John, the following situation must be factual:

$$\{\langle \text{know}, \text{John}, \langle \text{realized}, \{\langle \text{love}, \text{Mary}, \text{John}, 1\rangle\}, 0\rangle, 1\rangle\}.$$

Using truth-value indeterminates, the constraints CO_3 and CO_4 can be lumped together. The following general constraint now expresses the veridicality of knowledge:

(VK) $\{\langle \text{involve}, \{\langle \text{know}, x, \langle \text{realized}, E, \text{POL}_1\rangle, 1\rangle\}, \{\langle \text{realized}, E, \text{POL}_1\rangle\}, 1\rangle\}$

VK applies both to 'know_that' and to 'know_whether' contexts. The constraint states something about situations of the type where someone knows whether a certain situation type is realized: if the knowing subject knows that the type is realized, then it is in fact realized, if he knows that it is not realized, then it is in fact not realized.

Finally, note that it is the constraint VK that relates the facts expressed by means of 'know_whether' contexts to the world. Without such a constraint, the situation type $\{\langle \text{realized}, E, \text{POL}_1\rangle\}$ would have an anchor in <u>any</u> situation structure (for in any situation structure it is the case that type E is either realized or not realized). There is no constraint like VK for belief, and the ungrammaticality of examples like the following turns out to have a semantic explanation:

(d) * John believes whether Mary loves him.

VI.4 Conclusion

In this final chapter directions have been explored in which DR-theory, viewed as a theory of logical form and anaphoric disambiguation at the text level, may be extended. Focussing on the semantics of embedded sentences, two connections have been made: a connection of DR-theory with possible-world semantics in the spirit of Montague grammar, and a connection of DR-theory with Situation Semantics. Although it may seem that these two connections result in radically different frameworks, there are reasons to believe that the cleft between Montague semantics and Situation Semantics is less vast than Barwise & Perry suggest. I will not argue this point here, however.

It will be clear from this study that I do not believe at all that Transformational Generative grammar and the various current brands of logico-semantics - in the spirit of Montague grammar, Discourse Representation Theory or Situation Semantics - are incompatible enterprises. Indeed, I hope this book has given the reader an impression of the synthetic theory for the description of the syntax and semantics of natural language that becomes possible if one combines components developed in these several traditions.

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Samenvatting

In dit proefschrift wordt de verhouding onderzocht tussen theorieën over kwantificatie in nominale constituenten uit een linguistische en uit een logisch-semantische traditie. Het onderzoek is toegespitst op het kader dat nodig is voor de beschrijving van de onderlinge bereiksverhoudingen van nominale constituenten en de anaforie-verschijnselen met nominale constituenten in de hoofdrol. Nagegaan wordt of er wat betreft dit beschrijvingsapparaat een synthese mogelijk is tussen voorstellen afkomstig uit de Transformationeel-Generatieve grammatica en voorstellen uit verschillende richtingen binnen de logisch-semantische theorievorming, met name de Montague grammatica en Kamp's formele discourse representatie theorie.

Het proefschrift begint met een historische uiteenzetting, waarin een deel van het in de loop van de laatste honderd jaar ontwikkelde logische instrumentarium voor de analyse van kwantificatieverschijnselen de revue passeert. Daarna worden in hoofdstuk II verschillende voorstellen voor de beregeling van bereiksambiguiteiten en anaforische verschijnselen - met name: beperkingen op mogelijke anaforische verbanden - besproken, en waar nodig bekritiseerd of geherformuleerd. Tevens wordt er een voorstel gedaan om de syntaxis van de lidwoordgroep van enkelvoudige en meervoudige nominale constituenten te beregelen met behulp van een categoriaal systeem waaraan bepaalde categorie-veranderingsprincipes zijn toegevoegd.

In hoofdstuk III komt de manier aan de orde waarop in de Montague grammatica kwantificatieverschijnselen worden behandeld. Er wordt een voorstel gedaan om de syntactische component van de Montague grammatica in een explicietere vorm te gieten. Vervolgens wordt een compositionele semantiek gepresenteerd voor de lidwoordgroep-syntaxis uit het vorige hoofdstuk. Hoofdstuk III eindigt met een recept voor het wegwerken van bepaalde soorten betekenispostulaten die in Montague grammatica een grote rol spelen.

Hoofdstuk IV is gewijd aan de verhouding tussen enerzijds de taalkundige theorieën uit hoofdstuk II en anderzijds de Montague grammatica. Eerst wordt een eerdere poging tot synthese tussen de beide tradities besproken, de zogenaamde NC-opslag-theorie, waarin groot-bereik lezingen van nominale constituenten worden verkregen door middel van het 'opzouten' en dan pas later gebruiken van de logische vertalingen van die constituenten. Vervolgens wordt betoogd dat een elegantere synthese mogelijk is tussen Logische Vorm theorieën uit de Transformationeel Generatieve Grammatica en Montague Grammatica. Voorwaarde voor zo'n synthese is dat het Logische Vorm niveau wordt beschouwd als een *onderdeel* van de syntactische structuurbeschrijving, of zo men wil als een *uitbreiding* ervan, en niet als een alternatief voor een niveau van modeltheoretische interpretatie of iets dergelijks. Onder dit perspectief levert de vervanging in Montague grammatica van de zgn. inkwantificatieregels door regels die de *extractie* van nominale constituenten uit syntactische structuren verzorgen een versie van Montague grammatica op waarin syntactische structuren gaandeweg gedesambigueerd worden tot 'Logische Vormen', die dan vervolgens compositioneel kunnen worden geïnterpreteerd.

In hoofdstuk V wordt overgestapt op de bestudering van een theorie die representaties opbouwt voor een opeenvolging van meerdere zinnen, de discourse representatie theorie van Kamp. Achtergronden van deze theorie worden belicht en voorstellen tot herformulering en uitbreiding worden gedaan. Betoogd wordt dat de opgebouwde representaties bij uitstek geschikt zijn om de rol van 'Logisch Vormen' te spelen op het tekst-niveau. Deze stelling wordt aannemelijk gemaakt in een schets van een theorie van werkwoordgroeps- en zins-anaforen in termen van deze representaties. Hoofdstuk VI, tenslotte, geeft een terugblik over de afgelegde weg en eindigt met een blik en een paar stappen vooruit naar nieuwe, verder liggende wetenschappelijke horizonten.