

Restricted syntax – unrestricted semantics?*

Udo Klein
udo.klein@ling.uni-stuttgart.de

September 17, 2008

1 Introduction

While a considerable amount of work has focused on finding the most adequate restrictions on (i) the formal structure of natural languages and (ii) the relation between formal and semantic structure, less work has focused on clarifying how to restrict the semantic structure of natural languages. In order to know how to restrict semantic structure, it is necessary to know why one would want to restrict it. To sharpen this issue, I will discuss what is often taken to be one of the most important reasons for postulating compositionality, namely the explanation of successful communication by means of novel expressions. However, as it turns out, what the explanation of this requires is not actually compositionality itself (at least not as it is usually thought of), but a much more restrictive notion, which I formulated as hypothesis (H), namely that (i) linguistic structure is exhaustively characterised by means of a set of basic exponent-meaning pairs and a set of rules for combining exponent-meaning pairs, and that (ii) speakers and hearers use the same exponent-meaning pairs and the same rules for combining complex exponent-meaning pairs, albeit in different ways, when producing or respectively understanding a complex expression. After pointing out what I take to be some difficulties for two prominent semantic theories when viewed from the perspective of (H), I sketch some ideas for an alternative, in which (i) semantic operations access the dependencies of unsaturated entities directly by means of the dependency type, and not by means of the order in which the dependencies must be saturated, (ii) semantic composition can be formulated independently of the analysis of scope and binding, and (iii) no non-local rules are necessary in order to map the phenostructure of meaning into the tectostructure of meaning.

The structure of the paper is as follows. In section 2, I will briefly present the basic idea that the notion of Linear Context-Free Rewriting System provides an adequate restriction of syntactic structure. As for the restrictions on the relation between formal and semantic structure, a number of linguistic theories have converged around the idea that the notion of compositionality provides an adequate restriction of this relation. Section 3 argues that explanation of successful

*This research was supported by the German Science Foundation (project C2 *Case and Referential Context* in the SFB 732 *Incremental Specification in Context*). I would like to thank the organisers of the workshop on *Local modelling of non-local dependencies* at the DGfS 2008 for the opportunity to present this paper, and the workshop participants for helpful discussion.

communication by means of new expressions imposes a severe restriction on the relation between formal and semantic structure, namely that (i) linguistic structure is exhaustively characterised by means of a set of basic exponent-meaning pairs and a set of rules for combining exponent-meaning pairs, and that (ii) speakers and hearers use the same exponent-meaning pairs and the same rules for combining complex exponent-meaning pairs, albeit in different ways, when producing or respectively understanding a complex expression. I will then point out some important consequences of this simple hypothesis, as well as some differences between this hypothesis and the principle of compositionality as it is usually stated. In section 4 I present some of the basic ideas behind two prominent semantic theories, namely interpretive semantics and variable-free semantics, and then evaluate them in the light of the hypothesis (H) above. Unlike interpretive semantics, variable-free semantics does account for some aspects of (H), namely that the meaning(s) of every complex exponent¹ is (are) determinable by the meaning of the immediate parts and a semantic operation, and unlike interpretive semantics, variable-free semantics avoids the postulation of principles which make reference to non-local relations. However, I will point out some difficulties facing variable-free semantics when viewed from the perspective of (H): first, it predicts the possibility that some natural languages restrict complement clauses to those which e.g. do not contain ‘unbound’ pronouns, (ii) it would require non-local rules for mapping the phenostructure of meaning into the tectostructure of meaning, and (iii) it conflates the analysis of context-independent and context-dependent aspects of interpretation, which undermines the investigation of the relation between them. In section 5 I will sketch an alternative semantic theory which respects the consequences of the hypothesis (H) while at the same time avoiding the difficulties facing variable-free semantics. Section 6 will conclude with some open questions.

2 Restricted syntactic structure

Consider the set of symbols $\{a, b, c, [,], _ \}$ and the syntactic operation of concatenation:

$$R_1(x, y) = [x_y],$$

where $x, y \in \{a, b, c\}$. Given this set of entities and this syntactic operation, we can derive the exponent $[a_ [b_c]]$ by the following simple derivation:

1. $R_1(b, c) = [b_c]$
2. $R_1(a, [b_c]) = [a_ [b_c]]$

The derivation history of this exponent can be stated succinctly as $R_1(a, R_1(b, c))$. I shall refer to the derivation history of an entity e as its tectostructure² $TS(e)$, so that:

$$TS([a_ [b_c]]) = R_1(a, R_1(b, c))$$

Given a tectostructure $TS(e)$, I will call any entity which is either in the input or in the output of one of the rules used in the derivation history of e a

¹I will use the notions of exponent and expression interchangeably.

²This notion is derived from the notion of tectogrammar, which goes back at least to Curry (1963).

tectostructural part of e . So the tectostructural parts of $TS([a_ [b_c]])$ are b , c , $R_1(b, c)$, a and $R_1(a, R_1(b, c))$.

Note that the concatenation operation does not access any of the tectostructural parts of the exponents it applies to – it manipulates the entities x and y to which it applies *as a whole*. So the only structure that the concatenation operation can ‘see’ are the beginnings and ends of two strings x and y to which it applies. For an operation which does access some tectostructural parts consider:

$$R_2([x_y], z) = [x_z_y]$$

Applying this rule to the exponents $[a_ [b_c]]$ and c results in:

$$R_2([a_ [b_c]], c) = [a_c_ [b_c]]$$

The operation R_2 accesses (the right edge of) the leftmost immediate constituent of the first entity it applies to, namely x in $[x_y]$. Therefore, the structure of the exponent $[a_ [b_c]]$ which is accessible to the rule R_1 alone is different from the structure accessible to the rules R_1 and R_2 put together, although the tectostructure of this exponent is the same. In order to distinguish these two notions of structure I will use the notion of phenostructure to distinguish the structure of an exponent e which is accessible to the rules from the tectostructure (i.e. the derivation history) of e . So the phenostructure of the exponents of a grammar containing both R_1 and R_2 is clearly more complex than the phenostructure of the exponents of a grammar containing only R_1 .

Given a suitable set of rules, it is possible to access all tectostructural parts of all exponents in a language. Consider the rule:

$$R_3([\dots x \dots]) = [x_ [\dots a \dots]]$$

which replaces x with a and prefixes this new exponent with x . Applying this rule to the exponent $[a_ [b_c]]$ results in:

1. $[a_ [a_ [b_c]]]$, if tectostructural part a is targeted
2. $[b_ [a_ [a_c]]]$, if tectostructural part b is targeted
3. $[c_ [a_ [b_a]]]$, if tectostructural part c is targeted
4. $[[b_c]_ [a_a]]$, if tectostructural part $[b_c]$ is targeted
5. $[[a_ [b_c]]_a]$, if tectostructural part $[a_ [b_c]]$ is targeted

A more familiar way of describing this rule is that when it applies to an exponent e and targets an exponent x within e , then it moves x to the left of the constituent which results from replacing x in e with a . Note that in the present form this rule can access *all* tectostructural parts of the exponent x . Having such a rule as part of a grammar results in a maximally complex phenostructure, since all tectostructural parts of any exponent can be accessed by this rule.

A major problem with a linguistic formalism which allows for rules that can access any tectostructural part of the exponents they apply to is that we basically predict syntactic relations which do not appear to be attested³ – in

³Another major problem with such rules is that exponents of a language whose grammar contains such rules cannot be parsed efficiently. Assuming that the exponents of natural languages should be parsable in polynomial time for their grammars to be considered psychologically plausible models of the structure of natural languages, such rules are not desirable since they allow for the formulation of grammars whose exponents cannot be parsed in polynomial time.

other words the linguistic formalism is too permissive. To illustrate the power of such rules note that we can formulate e.g. a rule which assigns the nominative case to an NP and concatenates this with a VP, if the subject of the most deeply embedded verb is a pronoun.

$$R_4(x_{NP}, [\dots [y_{PRO} z_{IV}]]_{VP}) = [[x_{NP-w_{NOM}}]_{-}[\dots [y_{PRO} z_{IV}]]_{VP}]$$

So what would be an adequate restriction of the rules of a linguistic formalism? A breakthrough was achieved when Vijay-Shanker and Weir (1994) showed that a number of restrictive but different linguistic formalisms characterise the same class of string languages. Joshi et al. (1991) developed a system called Linear Context-Free Rewriting System (LCFR) which aims to capture the common properties shared by these formalisms. In order to present the kinds of rule permitted by LCFRS, I will first illustrate syntactic operations on pairs (and more generally n -tuples of strings), and then formulate the restrictions on the rules.

Consider the following sentence, which displays an instance of a long-distance dependency between **chocolate** and **likes**:

- (1) **Chocolate, John thought that Mary likes.**

Assuming that we have reasons to assign this exponent the tectostructure

- (2) $X_1(\text{John}, X_2(\text{think}, X_3(\text{Mary}, X_4(\text{likes}, \text{chocolate}))))$,

where X_i is a variable ranging over rule symbols, the question is whether we can find rules which derive the exponent in (1), while at the same time avoiding rules which can access all the tectostructural part of an expression. Note that if X_4 stands for the concatenation operation R_1 , then we do indeed need a rule which can access any tectostructural part of (1).

One way of avoiding such rules is to assume that rules can create and operate on pairs (or more generally n -tuples) of strings, not just on strings. This essentially allows the combination of **chocolate** and **likes**, as required by the assumed tectostructure, by means of e.g. the rule R_5 *without* actually concatenating them:

$$R_5(x, y) = \langle x, y \rangle$$

Applying this rule to **chocolate** and **likes** results in:

$$R_5(\text{likes}, \text{chocolate}) = \langle \text{chocolate}, \text{likes} \rangle$$

According to the tectostructure above, the next rule should combine **Mary** with the result of combining **likes** and **chocolate**. Assume that this rule concatenates **Mary** to the second entity of the pair $\langle \text{chocolate}, \text{likes} \rangle$:

$$R_6(x, \langle y, z \rangle) = \langle y, x_{-}z \rangle$$

Applying this rule as indicated above results in:

$$R_6(\text{Mary}, \langle \text{chocolate}, \text{likes} \rangle) = \langle \text{chocolate}, \text{Mary_likes} \rangle$$

Combining this with **thought** (ignoring for simplicity the complementiser **that**) by means of the same rule R_6 results in:

$$R_6(\text{thought}, \langle \text{chocolate}, \text{Mary_likes} \rangle) = \langle \text{chocolate}, \text{thought_Mary_likes} \rangle$$

Next we combine this exponent with the exponent **John**:

$$R_6(\text{John}, \langle \text{chocolate}, \text{thought_Mary_likes} \rangle) = \\ \langle \text{chocolate}, \text{John_thought_Mary_likes} \rangle$$

Finally, we need to apply a new rule R_7 which concatenates the two elements of a pair:

$$R_7(\langle x, y \rangle) = x_y$$

so that the result is:

$$R_7(\langle \text{chocolate}, \text{John_thought_Mary_likes} \rangle) = \\ \text{chocolate_John_thought_Mary_likes}$$

Groenink (1997) has shown that Linear Context Free Rewriting Systems (i.e. the system used to characterise what a number of linguistic formalisms have in common) are weakly equivalent to (i.e. they generate the same class of languages as) grammars whose rules operate on n -tuples of strings and which obey the following restrictions:

- (R1) the rules access the elements of a tuple as a whole, i.e. if a rule applies to an exponent $\langle x_1, x_2, \dots, x_n \rangle$ then the rule cannot access the phenostructure of x_i , which excludes e.g. rule

$$R(\langle x, y_z \rangle) = y_x_z$$

- (R2) every variable occurring in the body⁴ of a rule occurs exactly once in the head of the rule, which excludes e.g. rule⁵

$$R(x) = x_x$$

- (R3) every variable occurring in the head of the rule occurs exactly once in the body of the rule, which excludes e.g. rule

$$R(\langle x, y \rangle, x) = \langle y, x \rangle$$

Since languages are sets of signs, i.e. exponent-meaning pairs, not only syntactic rules/structure but also (i) semantic rules/structure and (ii) the relation between syntactic and semantic structure needs to be restricted. In the following section I will turn to why and how the relation between syntactic and semantic structure should be restricted.

⁴The body of a rule $R(x_0, x_1, \dots, x_{n-1}) = x_n$ consists of x_0, x_1, \dots, x_{n-1} and the head of the rule consists of x_n .

⁵There has been some debate in the literature (see e.g. Stabler (2004) and references therein) as to whether such rules should be allowed.

3 Restricted relation between formal and semantic structure

How should the relation between syntactic and semantic structure be restricted? In order to answer this it is necessary to clarify why this relation should be restricted in the first place. One major restriction on the relation between syntactic and semantic structure is imposed by the the explanation of successful communication by linguistic means.

It is plausible to assume that the process of interpretation involves both context-independent as well as context-dependent information, which moreover interact in an intricate way. The investigation of the relation between context-dependent and context-independent aspects of interpretation presupposes that we keep these two aspects separate, in the sense that they can both be characterised independently of one another. I will use the term ‘linguistic meaning’ to refer to the context-independent aspects of interpretation, so that to the extent that successful communication by a new linguistic expression cannot be explained *without* an account of context-independent information, a characterisation of the relation between exponents and their linguistic meaning(s) is an integral part of this explanation.

The fact that in most cases we manage to understand each other although we may have used an expression we never produced or heard before suggests that in general (at least) (i) given an exponent, its linguistic meaning(s) is (are) computable by the hearer, and (ii) given a linguistic meaning, the exponent(s) (having this meaning) is (are) computable by the speaker, too. I shall refer to this requirement as the *computability* of the relation between formal and semantic structure.

Another important fact about communication by linguistic means is that (i) if a language user can express a basic meaning m by means of exponent e then she can also interpret e as meaning m , and vice versa, and that (ii) if a language user can express the structure of m by means of the structure of exponent e then she can also interpret the structure of e as symbolising the structure m , and vice versa. I shall refer to this requirement as the *systematicity* of the relation between formal and semantic structure.

The computability and systematicity of the relation between formal and semantic structure suggests the following hypothesis as an account of how we successfully communicate the linguistic meaning, i.e. the context-independent aspects of interpretation, by means of a new expression:

- (H) If speaker and hearer use (i) the same basic exponent-meaning pairs and (ii) the same rules for producing or understanding complex exponent-meaning pairs (albeit in different ways), then the speaker can successfully communicate a complex linguistic meaning by means of a novel complex exponent. Consequently a natural language, i.e. a set of exponent-meaning pairs, should be exhaustively characterisable by means of a set of basic exponent-meaning pairs and a set of rules combining exponent-meaning pairs, such that applying the rules all and only the exponent-meaning pairs of a given language can be generated.

One way of spelling out (H) is by means of the notion of **interpreted grammar** introduced and developed in detail in Kracht (2008). Instead of presenting the technical details, I will focus on some basic ideas.

First, both the syntactic and semantic structure are specified in terms of a set of syntactic or respectively semantic entities on the one hand, and a set of syntactic or respectively semantic operations on the other hand (i.e. in terms of a syntactic and a semantic algebra). Secondly, there is a *strict separation* of syntactic and semantic structure in the sense that there is no entity or relation which is shared by both syntactic and semantic structure. Thirdly, there is a *strict integration*⁶ of syntactic and semantic structure in the sense that every exponent is associated with a meaning if (i) every immediate constituent exponent is associated with a meaning, and both the syntactic and semantic operations are defined for their immediate constituents (and vice versa⁷). Fourthly, the association of syntactic and semantic operations may be either one-to-one (most restrictive) or many-to-many (least restrictive). Fifthly, the syntactic and semantic operation may access either no tectostructural parts (most restrictive), only some tectostructural parts or all tectostructural parts (least restrictive).

In view of the current debates about the status of the principle of compositionality, it may be useful to distinguish between empirical and methodological aspects of (H). An empirical aspect of (H) is that it is postulated in order to explain the phenomenon of successful communication by means of a new exponent. Lacking a better way of explaining successful communication by new linguistic expressions, we are *forced* to adopt this hypothesis. The methodological aspects of (H) are related to the fact that the fourth and fifth points allow for varying degrees of restrictiveness, so that in order to get a handle on exactly how restrictive (i) the operations and (ii) the relation between syntactic and semantic operations should be, it is methodologically profitable to start with the most restrictive hypothesis, namely that operations may not access any (proper) parts of the tectostructure of the entities they apply to (which are not also part of the phenostructure), and that the relation between syntactic and semantic operations is one-to-one.

From this perspective the computation of the linguistic meaning of an exponent involves three mappings:

- (1) mapping phenostructure of exponent into tectostructure of exponent,
- (2) mapping tectostructure of exponent into tectostructure of meaning, and
- (3) mapping tectostructure of meaning into phenostructure of meaning

and the computation of the exponent given a linguistic meaning involves the reverse mappings, namely:

- (1') mapping phenostructure of meaning into tectostructure of meaning,
- (2') mapping tectostructure of meaning into tectostructure of exponent, and
- (3') mapping tectostructure of exponent into phenostructure of exponent

⁶This terminology may help clarify confusion that may arise by using the notion of autonomy, since this notion appears to be used in two different ways which basically correspond to the notions of 'strict separation' and 'strict integration'. On the one hand syntax has been claimed to be autonomous from semantics in the sense that no syntactic entity should be part of semantic structure. On the other hand it has been argued that syntactic structure cannot be profitably studied without semantic structure.

⁷That is, every meaning is associated with an exponent if (i) every immediate constituent meaning is associated with an exponent, and both syntactic and semantic rules are defined for their immediate constituents.

It is helpful to distinguish the specification of these mapping from the way in which these mappings are instantiated in the minds of language users. Similarly it is important to distinguish the conceptual separation between linguistic meaning (those aspects of interpretation which are invariant across contexts of use) and enriched meaning (linguistic meaning plus world knowledge and other context-dependent aspects) on the one hand, from the way in which linguistic meaning and world knowledge give rise to enriched meaning.

Finally, note some important differences between the hypothesis (H) and the principle of compositionality (PC) (and its various precisifications):

- PC The meaning of a complex expression is determined by the meaning of the parts of the expression and the way in which the expression parts are combined.

and hypothesis (H). First, note that (H) requires meanings to be structured entities. Without this requirement that meaning has a phenostructure it is not possible to provide a finite characterisation of the mapping from meaning to its tectostructure, and from the meaning tectostructure to the expression tectostructure, or as Frege (1923, 36) put it, “this would not be possible if we could not distinguish parts in the thought...”. The principle of compositionality on the other hand does not require anything of the kind. Secondly, note that taking (PC) together with the reverse principle according to which given a complex meaning, the exponent expressing it is determined by the exponents expressing the constituent meanings and the way in which the constituent meanings are related does not amount to (H). This is because these two principles taken together still do not account for systematicity. Thirdly, note that (H) does not require that for every syntactic operation there be exactly one semantic operation. What (H) requires is that speaker and hearer use the same associations between syntactic and semantic operations, and so it allows for syntactic operations which may be associated with more than one semantic operation. (PC) does not allow this, since given the meaning of the parts and the syntactic operation the meaning of the whole must be determinable, which it would not be if a syntactic operation is associated with two different semantic operations.

4 Unrestricted semantic structure?

4.1 Some restrictions imposed on semantic structure

(H) imposes a number of restrictions on semantic structure. First, as pointed out above, semantic structure is autonomous from syntactic structure in the sense that semantic structure must not share anything with syntactic structure.⁸ As pointed out in footnote 6, this sense of autonomy must be sharply distinguished from another sense of autonomy according to which both of these structures can and should be studied independently of one another. A consequence of this restriction is e.g. that indices cannot be shared – semantic rules cannot distinguish syntactic indices, and vice versa. Secondly, if a syntactic rule applies to exponents e_1, e_2, \dots, e_n then, this syntactic rule is associated with a semantic rule which applies to the meanings m_1, m_2, \dots, m_n where $\langle e_1, m_1 \rangle, \langle e_2, m_2 \rangle, \dots, \langle e_n, m_n \rangle \in L$. Thirdly, some meanings must be structured

⁸This requirement is for example violated in HPSG, and is therefore anything but trivial.

entities, for the same reason that some expressions must be structured, namely because the explanation of successful communication of new thoughts presupposes it. Fourthly, the mapping from the phenostructure of meaning to the tectostructure of meaning must be computable. Fifthly, the semantic structure should be restricted such that unattested semantic structures and dependencies are not permitted. And sixthly, a methodological requirement related to (H) is to begin with the most restrictive notion of structure, i.e. semantic rules cannot access the tectostructural parts of meaning⁹.

4.2 Interpretive semantics

In this section I will discuss some of the basic ideas behind a prominent theory of semantic composition, namely that proposed by Heim and Kratzer (1998).

4.2.1 Proposal

Heim and Kratzer (1998) assume a syntactic theory which for sentence:

- (3) **John offended every linguist.**

generates the following syntactic structure:

- (4) $[_S [_{DP_1} \text{every linguist}] [_S \text{John} [_{VP} \text{offended } t_1]]]$

which they treat as an abbreviation for the representation in (5):

- (5) $[_S [_{DP} \text{every linguist}] [1 [_S \text{John} [_{VP} \text{offended } t_1]]]]]$

In addition to indexed pronouns and indexed traces, HK also postulate so-called variable binders, which consists of numerical indices. The indexed pronouns and traces are interpreted by the so-called TRACES AND PRONOUNS RULE (TPR):

TPR If α is a pronoun or a trace, a is a variable assignment, and $i \in \text{dom}(a)$, then $\llbracket \alpha_i \rrbracket^a = a(i)$

Structures like $[1 [_S \text{John} [_{VP} \text{offended } t_1]]]$ are interpreted by the rule of PREDICATE ABSTRACTION (PA):

PA Let α be a branching node with daughters β and γ , where β dominates only a numerical index i . Then, for any variable assignment a , $\llbracket \alpha \rrbracket^a = \lambda x \in D. \llbracket \gamma \rrbracket^{a^{x/i}}$

Essentially then, this rule applies to a binary branching structure whose first daughter is an index β and whose second daughter is a structure γ , and creates a function from individuals x to values y which are like $\llbracket \gamma \rrbracket^a$ except that any dependency of the denotation $\llbracket \gamma \rrbracket^a$ on the value assigned to a pronoun or trace indexed with β is replaced with a dependency on x . According to this rule, the interpretation of the structure $[1 [_S \text{John} [_{VP} \text{offended } t_1]]]$ is:

- (6) $\lambda x \in D. \llbracket [_S \text{John} [_{VP} \text{offended } t_1]] \rrbracket^{a^{x/1}}$

i.e. the function which for all individuals x in the domain of individuals results in the truth-value 1 if and only if John offended x .

Assuming further that the meaning of $[_{DP} \text{every linguist}]$ is the function f such that:

⁹This is what Dowty (2007) calls context-free semantics.

- (7) $f(Q) = 1$ if and only if for all x in the domain of individuals, if x is a linguist then $Q(x) = 1$

the result of combining this function with the denotation of $[1 [_S \text{John} [_{VP} \text{offended } t_1]]]$ (by means of functional application) is the truth-value 1 if and only if:

- (8) for all x in the domain of individuals, if x is a linguist then John offends x

HK point out that since the syntactic rules generating the structure are optional nothing precludes the generation of the structure $[_S [\text{every diver}]_1 [_{VP} \text{defended himself}_1]]$, and by the interpretation rules, this sentence would denote the truth-value 1 if and only if for all x in the domain of individuals, if x is a diver then x defended the individual which the assignment function a assigns to the pronoun himself_1 , which is the wrong truth-condition. To block this truth-condition HK (have to) postulate a BINDING PRINCIPLE (BP):

- BP Let α and β be DPs, where β is not phonetically empty. Then α binds β syntactically at SS iff α bind β semantically at LF.

Together with the definitions of syntactic and semantic binding, this principle filters out structures in which α syntactically binds β if β is not also c-commanded by a variable binder, i.e. a numerical index – structures like $[_S [\text{every diver}]_1 [_{VP} \text{defended himself}_1]]$ are therefore licensed by the syntactic rules, but filtered out by the binding principle.

4.2.2 Evaluation with respect to hypothesis (H)

The first point to note about PREDICATE ABSTRACTION is that it applies to a complex syntactic structure, and that it accesses a numerical index. So this rule is an interpretation rule, in the sense that it provides the interpretation of a complex expression, but it is not a semantic operation in the sense required by (H) above, namely that it operates on the meanings of the immediate constituents of the corresponding syntactic rule.¹⁰ Put differently, in the analysis of HK (and for that matter in most analyses which employ lambda abstraction) there are complex expressions whose meaning is not determined by applying a semantic operation to the meanings of the immediate constituents of the complex expression. Instead, the meaning of the complex expression is determined by a rule which needs access to an immediate constituent of the syntactic entity, namely a numerical index. This raises the following question:

- (9) Is it possible to find a semantic operation equivalent to PREDICATE ABSTRACTION?

By PREDICATE ABSTRACTION the denotation of $[12 [_{\text{he}_{12}} \text{likes } \text{he}_{3}]]]$ is the function which when applied to an individual x has the value 1 if and only if $[[\text{he}_{12} \text{likes } \text{he}_{3}]]^{M,g[x/12]}$, and the denotation of the expression $[3 [_{\text{he}_{12}} \text{likes } \text{he}_{3}]]]$ is the function which when applied to an individual x has the value 1 iff $[[\text{he}_{12} \text{likes } \text{he}_{3}]]^{M,g[x/3]}$. Given a model M containing the three individuals a , b and c such that a likes b and c , and b likes c , these functions are

¹⁰Hence the label ‘Interpretive semantics’ in the title of the previous section.

different even if the assignment function g assigns the same individual c to all pronouns and indices. Given M and g , the application of the first function to an individual x results in the truth-value 1 iff x likes c , so that this function maps a and b to 1 and c to 0. The application of the second function to an individual x results in the truth-value 1 iff c likes x , so that this function maps a , b and c to 0, since in M c does not like anybody. Therefore, given the same M and g a semantic operation equivalent to PREDICATE ABSTRACTION must also result in different functions when applied to the meaning of the immediate constituents of the two expressions above. If the syntactic operation combines the index 12 with the expression **he₁₂ likes her₃** then the corresponding semantic operation would have to operate on c (the meaning of the index 12, which for our purposes we can regard as identical with the denotation of 12) and the condition that ‘ c likes c ’ (the meaning of **he₁₂ likes her₃** relative to M and g). If the syntactic operation combines the index 3 with the expression **he₁₂ likes her₃** then the corresponding semantic operation would have to operate again on c (because c is the value assigned by g to 3) and the condition that ‘ c likes c ’ (the meaning of **he₁₂ likes her₃**). But since no semantic operation can apply to the same entities and yield different results, this shows that no semantic operation can be found which is equivalent to predicate abstraction, if we assume that meanings are truth-conditions. Note that it does not help to assume that the denotation of a sentence is a set of assignments instead of a truth-value (which is the standard way of providing semantic operations for the existential and universal quantifiers in predicate logic, see Janssen (1986)), since the required semantic operation must operate on meanings, i.e. truth-conditions, as opposed to denotations (i.e. truth values or sets of assignment functions).¹¹

The second issue, pointed out in Jacobson (2007, 194ff), is that the BINDING PRINCIPLE postulated in Heim and Kratzer (1998, 264)

BP Let α and β be DPs, where β is not phonetically empty. Then α binds β syntactically at SS iff α bind β semantically at LF.

“is stated across non-local chunks of representation”. First, note that the definition of α syntactically binding β given in SYN-B

SYN-B A node α syntactically binds node β iff

- (i) α and β are coindexed,
- (ii) α c -commands β ,
- (iii) α is in an A-position,
- (iv) α does not c -command any other node which also is co-indexed with β , c -commands β , and is in an A-position.

involves the c -command relation, which is non-local because in order to establish whether α c -commands β the BINDING PRINCIPLE needs access not only to the mother node of α but also to all nodes dominated by the sister node of α . Secondly, the relation of semantic binding holding between a variable binder in a tree γ and a variable occurrence in γ :

¹¹Heim and Kratzer (1998, 14) emphasise that the *meaning* of a sentence is not its truth-value (this is its *denotation*), but should be specified in terms of its truth-conditions. See Larson and Segal (1995) for an elaborate defence of this view.

SEM-B A variable binder β occurring in a tree γ semantically binds a variable occurrence α in γ iff the sister of β is the largest subtree of γ in which α is (semantically) free.

is also non-local since it makes reference to the non-local notion of subtree. Jacobson points out that there is no problem with having principles which state restrictions on structure, as long as the domain required for stating the restrictions is local, because if the domain were local these restrictions could in principle be reformulated in terms of local rules which generate these structures.

Because this principle makes reference to non-local relations, the interface between syntactic and semantic structure is not exhaustively characterised by pairing local syntactic operations with local semantic operations. As Jacobson (2007, 193f) puts it, “*any* theory needs combinatory rules (or “principles”) which “build” larger expressions from smaller ones – and so a theory which puts all of the work into these is adding no new machinery. The view that the grammar itself also keeps track of representations and uses these in the statements of other constraints requires extra machinery – and so the burden of proof should be on that position”. In the next section I will present and discuss the basic ideas behind Jacobson’s attempt to “put all the work into [the rules]”, namely her version of variable-free semantics.

4.3 Variable-free semantics

4.3.1 Proposal

An utterance of sentence (10)

(10) Every man believed that he lost.

can be true in two types of circumstances: (i) in circumstances C in which for all individuals x it holds that if x is a man then x believed that x lost, or (ii) in circumstances C' in which for all individuals x it holds that if x is a man then x believed that the individual which the speaker means by **he** lost. I will introduce the variable-free approach of Jacobson by presenting her analysis of the ‘bound variable’ interpretation of (an utterance of) this sentence, and by comparing it with the analysis in Heim and Kratzer’s approach.

The first important difference is that in Jacobson’s approach pronouns are not indexed, whereas in the HK approach the pronouns are indexed. Secondly, in Jacobson’s approach the denotation of a pronoun is not an individual assigned by the assignment function (and thus of type $\langle e \rangle$), as in the HK approach, but the identity function on individuals $\lambda x_e.x$ (and thus of type $\langle e, e \rangle$). In the HK approach the denotation of **lost** can combine with the denotation of **he** by means of functional application. In Jacobson’s approach this is not possible, since the denotation of **lost** is of type $\langle e, t \rangle$, but the denotation of the pronoun is of type $\langle e, e \rangle$. To solve this type mismatch Jacobson proposes a rule **g** (in honour of Peter Geach):

$$\mathbf{g}(f_{\langle a, b \rangle}) = \lambda g_{\langle c, a \rangle}.\lambda x_c.f(g(x))$$

When this rule applies to the denotation $\llbracket \mathbf{lost} \rrbracket$, which is a function of type $\langle e, t \rangle$, and c is taken to be the type $\langle e \rangle$, then the result is:

$$\mathbf{g}(\llbracket \mathbf{lost} \rrbracket_{\langle e, t \rangle}) = \lambda g_{\langle e, e \rangle}.\lambda x_e.\llbracket \mathbf{lost} \rrbracket(g(x))$$

Since this function takes as its first argument a function of type $\langle e, e \rangle$, it can combine by functional application with the identity function on individuals, and the result is:

$$(\lambda g_{\langle e, e \rangle} . \lambda x_e . \llbracket \text{lost} \rrbracket (g(x))) (\lambda y_{\langle e \rangle} . y) = \lambda x . \llbracket \text{lost} \rrbracket (\lambda y_{\langle e \rangle} . y(x)) = \lambda x . \llbracket \text{lost} \rrbracket (x)$$

The third important difference between Jacobson's approach and HK's approach is that the result of combining $\llbracket \text{he} \rrbracket$ and $\llbracket \text{lost} \rrbracket$ in Jacobson's approach is a function from individuals, whereas in the HK approach it is a function from assignment functions, namely $\lambda g . \llbracket \text{lost} \rrbracket^g (g(\text{he}_3))$ (or a truth-value if the assignment function g is given).

Fourthly, in Jacobson's approach the identification of the individual losing with the individual believing is achieved by the **z** rule, which when applied to the denotation of **believes** results in:

$$\mathbf{z}(\llbracket \text{believes} \rrbracket_{\langle t, \langle e, t \rangle \rangle}) = \lambda g_{\langle e, t \rangle} . \lambda y_e . (\llbracket \text{believes} \rrbracket (g(y)))(y)$$

This rule first changes a function from entities of type t into a function from entities of type $\langle e, t \rangle$, and secondly it identifies the argument required to saturate the complement of **believes** with the individual believing. The **z**-rule¹² has a function comparable to co-indexation in the HK approach: it ensures that certain arguments of two predicates (in this case the **believes** and **lost**) are identical. So combining $\mathbf{z}(\llbracket \text{believes} \rrbracket)$ with $\lambda x . \llbracket \text{lost} \rrbracket (x)$ by means of functional application results in:

$$\begin{aligned} FA(\lambda g_{\langle e, t \rangle} . \lambda y_e . (\llbracket \text{believes} \rrbracket (g(y)))(y), \lambda x . \llbracket \text{lost} \rrbracket (x)) = \\ \lambda y_e . (\llbracket \text{believes} \rrbracket (\lambda x . \llbracket \text{lost} \rrbracket (x)(y)))(y) = \\ \lambda y . (\llbracket \text{believes} \rrbracket (\llbracket \text{lost} \rrbracket (y)))(y) \end{aligned}$$

The resulting function provides the argument for the denotation of **every man** (taken to be a generalised quantifier), yielding:

$$\begin{aligned} FA(\lambda Q . \forall x . (\llbracket \text{man} \rrbracket (x) \rightarrow Q(x)), \lambda y . \llbracket \text{believes} \rrbracket (\llbracket \text{lost} \rrbracket (y)))(y) = \\ \forall x . (\llbracket \text{man} \rrbracket (x) \rightarrow \lambda y . \llbracket \text{believes} \rrbracket (\llbracket \text{lost} \rrbracket (y))(y)(x)) = \\ \forall x . (\llbracket \text{man} \rrbracket (x) \rightarrow \llbracket \text{believes} \rrbracket (\llbracket \text{lost} \rrbracket (x))(x)) \end{aligned}$$

Jacobson thus proposes an analysis which has two important properties with respect to the hypothesis (H): first, the meaning of **all** expressions is determined by the meanings of their immediate syntactic constituents and a semantic operation. This contrasts with approaches to binding in terms of PREDICATE ABSTRACTION which, as I have shown above, do not (in fact cannot, given certain assumptions) determine the meaning of complex expressions by the meaning of the parts and a semantic operation. Secondly, in contrast to the HK approach, Jacobson does not postulate principles which make reference to non-local relations, and therefore the relation between syntactic and semantic structure is exhaustively characterised by associations between (i) syntactic and semantic

¹²See Jacobson (1999) for a fully general version of this rule, which may also apply to three-place predicates.

entities, (ii) syntactic and semantic categories, and (iii) local syntactic and semantic operations. Whether or not non-local principles turn out to be unavoidable for the analysis of some linguistic phenomenon is still an open question, but it should be pointed out that in a series of articles¹³ Jacobson has argued that it is indeed possible to analyse binding and quantification phenomena without making reference to “non-local chunks of representation”.

In the next section I will point out some aspects of the variable-free approach which I take to be problematic if the formalism is to be part of an explanation of successful communication and language acquisition along the lines sketched above.

4.3.2 Evaluation with respect to hypothesis (H)

First, note that Jacobson postulates different types of meaning for complements of attitude verbs, depending on whether or not the complement clause contains a pronoun which is ‘unbound’ in it. Assuming that (i) predicates s-select arguments depending on the type of denotation, and that (ii) a linguistic formalism should restrict (if not define) the notion of possible natural language, we predict languages in which some predicates select for complement clauses only if they do not contain a personal pronoun (which is ‘unbound’ in the complement clause).¹⁴ Consider a language which is identical to English except that sentences like (11b), in which complement clause contains a pronoun ‘unbound’ in it, are ungrammatical.¹⁵

- (11) a. Mary hopes that John arrived.
 b. *Mary hopes that he arrived.

Secondly, if (i) combinators are postulated which create or access non-local semantic dependencies, (ii) meanings are structured entities (which, as argued above, they should be if communication of linguistic meanings by means of new expressions is to be explained), and (iii) the tectostructure of (the meaning of) sentences like (12) is (13):

- (12) Chocolate, John thought that Mary doesn’t like.
 (13) $FA([\text{chocolate}], \lambda x. [\text{thought}]([\text{John}], [\text{like}]([\text{Mary}], x)))$

then the mapping from the phenostructure of the meaning of (12) to the tectostructure (13) appears to require a-rules which can access arbitrarily deeply

¹³See Jacobson (2007) and references therein.

¹⁴Denying the first premise of the argument would still not prevent this prediction to be made in theories in which there is a tight correspondence between syntactic and semantic categories.

¹⁵This point is related to an observation made in Sag (2007), namely that

while it is common-place to find a language containing a verb like *go*, which allows a directional PP complement, but not a NP object, there are no languages (as far as we know) where we find a verb like *go* that imposed the same requirement on the complementation pattern realized within its sentential complement. That is we would not expect to find a verb *og* whose selectional properties produced contrasts like the following:

- (1) a. Lee oged that someone ran into the room.
 b. *Lee oged that someone proved a theorem.

embedded constituents. Such rules are required if the semantic operations can access non-local dependencies, as will be discussed in more detail in section 5.

Thirdly, the variable-free approach conflates context-independent aspects of interpretation (those aspects which constitute linguistic meaning) with context-dependent aspects of interpretation. I take it to be obvious that the question whether the individual referred to by the pronoun **he** in sentence (10) (repeated for convenience below)

(14) Every man believed that he lost.

is to be understood as ‘bound’ by **every man** (i.e. as identical to the individual who believes), is clearly a context-dependent aspect of interpretation, and I also take it to be obvious that the ascription of the property of losing to the individual denoted by **he** is clearly a context-independent aspect of interpretation.

As argued in section 3, the conceptual distinction between context-dependent and context-independent aspects of interpretation requires the characterisation of these aspects to be independent of each other. For the case in point this means that it should be possible to *state* the semantic composition of **believes** with **that he lost** independently of the interpretation of **he**. In Jacobson’s variable-free approach this is, however, impossible, since in order to state the semantic composition of **believes** with **that he lost** it is necessary to decide first on whether to use rule **g** or **z** in order to lift the denotation of **believes**.¹⁶ Put differently, in Jacobson’s approach we cannot state the result of semantic composition without knowing how to type-lift **believes**. This is why it does not suffice to claim that the actual choice between **g** and **z** rules constitutes the context-dependent aspect of interpretation.

It may be useful to stress that precisely because the interaction between context-independent and context-dependent aspects of interpretation is so complex it is all the more necessary to keep them conceptually apart. This conflation of context-independent and context-dependent aspects of interpretation undermines the possibility of analysing the *relation* between them, since this analysis *presupposes* that these two aspects are separate and thus separately characterisable.

5 Towards an alternative

As a useful first approximation, the meaning of **offends** can be regarded as an entity *m* which is dependent on, or equivalently needs to be saturated with, (the representation of) an individual offending and (the representation of) an individual offended. One way of representing the fact that an entity is unsaturated is by means of placeholders, so that ‘*--1*’ in ‘*--1*offends*--2*’ represents the dependency of the meaning of **offends** on an individual offending, and ‘*--2*’ represents the dependency on an individual offended.

First, note that under a natural and intuitive conception of meaning, the meaning of **offends** does not fix the order in which the dependencies must be saturated. Secondly, note that if the meaning of **offends** is saturated by two individuals *i* and *j* then *i* and *j* are actually part of the resulting meaning

¹⁶HK also conflate these aspects of interpretation, since the semantic combination cannot be stated independently from co-indexation and predicate abstraction.

‘ i offends j ’. This is unlike the case of saturating functions whose values are unstructured entities, e.g. the function $\lambda x.x + 1$ whose arguments and values are natural numbers, since under the assumption that numbers are unstructured entities the argument of this function (e.g. number 3) is not part of the value of the function (number 4). While the placeholders in the function $\lambda x.x + 1$ simply encode a dependency of the unstructured value on the argument of the function, the placeholders in the meaning of **offends** do not just represent the dependency of the meaning on another entity, but also the structure of the resulting entity.

If the values of functions are structured entities, then it is possible to distinguish between local and non-local dependencies as follows:

- A dependency is local iff the saturating entity i is an immediate part of the resulting entity.
- A dependency is non-local iff it is not the case that the saturating entity i is an immediate part of the resulting entity.

The distinction is important for mapping the phenostructure of meaning into a tectostructure. If we allow for the semantic operations to create or access non-local dependencies, then the mapping from the phenostructure of meaning to a tectostructure will require rules which need access to arbitrarily deeply embedded constituents. To give an example, consider that if the value of the function $\lambda x_t.\lambda y_e.\llbracket\text{believed}\rrbracket$ is assumed to be structured, then Jacobson’s semantic operator **z** *creates* a non-local dependency:

$$\mathbf{z}(\llbracket\text{believes}\rrbracket_{\langle t, \langle e, t \rangle \rangle}) = \lambda g_{\langle e, t \rangle}.\lambda y_e.(\llbracket\text{believes}\rrbracket(g(y)))(y)$$

This is essentially the reason why under Jacobson’s analysis the mapping from the phenostructure to the tectostructure of meaning requires non-local rules, although the semantic operations themselves have access only to local information.

Despite important differences, the two approaches discussed above share two important assumptions. First, that the meaning of some natural language expressions should be analysed in terms of functions. And secondly, that these functions are of a special kind, namely functions which take their arguments one at a time (Curry-ed or Schönfinkel-ed functions), so that the basic semantic operation is therefore functional application. Whereas the first assumption is simply another way of stating that the meaning of some expressions is an entity that needs to be saturated, the second assumption is much stronger in that it states that the meaning of some expressions is an entity that needs to be saturated *in a certain order*. To clarify this point consider four different analyses of the meaning of **offends**:

1. $\llbracket\text{offends}\rrbracket = _1\text{offends}_2$
2. $\llbracket\text{offends}\rrbracket = \lambda 2.\lambda 1._1\text{offends}_2$
3. $\llbracket\text{offends}\rrbracket = \lambda 1.\lambda 2._1\text{offends}_2$
4. $\llbracket\text{offends}\rrbracket = \lambda \langle 1, 2 \rangle._1\text{offends}_2$

The first analysis simply states that the meaning of **offends** is an entity that needs to be saturated twice. The second analysis states that (i) the meaning of **offends** is an entity that needs to be saturated twice, and that (ii) dependency 2 needs to be saturated before dependency 1. The third analysis states that (i) the meaning of **offends** is an entity that needs to be saturated twice, and that (ii) dependency 1 needs to be saturated before dependency 2. The fourth analysis states that (i) the meaning of **offends** is an entity that needs to be saturated twice, and that (ii) the dependencies are saturated simultaneously. What distinguishes the first analysis from the second, third and fourth analysis is that it does not specify how the entity should be saturated (whether in a certain order, as analysis 2 and 3, or simultaneously as in analysis 4).

This additional specification of how entities should be saturated allows for using the same semantic operator for combining different functions with their arguments. If the placeholders have to be saturated in a particular way, and the semantic operation can access this information, then there is no need for the semantic operations to distinguish dependencies other than by their order in the saturation sequence. This is why the *same* semantic operation can be used to saturate *different* dependencies. Note that in order to specify the order in which dependencies are saturated, it is necessary to refer to these dependencies. Standardly it is assumed (explicitly or implicitly) that there is a limited number of dependency types, so that dependencies are ordered with respect to their type (agent, patient, theme, location, etc.). To take stock, the analysis of some meanings in terms of Curried functions consists of the following claims:

- some meanings are unsaturated entities
- dependencies can be categorised into different types
- dependencies must be saturated in a certain saturation order, which is determined with reference to the type of the dependencies
- the semantic operator accesses dependencies by their saturation order

If, on the other hand, saturation order is not part of the meaning of **offends** (so that the dependencies do not have to be saturated in a particular way), then the semantic operations need to distinguish dependencies in a different way. I propose that semantic operations should distinguish dependencies directly by means of their type. So instead of (i) using the dependency type to specify the order in which the dependencies have to be saturated, and (ii) making the semantic operation sensitive to saturation order, I propose that semantic operators refer directly to the dependency type. Summing up, the main claims of the alternative proposal of semantic composition is:

- some meanings are unsaturated entities
- dependencies can be categorised into different types
- the semantic operators accesses dependencies by their type

Since the basic datum is the part-of relation between exponent-meaning pairs, the question of how many types of dependencies should be postulated depends among other things on what distinctions are made in the syntax.

So instead of postulating a saturation order and a semantic operation which is sensitive to saturation order, I postulate that the semantic operation is sensitive to the type of dependency:

$$O_t(PRED\{-t, \dots\}, ARG) = PRED\{ARG_t, \dots\}$$

To give an example, if we assume a dependency type $\langle ag \rangle$ for ‘agent dependency’, then the corresponding semantic operation $O_{\langle ag \rangle}$ is:

$$O_{\langle ag \rangle}(PRED\{--\langle ag \rangle, \dots\}, ARG) = PRED\{ARG_{\langle ag \rangle}, \dots\}$$

The first important consequence of this analysis is that saturated and unsaturated entities do not have to be combined in a certain order. To see why this is a desirable property, note that if we postulate that the patient dependency has to be saturated before agent dependency, then some extra machinery is needed if for some reason¹⁷ we want to combine first the agent with the verb. The second important consequence is that two meanings which are analysed as unsaturated entities are identical iff the dependencies are pairwise of the same type and the same metalinguistic expression connects them. If meanings are analysed as Curried functions, then two meanings are the same if (i) the dependencies are pairwise of the same type and the same metalinguistic expression connects them, and (ii) the dependencies are saturated in the same order. To appreciate this point, note that the function $\lambda x \lambda y. 2x + y$ is different from $\lambda y \lambda x. 2x + y$, and for the same reason $\lambda x \lambda y. (x \text{ offends } y)$ is different from $\lambda y \lambda x. (x \text{ offends } y)$. As pointed out in Kracht (2007a, 294f), this means that if we find VSO languages like Gaelic where we have (syntactic) reason to assume that verbs combine first with the subject, the saturation order of the meaning m of an exponent e would have to be different from English, and therefore an analysis using Curried functions would be claiming that e.g. the meaning of Gaelic verb *feic* (to see) actually means something different from the English verb *to see*.

The second important consequence of this alternative is that the semantic operations operate only on the immediate constituents and their dependencies.¹⁸ This means that if we can avoid postulating rules, which like the **z** rule introduce non-local dependencies, there will be no need for non-local rules mapping the phenostructure of meaning into the tectostructure of meaning. In what follows I will indicate with a rough sketch how to account for the phenomena which Jacobson’s **z** rule is used to account for without postulating rules which create non-local dependencies.

Instead of analysing the meaning of pronouns as (i) determined by an assignment function, or (ii) as being the identity function on individuals, I propose that the denotation of pronouns is a pair consisting of an entity e and a condition specifying (some) properties of e . So the denotation of **he** is $\langle e, \text{male}(e) \wedge \text{person}(e) \rangle$, whereas the meaning of **she** is $\langle e, \text{female}(e) \wedge \text{person}(e) \rangle$. In order to combine **[[offends]]** with **[[he]]** it is necessary to adjust the semantic operation such that it passes on the restriction on the entities introduced by pronouns e :

$$O_t(\langle PRED\{-t, \dots\}, COND \rangle, \langle x, COND(x) \rangle) =$$

¹⁷For example, coordination or interpretation of fragments.

¹⁸It may be useful to emphasise that placeholders are *representations* of dependencies, and that the semantic operations operate on the entities represented not on the entities representing.

$$\langle PRED\{x_t, \dots\}, COND \cup \langle x, COND(x) \rangle \rangle$$

Given this rule and the meanings of **he** and **offends** as below:

1. $\llbracket \text{offends} \rrbracket = \langle \neg_{\langle ag \rangle} \text{offends} \neg_{\langle pat \rangle}, \emptyset \rangle$
2. $\llbracket \text{he} \rrbracket = \langle e, \text{male}(e) \wedge \text{person}(e) \rangle$

the combination of these two meanings by semantic operation $O_{\langle ag \rangle}$ is:

$$O_{\langle ag \rangle}(\langle \neg_{\langle ag \rangle} \text{offends} \neg_{\langle pat \rangle}, \emptyset \rangle, \langle e, \text{male}(e) \wedge \text{person}(e) \rangle) = \\ \langle e_{\langle ag \rangle} \text{offends} \neg_{\langle pat \rangle}, \{ \langle e, \text{male}(e) \wedge \text{person}(e) \rangle \} \rangle$$

Note that when we represented the meaning of the pronouns we simply chose the name e as a representation of an entity whose properties are only partially specified by the condition. However, there is a clear sense in which the name we have chosen simply should not matter. In other words, any name should be as good as e in the specification of the meaning of the pronouns. To implement this requirement¹⁹ I follow an idea presented in Kracht (2002) and stipulate that, roughly, the semantic operation renames all variable names by e.g. adding a prime. Thus altered, the combination of $\llbracket \text{offends} \rrbracket$ with $\llbracket \text{he} \rrbracket$ results in:

$$O'_{\langle ag \rangle}(\langle \neg_{\langle ag \rangle} \text{offends} \neg_{\langle pat \rangle}, \emptyset \rangle, \langle e, \text{male}(e) \wedge \text{person}(e) \rangle) = \\ \langle e'_{\langle ag \rangle} \text{offends} \neg_{\langle pat \rangle}, \{ \langle e', \text{male}(e') \wedge \text{person}(e') \rangle \} \rangle$$

Combining this with the meaning of **her** by the rule $O_{\langle pat \rangle}$ results in:

$$O_{\langle pat \rangle}(\langle e'_{\langle ag \rangle} \text{offends} \neg_{\langle pat \rangle}, \{ \langle e', \text{male}(e') \wedge \text{person}(e') \rangle \} \rangle, \langle e, \text{female}(e) \wedge \text{person}(e) \rangle) = \\ \langle e''_{\langle ag \rangle} \text{offends} e'_{\langle pat \rangle}, \{ \langle e'', \text{male}(e'') \wedge \text{person}(e'') \rangle, \langle e', \text{female}(e') \wedge \text{person}(e') \rangle \} \rangle$$

Exponents with such a meaning can be said to be true relative to a model iff there are individuals a and b in the model such that (i) a offends b (ii) a is a male person and (iii) b is a female person.

The third step in the sketch of an alternative is to separate binding and scope phenomena from semantic composition – since binding and scope are generally context-dependent, whereas semantic composition as part of an account of linguistic meaning is concerned with context-invariant aspects of interpretation. The high likelihood that linguistic meaning and world knowledge are used simultaneously in the interpretation of an exponent should not be allowed to undermine the distinction between context-independent linguistic meaning and world knowledge without extensive argument. First I will sketch how to analyse quantified exponents and then I indicate how to analyse co-indexation phenomena. The basic idea (developed further in Klein (2008)) is that the meaning of quantified exponents like e.g. **no student** consists in a set X , a restrictor on X , and an additional condition on X , so that the semantic composition is essentially like the composition of pronouns (given the necessary adjustment from pairs to triples). This means that the property is not predicated directly of individuals but first of a set of individuals, and that relations are between sets of individuals.

¹⁹Fine (2000) and Kracht (2007b) refer to this property as alphabetical innocence.

Under this view, scope phenomena can be analysed in terms of different ways of *evaluating* a relation between sets in terms of a relation between individuals. To give an example, the meaning

$$\langle X''_{\langle ag \rangle} \text{ offends } X'_{\langle pat \rangle}, \{ \langle X'', \llbracket \text{student} \rrbracket(X''), |X''| = 2 \}, \langle X', \llbracket \text{professor} \rrbracket(X'), |X'| = 3 \rangle \rangle$$

of the expression

$$(15) \quad \text{Exactly two students offended exactly three professors.}$$

can be evaluated in at least two different ways. According to the first evaluation there is a set X'' such that $\llbracket \text{student} \rrbracket(X'') \wedge |X''| = 2$ and

- for all elements e of X'' it holds that

$$\langle e_{\langle ag \rangle} \text{ offends } X'_{\langle pat \rangle}, \{ \langle X', \llbracket \text{professor} \rrbracket(X'), |X'| = 3 \rangle \} \rangle$$

- and for no element in $\{x | \llbracket \text{student} \rrbracket(x)\} - X''$ does it holds that

$$\langle e_{\langle ag \rangle} \text{ offends } X'_{\langle pat \rangle}, \{ \langle X', \llbracket \text{professor} \rrbracket(X'), |X'| = 3 \rangle \} \rangle$$

According to the second evaluation there is a set X' such that $\llbracket \text{professor} \rrbracket(X') \wedge |X'| = 3$ and

- for all elements e of X' it holds that

$$\langle X''_{\langle ag \rangle} \text{ offends } e_{\langle pat \rangle}, \{ \langle X'', \llbracket \text{student} \rrbracket(X''), |X''| = 2 \rangle \} \rangle$$

- and for no element in $\{x | \llbracket \text{professor} \rrbracket(x)\} - X'$ does it holds that

$$\langle X''_{\langle ag \rangle} \text{ offends } e_{\langle pat \rangle}, \{ \langle X'', \llbracket \text{student} \rrbracket(X''), |X''| = 2 \rangle \} \rangle$$

Note that in this analysis the result of the semantic composition of the meaning $\langle X, REST, COND(X) \rangle$ of a quantified exponent can be stated independently of how the relation involving the set X is evaluated, and therefore semantic composition which is a context-independent aspect of interpretation is characterisable independently of the scope relation, which is a context-dependent aspect of interpretation.

The fourth step is a sketch of the analysis of binding phenomena. As argued above, since binding is a context-dependent aspect of interpretation the semantic composition should not be made dependent on binding. Given the evaluations presented above, the desired ‘bound’ meaning of the sentence:

$$(16) \quad \text{No boy thought that he lost.}$$

is

$$\langle X''_{\langle ag \rangle} \text{ thought } [X''_{\langle ag \rangle} \text{lost}]_{\langle pat \rangle}, \{ \langle X'', \llbracket \text{boy} \rrbracket(X''), X'' = \emptyset \rangle \} \rangle$$

Evaluating this meaning we get that there is a set X'' such that $\llbracket \text{boy} \rrbracket(X'') \wedge X'' = \emptyset$ such that

- for all individuals e in X'' it holds that

$$\langle e_{\langle ag \rangle} \text{ thought } [e_{\langle ag \rangle} \text{lost}]_{\langle pat \rangle}, \emptyset \rangle \rangle$$

- for no individuals e in $\{x \llbracket \text{student} \rrbracket(x)\} - X''$ does it holds that

$$\langle e_{\langle ag \rangle} \text{ thought } [e_{\langle ag \rangle} \text{lost}]_{\langle pat \rangle}, \emptyset \rangle$$

The last remaining question is how to identify the value of the agent dependency of $\llbracket \text{thought} \rrbracket$ with the agent dependency of $\llbracket \text{lost} \rrbracket$. I propose to analyse binding as the context-dependent imposition of conditions on the saturation of dependencies. For the present example this means that after the combination of $\llbracket \text{thought} \rrbracket$ with $\llbracket \text{he lost} \rrbracket$ we add to the set of conditions on variables a new condition to the effect that the entity saturating the two agent dependencies is identical. To be explicit I postulate a rule IDENTIFY, which when applied to $\llbracket \text{thought} \rrbracket$ and $\llbracket \text{he lost} \rrbracket$ results in:

$$\text{IDENTIFY}(\langle x''_{ag} \text{ thought } [e' \text{lost}]_{pat}, \langle e', \text{male}(e') \wedge \text{person}(e') \rangle \rangle = \\ \langle x'''_{ag} \text{ thought } [x''' \text{lost}]_{pat}, \langle x''', \text{male}(x''') \wedge \text{person}(x''') \rangle \rangle$$

Combining this with the meaning of **no student** results in:

$$\langle X''''_{ag} \text{ thought } [X''''_{ag} \text{lost}]_{pat}, \{ \langle X''''', \llbracket \text{boy} \rrbracket(X'''''), X'''' = \emptyset \rangle, \langle X''''', \llbracket \text{male} \rrbracket(X''''') \wedge \llbracket \text{person} \rrbracket(X''''') \rangle \}$$

6 Conclusion

Of course, this sketch is only a sketch, so that a number of important issues need to be further developed or clarified. To mention only a three, the theory of quantification presented here is still in its embryonic stage and needs to be developed considerably in order to become a serious competitor. However, as pointed out in Klein (2008), the fact that the conservativity of natural language determiners is a consequence of this theory, and not simply a typological curiosity, is at least encouraging. The proper characterisation of the interaction between context-dependent and context-independent aspects of interpretation has also been beyond this brief sketch, but at least the investigation of this interaction is made possible by not conflating the characterisation of these aspects of interpretation. And thirdly, the question whether this semantic theory reifies dependencies (and what this would amount to) needs further clarification.

References

- Curry, H. (1963). Some logical aspects of grammatical structure. In *Structure of Language and Its Mathematical Aspects: Proceedings of the Twelfth Symposium in Applied Mathematics*, pp. 56–68. American Mathematical Society.
- Dowty, D. (2007). Compositionality as an empirical problem. In C. Barker and P. Jacobson (Eds.), *Direct Compositionality*, pp. 23–101. Oxford: Oxford University Press.
- Fine, K. (2000). Neutral relations. *The Philosophical Review* 109(1), 1–33.
- Frege, G. (1923). Logische Untersuchungen. Dritter Teil: Gedankengefüge. *Beiträge zur Philosophie des Deutschen Idealismus III*, 36–51.

- Groenink, A. (1997). *Surface without Structure*. Ph. D. thesis, Utrecht University.
- Heim, I. and A. Kratzer (1998). *Semantics in Generative Grammar*. Oxford: Blackwell.
- Jacobson, P. (1999). Towards a variable-free semantics. *Linguistics and Philosophy* 22(2), 117–184.
- Jacobson, P. (2007). Direct compositionality and variable free semantics: the case of "principle b" effects. In *Direct Compositionality*, Oxford Studies in Theoretical Linguistics. New York: Oxford University Press.
- Janssen, T. M. V. (1986). *Foundations and Applications of Montague Grammar — Part 2: Applications to Natural Language*, Volume 28 of *CWI Tract*. Amsterdam: Centrum voor Wiskunde en Informatica.
- Joshi, A. K., K. Vijay-Shanker, and D. Weir (1991). The convergence of mildly context-sensitive grammar formalisms. In T. W. Peter Sells, Stuart M. Shieber (Ed.), *Foundational Issues in Natural Language Processing*, pp. 31–82. MIT Press.
- Klein, U. (2008). Nominal quantification and evaluation. Manuscript.
- Kracht, M. (2002). Referent systems and relational grammar. *Journal for Logic, Language and Information*, 251–286.
- Kracht, M. (2007a). Compositionality: the very idea. *Research on Language and Computation* 5(3), 287–308.
- Kracht, M. (2007b). The Emergence of Syntactic Structure. *Linguistics and Philosophy* 30, 47–95.
- Kracht, M. (2008). Interpreted Languages and Compositionality. Manuscript.
- Larson, R. and G. Segal (1995). *Knowledge of Meaning*. Cambridge, MA: The MIT Press.
- Sag, I. A. (2007). Remarks on locality. In S. Müller (Ed.), *The Proceedings of the 14th International Conference on Head-Driven Phrase Structure Grammar*, Stanford, pp. 394–414. CSLI Publications.
- Stabler, E. (2004). Varieties of crossing dependencies. *Cognitive Science* 28(5), 699–720.
- Vijay-Shanker, K. and D. J. Weir (1994). The equivalence of four extensions of context-free grammars. *Mathematical Systems Theory* 27(6), 511–546.