THE LOGICAL FORM: A THEORY AND ITS APPLICATION TO GERMAN*

Soo-Song Shin and Min-Haeng Lee

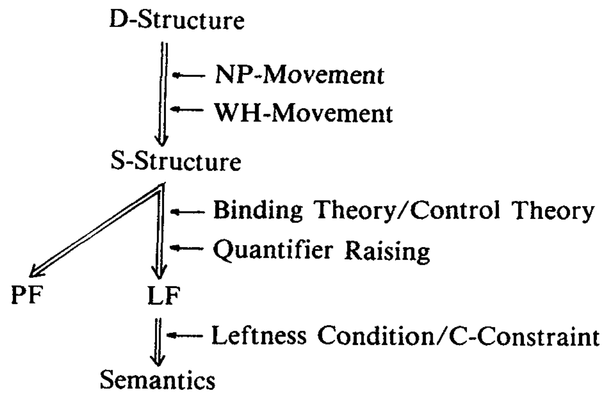
The purpose of this paper is to present a method of semantic interpretation of the logical form (LF) which has recently been developed in the GB-Theory. For this purpose we develop two kinds of indexing filter mechanisms. Only the well-formed LFs of the sentences which are filtered out from the S-Structures and the LFs by the two indexing filter mechanisms are translated into the structures of the languages of intensional logic. We will call this structure of intensional logic the LF's. We exemplify in this paper some translation rules based on Bartsch (1977, 1979). There are several new rules developed in this paper, for instance, rules for translating controlled PRO and arbitray PRO, rules for translating null θ-role terms, rules for translating quantifier phrases and their variables left by quantifier raising, and rules for detransitivization, etc.

The purpose of this paper is to present a method of semantic translation of the logical form (LF) which has recently been developed in the Government and Binding Theory. For this purpose we develop two kinds of indexing filter mechanisms. The first mechanism concerns the Binding Theory (BT, henceforth) and the PRO indexing filter revised from the Control Theory. This mechanism is applied to the S-Structure. The second indexing filter mechanism concerns the Leftness Condition and the C-Constraint (Higginbotham 1980) which are applied to the LF in order to derive only well-formed LFs of sentences.

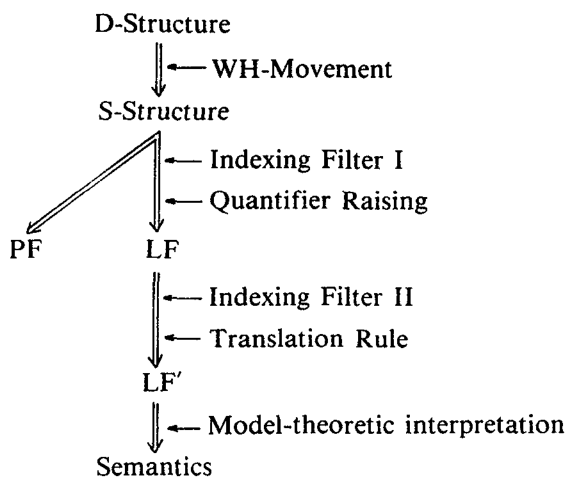
Only the well-formed LF's of the sentences which are filtered through from the S-Structures and the LF's by the two indexing filter mechanisms mentioned above are translated into the structures of the languages of intensional logic. We will call each of these new structures of intensional logic the LF's. These LF's receive then the model theoretic interpretation. In the following, two contrasting grammatical models are compared with each other: one is that of the GB-Theory and the other is a modified version of the GB-Theory for German developed by us.

* This paper was presented at the 84 Matsuyama Workshop on Formal Grammar, Matsuyama University, December 17-19, 1984. We are grateful to Sebastian Löbner, Universität Düsseldorf and Kiyong Lee, Korea University for their very helpful comments and suggestions.

A.



B.



I

Chomsky's BT and Control Theory, Chomsky's Leftness Condition, and Higginbotham's C-Constraint treat the indexing problems among NPs. There is, however, a great difference between the BT and the Control Theory on the one hand, and between the Leftness Condition and the C-Constraint on the other hand, because the former rules assign indices to NPs while the latter filter out falsely indexed NPs. First we examine BT and CT, then revise them for application to German as an Indexing Filter Rule (I).

The BT of Chomsky (1981) is considered as a theory by which the same index of an antecedent is assigned to the NP-trace, the reciprocal, reflexive, the pronominal and the R-expression. Shin and Lee (1984) proposed to remove the NP-movement from GB, so we need not examine any BT which concerns the NP-trace. Look at the following sentences:

(1) a. *Hans-Jakob*$_i$ verdächtigte *sich*$_i$/*ihn.
b. Hans-Jakob$_i$ wußte, daß man ihn$_i$/*sich$_i$ verdächtigte.
c. Die Kinder$_i$ lieben sich$_i$/*sie$_i$.
d. *Peter und Inge*$_i$ sprechen über sich$_i$/*sie$_i$.
e. Sie$_i$ haben sich$_i$/*sie$_i$ lange nicht gesehen.
f. *Nikolaus$_i$ sagte, Nikolaus$_i$ komme morgen.
g. *Er$_i$ sagte, Nikolaus$_i$ komme morgen.
h. *Wen liebte er$_i$ am besten?

When we compare (1a-e), we see that the positions of the reflexive *sichs* and the personal pronouns are complementarily distributed. The ungrammaticalness of the sentences (1f-h) seems due to the falsely indexed relationship among NPs, i.e., between Nikolaus$_i$ and Nikolaus$_i$, between *er*$_i$ and Nikolaus$_i$, and between *wen*$_i$ and *er*$_i$. Chomsky's BT explains very well why the sentences of (1f-h) are ungrammatical. Look at the BT of Chomsky (1981).

(2) a. An anaphor is bound in its governing category.
b. A pronominal is free in its governing category.
c. An R-expression is free.
(i) β is a governing category for α if and only if β is the minimal category containing α, a governor of α, and a SUBJECT accessible to α
(ii) A SUBJECT is AGR or the subject of an infinitive, a gerund, an NP or a small clause.
(iii) α is accessible to β if and only if β is in the c-command domain of α and assignment to β of the index of α would not violate $*[\gamma \ldots \delta \ldots]$, where γ and δ bear the same index.

Here the anaphor indicates reflexives, reciprocals and NP-traces, and the pronominal the personal pronouns. On the other hand there are two kinds of R-expressions. To the one kind belong those NPs which have a potentially referential head, e.g., *Hans, Buch, Wahrheit,* etc. To the other kind belong the variables left as a result of application of WH-movement and quantifier raising. To the governor belong the categories N, A, V, P and those morphemes with a tense feature. The definition of Binding is as follows:

(3) α is X-bound by β if and only if α and β are coindexed, β c-commands α, and β is in an X-position.

Now let us try to explain the ungrammaticalness of (1a-h) with the conditions stated in (2) and (3). The ungrammaticalness of sentence (1a) is due to the fact that the pronoun *ihn*$_i$ is bound by Hans-Jakob$_i$ in the governing category (GC) which is the whole sentence of (1a). This violates BT (B). In (1b) the GC of *ihn*$_i$ and *sich*$_i$ is the subordinate clause. The pronominal *ihn*$_i$ is ungoverned in its GC and therefore grammatical. On the other hand *sich*$_i$ is ungoverned and therefore violates the BT (A). In a similar way we can explain the grammatical and ungrammatical sentences of (c-e) containing the reflexive *sich*$_i$ and the pronominal *sie*$_i$ with BT (A) and (B). Those examples of (1f-h) violate BT (C). Nikolaus$_i$ in (f-g) is X-bound by either *er*$_i$ or *Nikolaus*$_i$, even though it must be free because it is an R-expression. In the same way (1h) is ungrammatical because the variable left by the WH-movement of *wen*$_i$ is X-bound by the pronominal *er*$_i$ and therefore violates the BT (C).

It might be true that we could explain many linguistic phenomema by the BT. However, there are still many problems left open in German. First we introduce those examples which can not be appropriately handled with BT. The following examples, i.e. the reflexives in (4b) and (5b) do not obey BT (A).

(4) a. Hans schlägt mich.
    b. Ich kämme *mich*.

(5) a. Hans schlägt dich.
    b. Du kämmst *dich*.

In German there is no morphological distinction between the pronominal and the reflexive of the first and the second person. Therefore, BT, which is considered in our paper as an indexing filter rule, cannot be applied to the first and the second person pronoun. On the other hand there are also German reflexives which have the morphological form of *sich*, but do not have any reflexive function and constitute only part of the predicate construction ('Verbteil'). Look at the following examples:

(6) a. Hans erholt *sich*.
    b. Peter freut *sich* sehr über die Nachricht.
    c. Bedienen Sie *sich* bitte dieses Wörterbuchs!

The *sichs* in (6a-c) are functionally quite different from those of the following:

(7) a. Inge meldet *sich* im Auslandsamt an.
    b. Hans wäscht *sich* einmal in der Woche.
    c. Pater rasiert *sich* täglich zweimal.
    d. Maria stellt *sich* der Dame vor.

The *sichs* in (6a-c) do not have any referential index because they are part of the predicate construction, while the *sichs* in (7a-d) have the same index as that of their antecedents. We can say that only the *sichs* in (7a-d) have real reflexive functions. The *sichs* in the following sentences have the meaning of reciprocal rather that of a reflexive:

(8) a. Die Studenten begrüßen *sich*.
    b. Hans und Peter schlagen *sich* im Klassenzimmer.

(9) a. Wir treffen *uns* heute nachmittag.
    b. Wann seht ihr *euch* wieder?

Let us look at another problem of BT concerning the possessive pronoun of German which seems to have two functions, namely anaphoric and reflexive functions. Consider the following examples:

(10) a. Ich schätze auch *seinen* Vater.
b. *Er* liebt *seine* Frau.

(11) a. *Die Kinder* dachten, daß *ihre* Bilder verkauft wurden.
b. *Sie* verkauften *ihre* Bilder.

(12) a. Peter wäscht *seinen* (= z.B. Günthers) Wagen.
b. Peter wäscht *seinen* Wagen.

In (10a) the *seinen* belongs to the pronominal according to BT while the *seine* in (10b) is considered as a reflexive rather than as a pronominal. This distinction corresponds to the *ihre* in (11a, b) and *seinen* (12a, b). They have the same morphological form, but are functionally different from each other. Under passivization we can get only grammatical sentences from the pronominal use of *sein* or *ihr*. Look at the following examples:

(13) a. Ich schätze auch *seinen* Vater.
b. *Sein* Vater wird von mir geschätzt.
c. *Er* liebt *seine* Frau.
d. **Seine* Frau wird von *ihm* geliebt.

This fact indicates that BT can not appropriately be applied to the possessive pronoun in German.

Up to now we have discussed problems arising from the application of the BT to German. For an appropriate application of the BT to German as an indexing filter rule the range of the BT must be severely restricted. Let us come to the next indexing filter rule revised from the Control Theory of Chomsky (1981). The Control Theory defines what the PRO as the subject of an infinitive clause actually refers to, i.e. what the antecedent of the PRO is. Chomsky's Control Theory assigns an index to the PRO according to the lexical property of the predicate of the main clause. In Shin and Lee (1984) it was argued that every index of an NP is already assigned on the level of D-Structure. Therefore Control Theory is according to our claim superfluous. In fact Chomsky's Control Theory has only the function of copying the lexical property indicated by Control Features to the S-Structure. This is in a sense a useless repetition of the same work. Now we leave the function of Control Theory to the lexical property, and instead we suggest for our purposes the following PRO-indexing filter rule:

(14) The indices of PROs are assigned according to the control-features indicated in the lexical entry of the head of the main predicate.

We try now to show how this definition appropriately explains the ungrammaticalness of the following sentence:

(15) **Boris$_i$* verführte *Katharina$_j$* dazu, PRO$_i$/PRO$_{arb}$ von der Heidelbeermarmelade zu naschen.

The control feature of the main predicate *verführen* indicates [Pa-K] and the PRO should have the index of the patient Katharina$_j$, however, it has the same index as that of Boris$_i$. From this we know that (15) is an ungrammatical sentence.

Let us now introduce the indexing filter rule (II) which is applied on the level of LF. This rule is composed of the Leftness Condition of Chomsky (1976) and the C-Constraint of Higginbotham (1980). Chomsky needed a Leftness Condition to describe weak crossover phenomena. It is defined as follows:

(16) The variable can not be the antecedent of a pronoun to its left.

According to this definition the ungrammaticalness of the following sentence can be explained:

(17) a. **Wen$_i$* liebt *seine$_i$* Frau?
b. **Wen$_i$* [*seine$_i$* Frau liebt x$_i$]

(18) a. **Seine$_i$* Frau liebt *jeden Mann$_i$*.
b. **Jeden Mann$_i$* [*seine$_i$* Frau liebt x$_i$]

With only BT and the PRO indexing filter rule we cannot explain why (17a) and (18a) are ungrammatical sentences. In this case the Leftness Condition forsees correctly the ungrammaticalness of (17) and (18). On the other hand the following sentences are grammatical according to the Leftness Condition (16).

(19) a. Niemand liebt seine Frau.
b. Niemand$_i$ [x$_i$ liebt seine$_i$ Frau]

(20) a. Jedes Kind liebt seine Mutter.
b. Jedes Kind$_i$ [x$_i$ liebt seine$_i$ Mutter]

(21) a. Wen liebt seine Mutter?
b. Wen$_i$ [x$_i$ liebt seine$_i$ Mutter]

In the LFs of (19-21) the variables appear to the left of their antecedents and do not violate the Leftness Condition. The ungrammaticalness of the following examples of Edmonson (1982: 191) can also be explained according to the Leftness Condition.

(22) a. **Seine$_i$* Frau wurde von *wem$_i$* getötet?
b. **Seine$_i$* Frau tötet *wen$_i$*?
c. **Der Chirug$_i$*, von *dem$_i$* *seine$_i$* eigene Frau operiert wurde, wurde angeklagt.

In (22a) and (b) variables appear to the left of *seine$_i$* after the application of WH-movement. They violate therefore the Leftness Condition. (22c) violates also the Leftness Condition if the relative pronoun *von dem*$_i$ is considered to be moved from behind the relative clause subject.

In order to regard it as an indexing filter rule we propose to modify the Leftness Condition as follows:

(23) Leftness Condition: A variable cannot be coindexed to the pronoun to its left.

There are, however, many ungrammatical sentences which do not violate the Leftness Condition. Look at the following sentence and its logical form:

(24) a. **Wessen*$_i$ Mutter liebt er$_i$?
b. wer$_i$[[x_i^{gen} Mutter]$_j$ liebt er$_i$ x_j]

As the x_j is not coindexed with the pronoun er$_i$, we can not expain the ungrammaticaness of (24) with the Leftness Condition. Therefore Higginbotham suggests the following C-Constraint which marks the LF as ungrammatical:

(25) (C): ...[$_{NP}$ ... x_i ...]$_j$ ... pronoun$_i$ ... x_j

In conformity with the C-Constraint the ungrammaticalness of the following English sentences and the corresponding German sentences can be explained:

(26) a. Everybody in *some city* hates *its* climate.
b. [Some city$_i$][everybody in x_i]$_j$ [x_j hates it$_i$s climate]

(27) a. **Its* climate is hated by everybody in *some city*.
b. *[Some city$_i$][everybody in x_i]$_j$ [it$_i$s climate is hated by x_j]

(28) a. Jeder in *irgendeiner* Stadt haßt *deren* Klima.
b. [(irgend)$_i$eine Stadt$_i$][jeder in x_i]$_j$ [x_j haßt deren$_i$ Klima]

(29) a. **Deren* Klima wird gehaßt von jedem in *(irgend) einer Stadt*.
b. *[(irgend) eine Stadt$_i$][jeder in x_i]$_j$[deren$_i$ Klima wird gehaßt von x_j]

The following few sentences cannot be, however, appropriately handled by the Leftness Conditions.

— *Wem*$_i$ gibt *seine*$_i$ Frau jeden Morgen einen Kuß?
— *Wen*$_i$ *seine*$_i$ Frau liebt, der muß ein glücklicher Mann sein.
— Irgendjemand hat seinen Hut vergessen, aber *seinen*$_i$ Schirm hat *niemand*$_i$ liegen lassen.

In this paper we let the solution of these problems open.

There seems to be a certain ordering of application among those rules belonging to our two different indexing filter mechanisms. BT and the PRO indexing rule precede the Leftness Condition and the C-Constraint because the former rules are applied on the S-Structures while the latter on the LFs. Between BT and the PRO indexing filter rule we need not give any ordering of application because the domain of their rule application is different from each other. The BT concerns pronouns, anaphors and R-expressions while the PRO indexing filter rule concerns only the assignment of indices for PRO elements. On the other hand, the Leftness Condition precedes the C-Constraint as shown above. In summary the following ordering among the rules is given:

$$(30)\quad \begin{array}{ccc} \left\{\begin{array}{c}\text{BT}\\ \text{PRO-indexing}\end{array}\right\} & \rightarrow & \underbrace{\text{Leftness Condition} \rightarrow \text{C-Constraint}} \\ \downarrow & & \downarrow \\ \text{Filter rule on} & & \text{Filter rule on} \\ \text{S-Structure} & & \text{LF} \end{array}$$

Now the indexing filter mechanisms filter out the mapping of the ungrammatical sentences from the S-Structures and the LFs into the LF's. The LF's are the structures of intensional logic and we acquire these LF's from the LFs by applying translation rules which are similar to those of Montague Grammar. Let us look at the problem of the representation of LF's which can receive model theoretic semantic interpretation.

II

In the following section we give examples of some translation rules which are based on R. Bartsch (1977, 1979). First we introduce the translation of term phrases which are treated in some contexts as extensional, but in other contexts as intensional. The following is a translation rule combining a term phrase with an n-place verb:

(31) T_{112}: If α'' is the translation of α' as a T, and $\lambda x_1 \dots x_n\ \beta''(x_1, \dots, x_n)$, with n places, is the translation of β' as a V^n, then the translation of $(\alpha', i)(\beta')$ is $\lambda x_1 \dots x_{i-}\ x_{i+} \dots x_n\ (\alpha''(\lambda x_i \beta''(x_1, \dots, x_{i-}, x_i, x_{i+}, \dots, x_n)))$, with x_{i-} as the variable that precedes x_i and x_{i+} as the variable that follows x_i.

If an n-place verb has an argument having intensional reading in its i-th place, we have the following translation of the verb:

(32) $\lambda x_1 \dots \wp_i \dots x_n\ \beta''_{*i}(x_1, \dots, \wp_i, \dots, x_n)$

A term phrase α' is translated as follows if it has an extensional reading: $\alpha'' = \lambda P \dots$

If a term phrase has, however, an intensional reading, it is translated as: $\alpha''_* = \lambda \wp \wp (\hat{}\lambda P \dots)$

Next, we need a syntactic rule and a translation rule treating the concatenation of the copula *sein* and the predicative adjective as follows:

(33) S_{35}: If α is an auxiliary verb and β a PR^n, then $\alpha(\beta)$ is a V^n, where PR^n is a predicative adjective.

T_{35}: If α' is an auxiliary verb *sein* and β'' is the translation of β' as a PR", then β'' is the translation of $\alpha'(\beta')$, i.e. *sein* does not change the semantic value of a predicative adjective.

example: *rot sein* is represented syntactically as $(\text{sein}'_{HV}\ (\text{rot}'_{PR})_V)$ and translated into intensional logic simply as rot".

Let us turn now to the treatment of subject and object clauses which are understood as normal term phrases:

(34) S_{42}: If β' is a sentence, then *daß*(β') is a term.
T_{42}: If β'' is the translation of β', then $\lambda\mathcal{P}\mathcal{P}\,(^\wedge\beta'')$ is the translation of daß(β'), where P is a variable over predicates of senses of sentences.

For instance, the concatenation of the verbs *glauben* and *erwarten* with their object clauses is translated into intensional logic as follows:

(35) a. λx glauben"(x, S)
b. λx erwarten"(x, S), where S is understood as a variable over senses of sentences.

With S_{42} and T_{42} we can describe the syntactic derivation and its translation into intensional logic for the following IV-phrases:

(36) a. glaubt, daß Maria glücklich ist
$\lambda x((\lambda\mathcal{P}\mathcal{P}\,(^\wedge\text{glücklich}''(m))(\lambda S\ \text{glaubt}''(x, S))$
$\Rightarrow \lambda x\ \text{glaubt}''(x, {}^\wedge\text{glücklich}''(m))$

b. erwartet, daß Peter gewinnt
$\lambda x((\lambda\mathcal{P}\mathcal{P}\,(^\wedge\text{gewinnt}''(p))(\lambda S\ \text{erwartet}''(x, S))$
$\Rightarrow \lambda x\ \text{erwartet}''(x, {}^\wedge\text{gewinnt}''(p))$

For our purpose those rules given above are enough, and we try now to introduce our new rules for mapping the LF into the LF′ of intensional logic. Our rules are restricted thereby only for the treatment of a controlled and an arbitrary PRO element, a null-θ term, quantificational phrase with its variable, and a detransitivized passive phrase.

The meaning of PRO is new in usual logical language. The PRO element can be divided into two kinds. One concerns the case where it has as its antecedent a coindexed R-expression within the sentence. The other concerns the case where it has its antecedent outside the sentence. We write the PRO of the former case as $\text{PRO}_{i/j}$ and the PRO of the latter case as PRO_{arb}. The translation of $\text{PRO}_{i/j}$ is taken over from its antecedent, i.e. from its controller. Look at the following sentence and its logical form.

(37) a. Peter scheint Maria zu lieben.
b. Peter_i scheint [$_{\bar{S}}$ PRO_i Maria zu lieben]

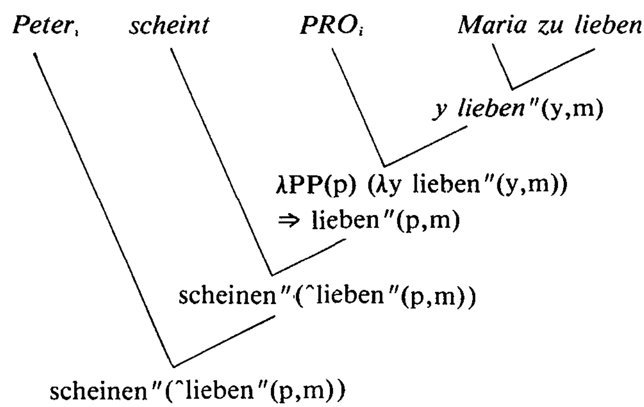
In (37b) we know that the subject *Peter* has no θ-role because the verb *scheinen* does not give any θ-role to its grammatical subject, and therefore does not contribute to the meaning of the sentence. We assume rather that the *Peter* gives its meaning to the $PRO_{i/j}$. In order to describe such a construction as (37b), we need the following translation rule for the null θ-role term:

(38) T_{23}: If α is a null θ-role term and β'' is the translation of β' as a V^n, then the translation of $\alpha'(\beta')$ is β''.

Let us now try to translate step by step the LF (37b) into the LF′ of intensional logic.

(39) 1. Maria zu lieben $\Rightarrow \lambda y$ lieben″(y,m)
2. PRO_i Maria zu lieben $\Rightarrow \lambda PP(p)(\lambda y$ lieben″(y,m))
$\Rightarrow$ lieben″(p,m)
3. Peter scheint Maria zu lieben $\Rightarrow$ scheinen″(^lieben″(p,m))

The syntactic derivation and semantic translation of the above can be given in the following structure:

(40)


The result of the translation of (39) step 3 shows that the verb *scheinen* takes the whole clause translation *lieben″(p,m)* as its argument, but not the grammatical subject *Peter*. This translation reflets very well the semantic relationship between the constituents of the sentence.

Let us now turn to the treatment of the arbitrary PRO which does not have an antecedent within the sentence. Look at the following sentence and its logical form:

(41) a. Es ist schwer, Deutsch zu lernen.
b. Es ist schwer [$_{\bar{S}}$ PRO_{arb} Deutsch zu lernen]

In order to translate the logical form into the structure LF′ of intensional logic we need the following translation rule for the PRO_{arb}.

(42) T_{24}: If α' is PRO_{arb} and $\lambda x_1 \ldots x_n \beta''(x_1, \ldots, x_n)$ is the translation of β' as a V^n, then the translation of $(\alpha', i)(\beta')$ is $\lambda x_1 \ldots x_{i-}, x_{i+} \ldots x_n \exists y(\beta''(x_1, \ldots, x_{i-}, y, x_{i+}, \ldots, x_n))$

With the T_{24} let us try to translate step by step the LF (41b) into LF′.

(43) 1. Deutsch zu lernen
λx lernen″(x,d)
2. PRO_{arb} Deutsch zu lernen
$\exists y$[lernen″(y,d)]
3. ist′ schwer ⇒ schwer″
4. es ist schwer ⇒ λS schwer″(S)
5. es ist schwer [$_S PRO_{arb}$ Deutsch zu lernen]
$\lambda \mathcal{P} \mathcal{P}(\hat{}\, \exists y$[lernen″(y,d)])($\hat{}\lambda S$ schwer″(S))
λS schwer″(S)($\hat{}\exists y$ lernen″(y,d)) ⇒
schwer″($\hat{}\exists y$[lernen″(y,d)])

The syntactic derivation and the corresponding semantic translation of (41) can be given in the following structure:

(44) *es ist schwer* [PRO_{arb} *Deutsch zu lernen*]

λS schwer″(S) λx lernen″(x,d).

$\exists y$[lernen″(y,d)]

schwer″($\hat{}\exists y$[lernen″(y,d)])

The quantificational phrases and their variables left by an application of quantifier raising play very important roles in GB-Theory. The variables of GB-Theory are, however, understood as namelike expressions and therefore they are quite different from those variables of the entity type in logic. In the following we write the variables of the namelike expression as $VA_{i/j}$ and the variables of the entity type as x, y, or z. The $VA_{i/j}$ belongs to the term phrase, and is translated into intensional logic as $\lambda PP(v_i)$. Let us try now to translate the logical form of the following sentence in which a VA_i appears:

(45) a. Hans liebt ein Mädchen.
b. Ein Mädchen$_i$[$_S$Hans liebt VA_i]

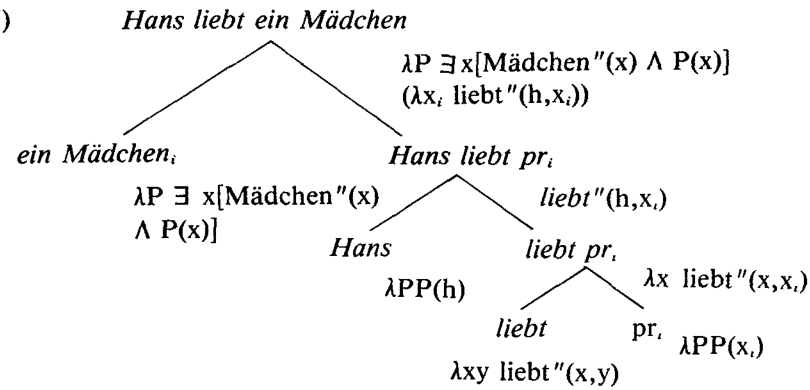
The logical form (45b) is translated into the LF′ of intensional logic as follows:

(46) 1. VA_i ⇒ $\lambda PP(V_i)$
2. liebt VA_i ⇒ $\lambda x\, \lambda PP(v_i)(\lambda y$ lieben″(x,y))
⇒ λx lieben″(x,v_i)

3. Hans liebt $VA_i \Rightarrow \lambda PP(h)(\lambda x\ lieben''(x,v_i))$
$\Rightarrow lieben''(h,v_i)$

Now we need some translation rules concerning the concatenation of the quantifier phrase *ein Mädchen* with the category S including VA_i. The LF (45b) reminds us of the derivation of the sentence with a quantificational phrase in Montague Grammar. Let us compare LF (45b) with the following derivation.

(47)



In Montague Grammar sentence (47) is derived by concatenation of the quantifier phrase *ein Mädchen* with the open sentence *Hans liebt pr*$_i$. The rule needed for such concatenation is called a quantificational rule. We can use the following very similar translation rule mapping LF (45b) into the LF′ of intensional logic.

(48) T_{36}: IF α'' is the translation of α' as a QP (quantificational phrase) and β'' the translation of β' as an open sentence wiht a VA(riable)$_i$, then the translation $\alpha'(\beta')$ is $\alpha''(\lambda v_i(\beta''))$, where the VA_i is translated into $\lambda PP(v_i)$

By using T_{36} we can now proceed with the translation of (45b) after the step (46) 3.

(46) 4. ein Mädchen $\Rightarrow \lambda P\ \exists x[Mädchen''(x) \wedge P(x)]$
5. ein $Mädchen_i$ [$_s$ Hans liebt VA_i] $\Rightarrow$
$\lambda P\ \exists x[Mädchen''(x) \wedge P(x)](\hat{}\lambda v_i\ lieben''(h,v_i))$
$\Rightarrow \exists x[Mädchen''(x) \wedge \lambda v_i\ lieben''(h,v_i)(x)]$
$\Rightarrow \exists x[Mädchen''(x) \wedge lieben''(h,x)]$

The result of the translation of (45b) is exactly like that of derivation (47). In the following structure we represent the syntactic derivation and corresponding semantic translation. (see (49))

In connection with the translation of quantificational phrases let us try to handle a slightly complicated problem such as the translation problem of the PRO-element coindexed with a VA which is left bv QR application.

(49) ein Mädchen$_i$ Hans *liebt* VA_i

$$\lambda P\ \exists x[\text{Mädchen}''(x) \wedge P(x)] \qquad \lambda PP(h) \qquad \lambda xy\ \text{lieben}''(x,y) \qquad \lambda PP(v_i)$$

$$\lambda x\ \text{lieben}''(x,v_i)$$

$$\text{lieben}''(h,v_i)$$

$$\lambda P\ \exists x[\text{Mädchen}''(x) \wedge P(x)]\,(\lambda v_i\ \text{lieben}''(h,v_i))$$
$$\Rightarrow \forall x[\text{Mädchen}''(x) \wedge \text{lieben}''(h,x)]$$

In the LF of the following sentence the PRO$_i$ receives its translation not from the quantifier phrase *jeder Mann$_i$*, but from VA$_i$, i.e., the trace of *jeder Mann$_i$*.

(50) a. Jeder Mann scheint, Maria zu lieben.
b. Jeder Mann$_i$ [$_S$ VA$_i$ scheint [$_{\bar{S}}$ PRO$_i$ Maria zu lieben]]

Let us start with the translation of $\bar{S}$. The PRO$_i$ receives from its controller VA$_i$ the same translation as VA$_i$, i.e. $\lambda PP(v_i)$.

(51) 1. Maria zu lieben $\Rightarrow \lambda x\ \text{lieben}''(x,m)$
2. PRO$_i$ $\Rightarrow \lambda PP(v_i)$
3. PRO$_i$ Maria zu lieben $\Rightarrow \text{lieben}''(v_i,m)$

Now VA$_i$ does not have any θ-role (a null θ-term) and therefore no semantic translation, because it gives its own translation to the coindexed PRO-element. We have now the following translation process for LF (50b) continued from (51) step 3.

(51) 4. [$_S$ VA$_i$ scheint [$_{\bar{S}}$ PRO$_i$ Maria zu lieben]]
scheinen″(lieben″(v_i,m))
5. jeder Mann [$_S$ VA$_i$ scheint [$_{\bar{S}}$ PRO$_i$ Maria zu lieben]]
$\Rightarrow \lambda P\ \forall x[\text{Mann}''(x) \rightarrow P(x)]\ (\lambda v_i\ \text{scheinen}''({}^\wedge\text{lieben}''(v_i,m)))$
$\Rightarrow \forall x[\text{Mann}''(x) \wedge \lambda v_i\ \text{scheinen}''({}^\wedge\text{lieben}''(v_i,m))(x)]$
$\Rightarrow \forall x[\text{Mann}''(x) \wedge \text{scheinen}''({}^\wedge\text{lieben}''(x,m))]$

In going over to step 5 from step 4 T_{36} is applied. The whole derivation looks as follows:

(52) *jeder Mann*$_i$ *VA*$_i$ *scheint* *PRO*$_i$ *Maria zu lieben*

$\lambda P\ \forall x[\text{Mann}''(x) \rightarrow P(x)]$ $\lambda x\ \text{lieben}''(x,m)$

$\text{lieben}''(v_i,m)$

$\text{scheinen}''({}^\wedge\text{lieben}''(v_i,m))$

$\text{scheinen}''({}^\wedge\text{lieben}''(v_i,m))$

$\lambda P\ \forall x[\text{Mann}''(x) \wedge P(x)]\ (\lambda v_i\ \text{scheinen}''(\text{lieben}''(v_i,m)))$
$\Rightarrow \forall x[\text{Mann}''(x) \wedge \text{scheinen}''(\text{lieben}''(x,m))]$

Next we come to the translation of the reflexive *sich*. The reflexive has the translation of its antecedent which is either an R-expression or a VA. Look at the following sentence:

(53) a. *Peter*$_i$ wäscht *sich*$_i$.
b. *Jede Frau*$_i$ liebt *sich*$_i$.

In (53a) *sich*$_i$ takes over the semantic translation of Peter$_i$. However in (b) *sich*$_i$ has not the semantic translation of *jede Frau*$_i$, but that of the trace VA$_i$ left by *jede Frau*$_i$ through the application of QR, LF and the semantic translation of the LF. Thus LF′ looks as follows:

(54) a. *jede Frau*$_i$ [$_S$ VA$_i$ liebt *sich*$_i$]
b. $\forall x\ [\text{Frau}''(x) \rightarrow \text{lieben}''(x,x)]$

In the case of personal pronouns we have two kinds of description as in the case of PRO-elements. Personal pronouns can have their antecedents either within the sentence or outside the sentence. In the former case the pronouns take over their semantic translation of the antecedents in the sentence, while in the latter case they behave like free variables according to Cooper (1979). This kind of pronoun is then translated into $\lambda PP(x_0)$ and the value of x_0 is dependent on context use. We explain the description of personal pronouns with the following sentences:

(55) a. *Kafka*$_i$ denkt, daß *er*$_i$ außerordentlich ist.
b. Jeder Mann$_i$ glaubt, daß er$_i$ ankommt.
c. Er rennt. (Bartsch 1979)

In the translation of (55a) and (b) there appear no free variables. However, in (55c), a free variable does appear.

(56) a. denken″(k, ^außerordentlich″(k))
b. $\forall x$[Mann″(x) $\rightarrow$ glauben″(x, ^ankommen″(x))]
c. rennen″(x_0)

The free variable x_0 in (56c) receives its semantic value according to the given context.

Our last example of semantic translation concerns the "detransitivization" rule of Dowty (1981). This rule is used to treat the following sentence containing an elliptical element:

(57) Jedes Mädchen ißt.

For our purposes we modify now the detransitivization rule as follows:

(58) T_{46}: If α is V^n and the i-th argument of α does not appear in a sentence, then the α' as a V^{n-1} is translated into $\lambda x_1 \ldots x_{i-}, x_{i+} \ldots x_n \exists x_i\, \alpha'(x_1, .., x_{i-}, x_i, x_{i+}, \ldots, x_n)$

With the modified detransitivization rule we can give the semantic translation of the following derivation:

(59) *Jedes Mädchen*$_i$ $[_S$ *VA*$_i$ *ißt*$]$

$\lambda P\exists x$ [Mädchen″(x) $\rightarrow$ P(x)]

$\lambda PP(v_i)$ $\lambda x_1\exists x_2$ [essen″(x_1,x_2)]

$\exists x_2$ [essen″(v_i,x_2)]

$\lambda P\ \forall x$[Mädchen″(x) $\wedge$ P(x)]($\lambda v_i\exists x_2$[essen″(v_i,x_2)])
$\Rightarrow \forall x$[Mädchen″(x) $\wedge \exists x_2$[essen″(x,x_2)]]

The result of the translation gives an appropriate base for the semantic interpretation of sentence (57). The translation rule T_{46} can also be used to describe agentless passivization.

(60) Die Tür wird geöffnet.

According to Shin/Lee (1984) each lexical entry of the active verb *öffnen* and the passive participle *geöffnet* can be given as follows:

(61) a.
$$\begin{bmatrix} \text{PC:} & \text{öffnen} \\ \text{KC:} & NP^n_1,\ NP^a_2,\ V^{PC} \\ \text{LC:} & \text{ÖFFNEN}\ (x_1,x_2),\ 1 = \text{Agens},\ 2 = \text{Patiens} \end{bmatrix}$$

b.
$$\begin{bmatrix} \text{PC:} & \text{geöffnet} \\ \text{KC:} & NP^n_2,\ \text{von}\ NP^d_1,\ PV^{pc} \\ \text{LC:} & \text{ÖFFNEN}\ (x_1,\ x_2),\ 1 = \text{Agens},\ 2 = \text{Patiens} \end{bmatrix}$$

PC = Phonological Characterization
KC = Syntactic Characterization
LC = Logical Characterization
V = active verb
PV = passive verb

Each of the logical characterizations of *öffnen* and *geöffnet* in (61a) and (b) is designated as ÖFFNEN (x_1,x_2). Therefore *öffnen* and *geöffnet* represent their meaning logically as identical, i.e. both of them can be represented as the semantic translation $\lambda x_1 x_2$ öffnen″(x_1,x_2) according to Bartsch.

Let us try now to translate sentence (60) into the LF′ of intensional logic. The passive participle *geöffnet* is a two place predicate as its LC in (61b) indicated. We see, however, that in (60) one argument is deleted. Therefore we have to apply T_{46} to sentence (60), in order to get an appropriate semantic translation. Before this, however, we must know which argument is deleted. According to the syntactic structure KC in the lexical entry *geöffnet* we see that the argument marked with the nominative case is the second argument, and we come to know that the deleted argument in (60) is the first argument. In summarizing the above explanation we give the following derivation and its semantic translation of the sentence (60):

(62) *Die Tür* *wird* *geöffnet*

$\exists y[\forall x[\text{Tür}''(x) \leftrightarrow x = y] \wedge P(y)]$ $\qquad$ $\lambda x_2 \exists x_1[\text{öffnen}''(x_1,x_2)]$

$\lambda x_2 \exists x_1[\text{öffnen}''(x_1,x_2)]$

$\exists y[\forall x[\text{Tür}''(x) \leftrightarrow x = y] \wedge \exists x_1 \text{ öffnen}''(x_1,y)]$

The semantic translation of the passivized structure which has a quantifier phrase as an argument could also be easily given. Look at the following sentence and its semantic translation:

(63) Eine Theorie wird von jedem Wissenschaftler entwickelt.

(64) $\exists y[\text{Theorie}'(y) \wedge \forall x[\text{Wissenschaftler}'(x) \rightarrow \text{entwickel}'(x,y)]]$

On the other hand, the following active sentence corresponding to the above passive sentence has two logical forms, and therefore two semantic translations of LF′s, because of two different scopes:

(65) Jeder Wissenschaftler entwickelt eine Theorie.

(66) a. jeder Wissenschaftler$_i$[$_s$eine Theorie$_j$[$_s$VA$_i$ VA$_j$ entwickeln]]
b. $\forall x[\text{Wissenschaftler}''(x) \rightarrow \exists y[\text{Theorie}''(y) \wedge \text{entwickeln}''(x,y)]]$

(67) a. eine Theorie_j[jeder Wissenschaftler_i[VA_i VA_j entwickeln]]
b. $\exists y[\text{Theorie}''(y) \wedge \forall x[\text{Wissenschaftler}''(x) \rightarrow \text{entwickeln}''(x,y)]]$

Comparing (66a,b) with (67a,b) we realize that the ordering of quantifier phrases on the LF-level plays a very important role in semantic translation. It is still an open problem, however, why the passive sentence (63) has ony one LF with unchanged order of the quantifier phrases, whereas the corresponding active sentence has two LFs with a different ordering of the quantifier phrases. Apparently it is due to the fact that a subjacency constraint and a strong ordering of quantifier phrases govern in deriving a passive sentence from the S-Structure into the LF, and again from this into the LF′. Here we leave this problem open.

Up to now we have established several new translation rules, such as rules for translating controlled and arbitrary PRO, rules for translating null θ-role terms, rules for translating quantifier phrases and their variables left by quantifier raising, and rules for detransitivization, etc. In this way we can map the syntactic structure of Chomsky's LF into the semantic structure of the LF′ of Montague Grammar, with which we can begin the semantic interpretation of sentences.

REFERENCES

Bartsch, Lenerz, and Ullmer-Ehrlich (1977) *Einführung in die Syntax*, Scriptor Verlag, Kronberg/ks.

Bartsch, R. (1979) 'The Syntax and Semantics of Subordinate Clause Constructions and Pronominal Coreference,' in F. Heny and H. S. Schnelle, eds., *Syntax and Semantics* 10, Academic Press, New York.

Braunmüller, K. (1977) *Referenz und Pronominalisierung*, Max Niemeyer Verlag, Tübingen.

Bresnan, J. (1982) 'The Passive in Lexical Theory,' in J. Bresnan, ed., *The Mental Representation of Grammatical Relations*, MIT.

Chomsky, N. (1976) 'Conditions on Rules of Grammar,' *Linguistic Analysis* 3.4.

__________ (1981) *Lectures on Government and Binding*, Foris Publications, Dordrecht.

Cooper, R. (1979) 'The Interpretation of Pronouns,' in F. Heny and H. S. Schnelle, eds., *Syntax and Semantics* 10, Academic Press, New York.

Dowty, D. R. (1981) 'Quantification and the Lexicon,' in M. Moorgat, H.v.d. Hulst and T. Hoekstra, eds., *The Scope of Lexical Rules*, Foris Publications, Dordrecht.

Edmonson, J.H. (1982) *Einführung in die Transformationssyntax des Deutschen*, Gunter Narr Verlag, Tübingen.

Halvorsen, P. -Kr. (1983) 'Semantics for Lexical-Functional Grammar,' *Linguistic Inquiry* 14.4.

Harbert, W. (1982) 'In Defense of Tense,' *Linguistic Analysis* 9.1.

Higginbotham, J. (1980) 'Pronouns and Bound Variables,' *Linguistic Inquiry* 11.4.

__________ (1983) 'Logical Form, Binding, and Nominals,' *Linguistic Inquiry* 14.3.

Hornstein, N. (1984) *Logic as Grammar*, MIT, Cambridge.

Isacenko, A.v. (1965) 'Das Syntaktische Verhältnis der Beziehungen von Körperteilen im Deutschen,' *Studia Grammatica* V, Berlin.

May, R. (1977) *The Grammar of Quantification*, Ph.D. dissertation, MIT.

Růžička, R. (1983) 'Remarks on Control,' *Linguistic Inquiry* 14.2.

Shin and Lee (1984) 'Einige handvolle Probleme der GB-Theorie bei der dt. Satzanalyse,' *Linguistic Journal of Korea* 9.2.

Stowell, T. (1981) *Origins of Phrase Structure*, Ph.D. dissertation, MIT.

Department of German
Seoul National University
San 56-1 Sinlim-dong, Kwanak-ku
Seoul 151
Korea