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ON PROBLEMS CONCERNING THE QUANTIFICATION RULES IN MONTAGUE GRAMMAR

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On problems concerning the quantification rules in Montague grammar *)

by

Theo M.V. Janssen

ABSTRACT

In Montague grammar variables such as he_1, he_2 ... give rise to two kinds of problems. They can occur in cases where they should not, and they can be lacking in cases where they are wanted. Several proposals for dealing with these problems are discussed and a principle is proposed which guarantees that variables occur just in case they are required. In order to give this principle the form of a restriction on grammars, some new syntactic tools are used, which are borrowed from van Wijngaarden grammars. These tools are also useful for the treatment of verb tenses.

KEY WORDS & PHRASES: *Montague grammar, van Wijngaarden grammar, tense, subcategorization.*

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*) This report will be submitted for publication elsewhere.

1. PROBLEMS WITH VARIABLES

MONTAGUE 1973, henceforth PTQ, contains in its vocabulary he_1, he_2 ... as expressions of the category of terms. Such words which bear indices, I call syntactic variables (or shortly: variables). On the one hand these variables are not words of English; on the other hand they occur in intermediate stages of PTQ productions of English. Occurrences of these variables are removed by rules like S_3 (relative clause formation) and S_{14} (term substitution); I call them quantification rules. When using these rules two kinds of problems arise.

The first problem is that variables may arise in situations where they are not desired. According to the rules of PTQ, the expression

(1) He_7 *runs*

is a well-formed expression of the category of sentences. It translates into an expression containing a free variable:

(2) $\underline{run}\ (x_7)$.

The word he_7, however, is not an English word; therefore (1) cannot be a correct English sentence. So the PTQ grammar is not adequate in this respect.

The second kind of problems concerns situations in which specific syntactic variables are wanted, but where there are no such occurrences. According to the rules of PTQ, one may apply $F_{14,1}$ to the termphrase *a unicorn* and the sentence *John loves Mary*. Syntactically there are no problems: one has to substitute *a unicorn* for the first occurrence of he_1, and this is quickly done since there are no such occurrences. Thus the sentence

(3) *John loves Mary*

is produced with translation:

(4) $\lambda P[\exists u[\underline{unicorn}_*(u) \wedge P(^\wedge u)]](^\wedge\lambda x_1\ \underline{love}_*(j,m))$

Notice that this translation contains a vacuous λ-abstraction. Formula (4) reduces to (5):

(5) $\exists \underline{u}[\underline{unicorn}_*(\underline{u}) \wedge \underline{love}_*(\underline{j},\underline{m})]$

So (3) obtains a reading which implies the existence of unicorns. This is, however, not a possible reading of (3). A related problem arises for relative clauses. A relative clause has to contain a pronoun as is demonstrated by the incorrectness of

(6) *John loves the man such that Mary walks.*

Consider now the following example (GROENENDIJK & STOKHOF 1976). According to PTQ, the sentence

(7) *John loves the man such that he walks*

can be formed, using $S_{14,1}$, from the termphrase *John* and the sentence

(8) *He$_1$ loves the man such that he$_1$ walks.*

The subphrase *man such that he$_1$ walks* is formed, using $S_{3,1}$, from *man* and *he$_1$ walks*. With this production, the translation of (7) says that the person who walks, is John. The only possible reading of (7) is, however, that the man who is loved by John is the one who is walking. This demonstrates that a relative clause has to contain a pronoun which refers to the head noun. In other words: if one uses $S_{3,n}$, then the sentence has to contain an occurrence of *he$_n$*.

2. PROPOSALS FROM THE LITERATURE

Although it is not the main theme of his paper, RODMAN 1976 makes some interesting remarks on the signalized problems concerning syntactic variables. His approach is of syntactic nature. Concerning sentences containing unbound syntactic variables he states that they are 'thrown out' because of 'a convention that is implicit in Montague's work, viz, that an expression containing a free variable is ill-formed' (p. 167). Concerning wanted variables, his opinion can be concluded from the following. His rule for relative clause formation is, just as in PTQ, formulated as a rule working for all combinations of nouns and sentences. When he considers a combination of a common noun with a sentence which does not contain a relativizable pronoun, he writes 'derivation blocks' (p. 170). So there seems to be a general convention as well for the other kinds of problems. The idea that the derivation should stop in such a case, can also be found with other authors, but they present it as explicit conditions on the input sentence (GROENENDIJK & STOKHOF 1976, KARTTUNEN 1977).

This syntactic approach is attractive, since it has as consequence that, after a small change of the grammar, the correct structures are produced. In fact, certain aspects of this approach will figure in the solution proposed in section 3. But in the form presented by Rodman, it is a dangerous approach since it amounts to a filter; and a filter is a powerful tool which can also be used for unintended applications. I will demonstrate that Rodman's throw-out convention is such a dangerous tool. A related argumentation applies to the solutions to the other problem (blocking-convention as well as explicit restrictions).

Consider the situation that one wishes to incorporate in the grammar an obligatory rule which transforms sentences into sentences by performing some action which we call swopping. Let us assume that we have a formulation F_{SW} of the swopping action (it is irrelevant for our discussion to know what swopping really is). The obligatory character of the rule can be obtained by means of the throw-out filter and some changes in the rules. The rules which produce a sentence from expressions which are not sentences themselves, have to be changed. After having formed the sentence, two occurrences of he_7 are written in front of the sentence (below I will explain this number). So S_4 becomes:

S_4: If $\alpha \in P_T$ and $\beta \in P_{IV}$ then $F'_4(\alpha,\beta) \in P_t$,
where $F'_4(\alpha,\beta) = he_7\ he_7\ F_4(\alpha,\beta)$
and where F_4 is as in PTQ.

The swopping rule becomes:

Swop: if $\alpha \in P_t$ then $F_{sw}(\alpha) \in P_t$, where $F_{sw}(\alpha) = \underline{\alpha}$, and $\underline{\alpha}$ is obtained from α by first deleting a sequence of two consecuting occurrences of he_7 and next performing the swopping action.

An expression of the category sentence to which the swopping rule is not applied, will contain the sequence he_7 he_7 and thus be filtered out according to the convention. A sentence which has undergone swopping does not contain such a sequence and will pass the filter. So we used the sequence he_7 he_7 as a mark for the swopping rule. Conjoined sentences will have two such marks and both sentences will be swopped. One has to be careful that the marks are not disturbed by other rules. An application of $S_{14,7}$ which substitutes *John* for the first he_7 would demolish the mark. Therefore $S_{14,n}$ has to be changed into

$S_{14,n}$: If $\alpha \in P_T$ and $\phi \in P_t$, then $F'_{10,n}(\alpha,\phi) \in P_t$, where $F'_{10,n}$ is as $F_{10,n}$ in PTQ with the difference that $F'_{10,n}$ does not change sequences of two consecutive he_n's.

Here one sees the use of having added in S_4 two, rather than one occurrence. A variable used for the usual purposes cannot occur in a sequence of two consecutive variables, so the ones used for rule ordening can now be recognized. If we would have used just one, this would not have been the case.

The above example concerns a single obligatory rule. Related methods can be used to encode any rule ordering. I have objections against this use of variables. It it not in the style of Montague grammar to have obligatory rules or any other restriction on the ordering of rules. This is expressed by Partee in her work concerning the wellformedness constraint (PARTEE 1979). If one accepts this view, then one should not allow to have arbitrary rule ordering encoded by the he_n's. And if one does not accept this view and one wishes to have a prescribed rule-ordering, then one should do so in an explicit component for the rule ordering (as such is done in transformational grammars). Variables are introduced for pronouns and scope treatment, not for rule ordering. That is an abuse of variables which should be made impossible.

COOPER 1975, explicitly discusses the problems concerning variables and he presents approaches of a semantic nature. His ideas are especially interesting since they form the fundament for the approach of BACH & COOPER 1978, in which it is argued that it is possible to have in Montague grammar a termphrase-sentence analysis of relative clause contructions instead of the usual common noun-sentence analysis.

We have seen that constructions, in which variables are wanted but are not there, give rise to vacuous λ-abstraction. Cooper proposes to assign no truth value to such an expression containing vacuous abstraction. He obtains this effect by a restriction on the usual definition of interpretation of $\lambda u\alpha$. '... the function denoted by the abstraction expression $\lambda u\alpha$ is only defined for entities within its domain if a different assignment to the variable u will yield a different denotation for α' (p. 246). As he signalizes, this has as consequence 'that $\lambda u\alpha$ is undefined not only if α does not contain a free occurrence of u, but also if α is a tautology. Thus, for instance, according to this definition, $\lambda u[u=u]$ represents a function which is undefined for any entity. However, the technique of supervaluation ... will show these expressions to be defined but not those where α is not a tautology'. A complicated solution.

One of Coopers proposals concerning free variables is to 'design the semantics in such a way that any formula containing a free occurrence of a variable is shown to be truth-valueless' (p. 257). As consequence of this proposal

(9) $\underline{walk}\ (x)$

gets for no point of reference a truth value; it represents the nowhere defined intension. As a subexpression in the formula:

(10) $\exists x[\underline{man}(x) \wedge \underline{walk}(x)]$

it does have another meaning. So we lost the Fregean principle of compositionality: the meaning of (10) is not built up from the meaning of (9). A related objection arises if one observes that also

(11) $\underline{talk}(x)$

gets for no point of reference a truth value. So (9) and (11) are intensionally equivalent and according to a rule of intensional logic interchangeable in all contexts. Now (10) constitutes a context in which this is not the case. So acceptance of this proposal would turn the so basic substitution law unvalid.

Another approach finds its origin in Universal Grammar (MONTAGUE 1970). It is practiced by GROENENDIJK & STOKHOF 1976 and it is one of the proposals of COOPER 1975. In syntax one has a rule which deletes indices, thus delivering a correct expression. In the semantics, free variables are interpreted by the current variable assignment. Notice that this leads us away from PTQ since there a formula is defined to be true for a point of reference if and only if it is true for every variable assignment (p. 250). So $\underline{run}(x)$ means the same as its universal closure: $\forall x[\underline{run}(x)]$. Therefore this definition has to be dropped.

There are more problems with this approach. Consider:

(12) *He runs* with the translation

(13) $\underline{run}(x)$.

For each variable assignment (13) obtains an interpretation. One of the possible assignments is that x_7 refers to the utterer of the sentence under consideration; so (12) is interpreted as *I run*. It may also be the case that x_7 is the person spoken to, thus meaning *You run,* or it may handle about a female person, meaning *She runs*. Beside these syntactic inadequacies, there are also semantic ones; depending on the linguistic and situational context, the pronoun *he* can refer only to certain individuals (e.g. the person mentioned in the last utterance or the person pointed at by the speaker).
None of the authors mentioned above does explicitly signalize these complications. They can be dealt with by means of a device from Universal Grammar (MONTAGUE) 1970): considering not all variable assignment functions for evaluating a complete sentence, but only a subset thereof. This approach, however, gives rise to a strange situation. In the light of the above arguments, just a few assignments for occurring free variables are possible in any particular situation. The free variables cannot vary and are more like constants. Moreover, the variable assignment function g is by its nature independent of context or point of reference, whereas the function for interpreting constants

depends on information concerning the time and possible worlds. Why not then translate such pronouns by constants as is done in BENNETT 1978?

3. THE VARIABLE PRINCIPLE

In the previous section, we have considered several proposals dealing with the problems concerning variables. The syntactic approach aims at avoiding the problematic cases, but, in doing so, unattractive tools are introduced. The semantic approaches try to do something useful with the arising problematic cases. These semantic proposals do not give me the impression that the authors are quite satisfied by such cases, but that they rather try to find an escape from a situation they would prefer not to be confrontated with. I will put forward a proposal which combines syntactic and semantic aspects and which has as consequence that variables arise just in case they are required.

In my opinion the existing proposals all ignore the special character of variables. This special character is, in an informal way, expressed by *the variable principle*:

Syntactic variables correspond closely with semantic variables.

Several arguments for this correspondence can be found in PTQ and related works. The most immediate is that syntactic variables translate into logical variables (The term variable he_n is translated as $\lambda PP\{x_n\}$, and the CN-variable one_n, which is discussed in HAUSSER 1979, is translated as P_n). Another correspondence is that if a syntactic rule removes all occurrences of a syntactic variable, the corresponding translation rule binds the corresponding logical variable ($S_{3,n}$ and $S_{14,n}$). And rules not binding logical variables do not remove syntactic variables. The consequence of these correspondences is that in PTQ an expression contains an indexed syntactic variable if and only if its translation contains a free logical variable. I consider the correspondences among syntactic and logical variables not as accidental, but as fundamental, and propose to follow in Montague grammar the variable principle. The above formulation of the principle is, of course, rather informal; a more exact contence is given to it below.

Let us start by recalling that by a syntactic variable is understood a word which bears an index, and that by a syntactic quantification rule is understood a rule that has the effect that all occurrences of a syntactic variable are in some way removed. By the <u>*variable principle*</u> we understand the following requirements:

1a) *The translation of a syntactic variable contains a free occurrence of a logical variable.*

1b) *This is the only way to introduce a free occurrence of a logical variable.*

2a) *If a syntactic rule removes occurrences of a variable, the related translation rule binds the corresponding logical variable.*

2b) *If a translation rule introduces a binder for a free logical variable, the related syntactic rule removes the corresponding syntactic variables.*

3a) *In the complete analysis of a sentence, each syntactic variable has to be removed by a syntactic quantification rule.*

3b) *If a syntactic quantification rule is used, it has actually removed the occurrences of a syntactic variable.*

Clause 3 is formulated for syntactic rules. Since the clauses 1 and 2 force a correspondence of syntactic and semantic rules, clause 3 has an equivalent logical counterpart. This semantic version of clause 3 cannot be formulated as easy as the syntactic one, since it demands for a logical counterpart of the notion 'complete analysis of a sentence'. Therefore I prefer the syntactic formulation.

As the reader has learned from the previous discussion, the principle is intended for the usual syntactic and logical variables. It does not apply to the so-called context variables which are especially introduced for dealing with several aspects of contextual influence (examples are Γ of HAUSSER 1979 and v_c of GROENENDIJK & STOKHOF 1979). Such variables are not interpreted by the variable assignment function g and they might be called context constants as well.

Let us go back to the principle and see what it says about the several proposals we considered. As mentioned before, requirement 1b is obeyed by all existing proposals. This requirement is also proposed by Partee as a constraint on indexed notations (PARTEE 1979). Requirements 1b and 2b are not fulfilled by the proposals of COOPER 1975 and BACH & COOPER 1978.

My abuse-example concerning Rodman's 'throw-out' convention does not obey 1b nor 2a. Clause 3 makes that the original problems concerning PTQ we discussed before, do not arise. Restrictions with the same effect as clause 3 are used in JANSSEN 1976. The conventions of Rodman express the same aims as 3a and 3b, but now the abuse of variables is prevented by clause 1 and 2. So the variables arise just in case they are wanted.

The clauses 1 and 2 define restrictions on possible grammars. In order to make sure that these restrictions are decidable, I should define a format for rules from which it is possible to check whether these restrictions are satisfied. Since in all concrete proposals it is easily checked whether these clauses are satisfied, I will not define such a format. It seems that clause 3 has to be taken as a global constraint on possible derivations. If one has no objections against such a constraint, then the variable-principle has thus solved the problems concerning variables. I do have objections against global constraints. They are even stronger than filters since filters impose constraints on the final outcome of a production process, whereas global constraints take the whole process into account. As we have seen before, filters (and thus global constraints) are dangerous since they are so powerful. Global constraints allow for making the information contained in other parts of the grammar worthless. In Montague grammar, the syntactic rules provide for the information which kinds of expressions may be combined to form new expressions of a certain kind, but global constraints would make it possible that the rules combine rubbish to rubbish, leaving it to the constraint to say which combinations make sense. Because of such arguments I would not like to incorporate global constraints in general. But accepting clause 3 as the only constraint would be rather ad hoc. Therefore I will describe in the next section tools which make it possible to consider clause 3 as a restriction on the possible rules in a Montague grammar instead of considering it as a global one. After having done so, the variable principle can be taken as a decidable restriction on possible Montague grammars.

4. HYPERRULES AND VARIABLES

In this section I describe a grammar which is in some aspects a generalization of the PTQ syntax. I start with a description of the framework, some simple examples follow thereafter.

The categories may be compound symbols and it is allowed that there are an infinite number of them. We can handle an infinite number by means of a finite number of schemes of rules. These schemes are called hyperrules and they constitute the hypergrammar. Such hyperrules are alike PTQ rules, but they contain variables. By an appropriate substitution for these variables a hyperrule is transformed into a rule which may actually be used in a production. The information what is to be substituted for a certain variable is described by grammatical tools as well. Besides the hyperrules, we have another set of rules, called metarules. These metarules constitute a grammar (say context free) in which the variables from the hyperrules occur as auxiliary symbols. The set of strings of terminal symbols of the metagrammar which can be produced from a variable, constitutes the set of possible substitutions for this variable. For each metavariable M we have the variants $M_1,\ldots M_9$. For these variants we have the same metarules as for M. If a hyperrule contains occurrences of different variants of a metavariable, these may be replaced by different terminal productions. The same variants are of course to be replaced by the same terminal productions. For convenience, we will present the metarules only for one variant (say M) and not for the others $(M_1,\ldots M_9)$. So our syntactic framework consists of two levels: the metagrammar and the hypergrammar. This conception of a grammar (and the related terminology) is due to van Wijngaarden who developped this kind of grammar for the formal description of the programming language Algol 68 (VAN WIJNGAARDEN 1975). In certain details our framework deviates from the standard form of a van Wijngaarden grammar (see appendix). A linguistically oriented example of such a grammar can be found in VAN WIJNGAARDEN 1970. The main use of the organization of the syntax in two levels is that it thus provides for a technical handsome, readable, and understandable way for dealing with a large set of rules.

Compound category symbols and metarules are new in Montague grammar, but hyperrules are not. Consider the rule for relative clause formation:

$S_{3,N}$: If $\zeta \in P_{CN}$ and $\phi \in P_t$ then $F_{3,N}(\zeta,\phi) \in P_{CN}$ where $F_{3,N}(\zeta,\phi) = \zeta$ *such that* ϕ'.. and ϕ' comes from ϕ by replacing each occurrence of he_N... .

This rule cannot be considered as involving the literal expression he_N since the fragment has no such an expression.

The rule rather is a scheme which, for each choice of a number for N, gives a rule. One might add the following eleven metarules to the grammar (a | separates alternatives):

$$N \rightarrow \mathit{1} \mid \mathit{2} \mid \mathit{3} \mid \mathit{4} \mid \mathit{5} \mid \mathit{6} \mid \mathit{7} \mid \mathit{8} \mid \mathit{9} \mid N\mathit{0} \mid NN.$$

Note that due to the convention, all occurrences of the metavariable N in $S_{3,N}$ have to be replaced by the same terminal production of N, so by the same representation of a number. The above demonstrates that one does not have to understand numbers in order to handle $S_{3,N}$; one can express everything with pure grammatical tools. Since this is rather obvious, one might omit these metarules. Note that we have the convention to write metavariables in capital (N).

Another example of a PTQ hyperrule is S_1. It reads:

$B_A \subset P_A$ for every category A.

Here A is variable over categories. Its range might be made explicit by means of metarules:

A → Term | Sent | Intr Verb | ... .

A first new example of the framework is the use of compound category symbols for subcategorization. There are arguments for distinguishing among the nouns the mass nouns (e.g. *gold*) and the count nouns (e.g. *ring*). In some respects they behave the same (relative clause formation), and in other respects they behave differently (term formation). Using two separate categories would have as consequence that we have to duplicate the rules for which they behave the same. This is unattractive and can easily be avoided by the use of hyperrules. Let CM be a metavariable which can be replaced by 'Count' as well as by 'Mass'. Then we may have the hyperrules

S_2 if $\alpha \in$ Count Noun then $F_1(\alpha)$, $F_2(\alpha)$, $F_3(\alpha) \in T$ where F_1, F_2 and F_3 are as in PTQ;

$S_{3,N}$ if $\alpha \in$ CM Noun and $\beta \in S$ then $F_{4,N}(\alpha,\beta) \in$ CM Noun.

Note that S_2 is a hyperrule without a metavariable, so it is a rule in its present form. The rule says that the phrase *a ring* can be produced, but *a gold* cannot. Hyperrule S_3 expresses that a count noun with a relative clause (*ring such that it is in Amsterdam*) remains a count noun and a mass noun with a relative clause (*gold such that it is in Amsterdam*) remains a mass noun.

The use of a metagrammar is especially clear in case there are more levels of subcategorization and possibly crosslinks. I present a metagrammar for the subcategorization which is mentioned in CHOMSKY 1965 (p85). It is striking that Chomsky uses rewriting rules for the formal representation of subcategorization as well.

COMMON $\rightarrow$ COUNT | NONCOUNT.
COUNT $\rightarrow$ ANIMATE | -animate cn.
NONCOUNT $\rightarrow$ SGN abstract cn.
ANIMATE $\rightarrow$ SGN human cn.
SGN $\rightarrow$ + | -.

Again, the auxiliary symbols of the metagrammar are written in capitals. This metagrammar implicates, according to the substitution convention, that a hyperrule containing ANIMATE as metavariable, represents 2 actual rules (for the subcategories +human cn and -human cn) and that a hyperrule containing COMMON represents 5 actual rules.

Note that up till now, we used the terminology category/subcategory without defining their difference. On the level of actual rules there is no distinction between them: they both are indices of sets of expressions. The above kind of grammar makes it possible to make a formal distinction. Categories are names from the metagrammar which do not occur at the right hand side of a metaproduction rule. Subcategories of a certain category are all names that can be produced from that category using the metarules. In the sequel I will use in most cases 'category' in the PTQ sense: as an index of a set of expressions. So it may in many cases be replaced by 'subcategory'.

Below I will formulate clause 3 of the variable principle within the syntactic rules. For this purpose I consider a category name as a compound symbol consisting of a category name as the ones in PTQ, and a bag of integers. A bag (or multiset) is a set in which an element may occur more than once. This bag indicates which indices occur unremoved in the expressions of that category. So *he*$_2$ *or he*$_3$ is an expression of the category $(T,\{2,3\})$ or equivalently $(T,\{3,2\})$. We write this as *he*$_2$ *or he*$_3$ $\in (T,\{2,3\})$. Other examples are *he*$_4$ *or he*$_4$ $\in (T,\{4,4\})$ and *John* $\in (T,\{\ \})$. The language generated by the grammar is the set of English sentences which contain no indexed terms, so it is the set of expressions of the category $(S,\{\ \})$ or in PTQ terminology $(t,\{\ \})$. The hyperrules we need, contain variables for integers (N) and for bags $(BAG_1, BAG_2, \ldots)$. Let us adopt the following notations:

$BAG_1 \cup BAG_2$ denotes the bag consisting of the bag-union of the bags BAG_1 and BAG_2. So $\{1,2\} \cup \{2,3\} = \{1,2,2,3\}$.

BAG $\underline{w}$ N Is a compound expression indicating that BAG contains element N (w~with).

BAG - N Idem for the bag obtained from BAG by removing all occurrences of N. So $\{1,2\} - 1 = \{2\}$.

The hyperrule corresponding with S_4 reads:

HS_4: If $\alpha \in (T,BAG_1)$ and $\beta \in (IV,BAG_2)$ then $F_4(\alpha,\beta) \in (S,BAG_1 \cup BAG_2)$

This hyperrule states that the syntactic variables in the sentence are the union of syntactic variables in the T-phrase and the IV-phrase. An instance of a rule obtained from HS_4 is:

if $\alpha \in (T,\{1,2\})$ and $\beta \in (IV,\{\ \})$
then $F_4(\alpha,\beta) \in (S,\{1,2\})$.

This rule may be used in the production of *He*$_1$ *or he*$_2$ *runs*. Corresponding with S_2, $S_5 \cdot\cdot S_{13}$, and S_{17} we have analogous hyperrules. With $S_{14,N}$ corresponds:

$HS_{14,N}$: if $\alpha \in (T,BAG_1)$ and $\beta \in (S,BAG_2\ \underline{w}\ N)$ then $F_{10,N}(\alpha,\beta) \in$
$\in (S,BAG_1 \cup [BAG_2-N])$.

An instance of $HS_{14,N}$ is:

if $\alpha \in (T,\{\ \})$ and $\beta \in (S,\{2,3\})$ then $F_{14,2} \in (S,\{3\})$.

This rule may be used in the production of *John loves him*$_3$ from *John* and *he*$_2$ *loves him*$_3$. The hyperrules corresponding with S_3, S_{14}, and S_{15} are analogous.

One observes that the expression BAG_2 $\underline{w}$ N guarantees that $\mathrm{HS}_{14,N}$ is only applied to sentences containing occurrences of he_N. So the clause 3b of the variable principle that a quantification rule must remove an actual occurrence of a variable, can be expressed within the syntactic rules: the rule only applies to the subcategory consisting of expressions containing such a variable. So clause 3b can be checked by looking to the rules: does a rule which removes occurrences of a variable he_N, indeed operate on the related subcategory of expressions containing he_N, and does it deliver an expression of a subcategory from which the index in question is indeed removed? So 3b is now a restriction on the rules of the grammar. Clause 3a that each variable is removed, is guaranteed by defining the generated languages as being the set of expressions of category (S,{ }) (or in PTQ-like terminology of category (t,{ })).

I have implicitly assumed that the reader has some non grammatical knowledge since what bags are, and what $\cup$, $\underline{w}$ and - mean is not formulated within the grammar. This can be provided for in the following way. One adds metarules which produce from BAG actual bags and one adds hyperrules which produce from any instance of BAG-N the bag in question (so from {1,2}-1 they produce {2}). It requires some technics fo formulate such hyperrules; therefore they are presented in an appendix.

5. AN APPLICATION TO VERB TENSE

Hyperrules are extremely useful in cases where a lot of closely related rules are needed. Such a case is constituted by the rules for tense and sign. In order to demonstrate this, I will present a grammar for the treatment of the sign and the PTQ tenses of verbs. The grammar deals with the following phenomena which are not treated in PTQ.

1) Negated iv-phrases are possible:

(14) *John tries not to run.*

Notice that *try to* cannot be combined with a tensed iv-phrase. This sentence is also incorporated in the fragment of BENNETT 1976. His solution is improved in the sense that the iv-phrase

(15) *not to run slowly*

can, in our fragment, not obtain the reading in which *slowly* has wider scope than the negation.

2) As in PTQ, tensed variants of conjunctions and disjunctions are possible. Syntactic details are changed in order to produce

(16) *John has walked and talked*

instead of the PTQ version

(17) *John has walked and talk.*

3) Distinct from PTQ, we allow for conjunction and disjunction of arbitrarily tensed sentences and iv-phrases such as

(18) *A president has walked and will talk.*

The translation of this sentence will express that both actions concern a present president.

4) The PTQ grammar provides for two readings of the sentence

(19) *Every president will not walk.*

These are

(20) $\forall x[\underline{president}(x) \rightarrow \neg \mathrm{W}[\underline{walk}(x)]]$

and

(21) $\neg \mathrm{W}[\forall x[\underline{president}(x) \rightarrow \underline{walk}(x)]]$

If (21) indeed is a possible meaning of this sentence, then, in my opinion, also (22) is:

(22) $\neg[\forall x[\underline{president}(x) \rightarrow \mathrm{W}\ \underline{walk}(x)]]$.

The grammar presented below produces all these three readings. If one judges that (21) and (22) cannot be readings of the sentence, a single hyperrule has to be removed from the grammar.

The main purpose of presenting a grammar for the above phenomena is to demonstrate the use in syntax of hyperrules. I do not intend to say something new about semantical concepts concerning verb tenses: the same model and the same semantical operators for tense are used as in PTQ. This means that we only deal with the reportive use of tenses (see BENNETT 1977). The semantical problems raised by the new constructions mentioned above, all have to do with the scope of the operators W, H and $\neg$. Also the treatment of morphology is as simple as in PTQ: I do not use features. In the formulation of the hyperrules I assume that it is always possible to identify the mainverbs of iv-phrases. The auxiliary verbs *will, have* and *do* may function as mainverbs as well. The possibility of identification of mainverbs can be obtained by using recursive definitions as in FRIEDMAN 1979 (or the #-mark of BENNETT 1976 or the subfunctions of PARTEE 1979). Moreover we assume that by related means the iv-phrase of a sentence can be identified. The syntactic formation rules do not treat (as is done in PTQ), the action of 'replacing a verb by its negative future form' as a single syntactic action, but rather as the composition of 'replacing by its future form' and 'negating' which are performed by two independent syntactic rules.

The PTQ category t (in our terminology S) will have several subcategories. For instance, there is a subcategory for each tense. This relationship subcategory - tense is indicated by the following pairs: sent - present tense, past sent - simple past, fut sent - future tense. Each negated tense constitutes a subcategory and there is also a subcategory of unspecified tense (for conjunctions and disjunctions). All subcategories translate into expressions of the same logical type: the type of sentences. For IV-phrases there is an analogous subcategory system. The intransitive verbs themselves are in the subcategory iv. The subcategory system is formally described by means of the following metarules (the symbol λ denotes the empty string):

$$
\begin{aligned}
S &\rightarrow \text{TENSED sent.}\\
IV &\rightarrow \text{TENSED iv.}\\
\text{TENSED} &\rightarrow \text{SGN TNS} \mid \text{tns.}\\
\text{SGN} &\rightarrow \text{neg} \mid \lambda.\\
\text{TNS} &\rightarrow \text{past} \mid \text{fut} \mid \lambda.
\end{aligned}
$$

The hyperrules presented below replace the PTQ-rules S_4(IV+T), S_8(IV/IV+IV), S_{10}(IV//IV+IV) and S_{17} (tensed variants of S_4). The description of an hyperrule has the following parts:

H: Information about the categories involved in the hyperrule. We write e.g. "$\phi \in$ neg sent" for "ϕ is a phrase of the subcategory neg sent".

T: The translation rule is defined by presenting its output. In this, by ϕ', ψ', α' and β' are understood the translations of ϕ, ψ, α and β mentioned in the H-part.

F: A specification of the string manipulation function used in the H-part. For the ease of reference, the function F will bear the same index as the hyperrule in which it is used, even where the same operation is used in more than one rule. (This convention and the one for T is also practised in DOWTY 1978).

E: -Optionally- an example.

R: -Optionally- some remarks.

H_{101}: If $\alpha \in$ T and $\beta \in$ TENSED iv then $F_{101}(\alpha,\beta) \in$ TENSED sent.

T_{101}: $\alpha'(\hat{}\beta')$

F_{101}: $F_{101}(\alpha,\beta) = \alpha\underline{\beta}$, where $\underline{\beta}$ is obtained from β by replacing β by their third person singular present form, provided that they are not yet in some third person singular form.

E_{101}: F_{101}(*John, walk*) = *John walks*
F_{101}(*John, will walk*) = *John will walk.*

R_{101}: Since there are, according to the metarules, six possible substitutions for TENSED, one can make six actual rules out of H_{101}.

H_{102}: If $\alpha \in$ iv then $F_{102}(\alpha) \in$ past iv.

T_{102}: $\lambda x\ H[\alpha'(x)]$.

F_{102}: Remove all occurrences of the mainverb *do* in α and next replace all mainverbs in α by their past participle and write *have* in front of the thus changed α.

E_{102}: F_{102}(*walk and talk*) = *have walked and talked*
F_{102}(*walk and do not talk*) = *have walked and not talked.*

R_{102}: The above iv yields the reading in which the subject is outside the scope of the tense operator.

H_{103}: If $\phi \in$ sent then $F_{103}(\phi) \in$ past sent.

T_{103}: $H(\phi')$.

F_{103}: Apply F_{102} to the iv-phrase of ϕ, next replace mainverb *have* by *has*.

R_{103}: The subject is inside the scope of the tense operator.

H_{104}: If $\alpha \in$ iv then $F_{104}(\alpha) \in$ fut iv.

T_{104}: $\lambda x\ W[\alpha'(x)]$.

F_{104}: Remove all occurrences of the mainverb *do* in α and write *will* in front of the thus changed α.

E_{104}: F_{104}(*walk and do not talk*) = *will walk and not talk.*

R_{104}: See R_{102}.

H_{105}: If $\phi \in$ sent then $F_{105}(\phi) \in$ fut sent.

T_{105}: $W(\phi')$.

F_{105}: Apply F_{104} to the iv-phrase of ϕ.

R_{105}: See R_{103}.

H_{106}: If $\alpha \in$ TNS iv then $F_{106}(\alpha) \in$ neg TNS iv.

T_{106}: $\lambda x\ \neg[\alpha'(x)]$.

F_{106}: If α has just one mainverb and this is *will, have, do,* or *be,* then insert *not* behind it; in all other cases write *do not* in front of α.

R_{106}: Conjuncted and disjuncted tensed iv-phrases are of the subcategory tns iv. Therefore no instance of H_{106} applies to them.

H_{107}: If $\phi \in$ TNS sent then $F_{107}(\phi) \in$ neg TNS sent.

T_{107}: $\neg[\phi']$.

F_{107}: Apply F_{106} to the iv-phrase of ϕ, next replace mainverb *do* by *does*.

R_{107}: Conjuncted and disjuncted sentences are of the subcategory tns sent. Therefore no instance of H_{107} applies to them. We have discussed the ambiguity of sentence (19). If one wishes to have only one reading for such sentences, then H_{107} has to be removed from the grammar.

H_{108}: If $\alpha \in$ IV//IV and $\beta \in$ SGN iv then $F_{108}(\alpha,\beta) \in$ iv.

T_{108}: $\alpha'(\hat{}\beta')$.

F_{108}: If β starts with *do not* then delete this and insert *not* before the first *to* in the IV//IV-phrase. Otherwise concatenate α and β.

E_{108}: F_{108}(*try to, run*) = *try to run*

F_{108}(*try to, do not run*) = *try not to run*.

H_{109}: If $\alpha \in$ IV/IV and $\beta \in$ iv then $F_{109}(\alpha,\beta) \in$ iv.

T_{109}: $\alpha'(\hat{}\beta')$

F_{109}: $F_{109}(\alpha,\beta) = \beta\alpha$.

E_{109}: F_{109}(*slowly, run*) = *run slowly*.

R_{109}: Since adverbs can only be combined with an untensed and unsigned iv-phrase, a phrase like *do not run slowly* can only have the reading with slowly inside the scope of negation (see remark on (15)).

H_{110}: If $\alpha \in$ iv and $\beta \in$ SGN iv then $F_{110}(\alpha,\beta) \in$ iv.

T_{110}: $\lambda x[\alpha'(x) \wedge \beta'(x)]$.

F_{110}: $F_{110}(\alpha,\beta) = \alpha$ *and* β.

R_{110}: The asymmetry in this hyperrule makes that the negation in:

(23) *John will not walk and talk*

applies to *will walk and talk,* and not just to *walk* (cf. FRIEDMAN 1979).

H_{111}: Analogously to H_{110} for disjunction.

H_{112}: If $\alpha \in$ TENSED$_1$iv and $\beta \in$ TENSED$_2$iv then $F_{112}(\alpha,\beta) \in$ tns iv.

T_{112}: see T_{110}.

F_{112}: see F_{110}.

R_{112}: This rule is used in the production of

(24) *John will not walk and talks.*

(cf. R_{110})

H_{113}: Analogously to H_{112} for disjunction.

H_{114}: If $\phi \in$ TENSED$_1$sent and $\psi \in$ TENSED$_2$sent then $F_{114}(\phi,\psi) \in$ tns sent

T_{114}: $\phi' \wedge \psi'$.

F_{114}: $F_{114}(\phi,\psi) = \phi$ *and* ψ.

H_{115}: Analogously to H_{114} for disjunction.

These 15 hyperrules describe in a handsome way 164 actual rules, so the use of hyperrules reduced the length of the grammar by a factor 10. If I would also incorporate other tenses such as the past perfect, the benefit would still be more. Note that there is no syntactic problem in replacing H_{112}-H_{115} by two rules using one metavariable for both iv and sent, but then we would not be able to find two corresponding semantic rules.
Below I present three examples. All expressions are preceded by the name of the subcategory they belong to. From this information one easily concludes which actual rule is used.

1) sent: *John tries not to run*

T: *John* iv: *try not to run*

IV//IV: *try to* neg iv: *do not run*

iv: *run*

the corresponding translation yields:

$$\underline{try\ to}_{*}(j, \lambda u \neg \underline{run}_{*}(u))$$

2) past sent: *John has walked and talked*

T: *John* past iv: *have walked and talked*

iv: *walk and talk*

iv: *walk* iv: *talk*

the corresponding translation yields

$$H(\underline{walk}(j) \wedge \underline{talk}(j))$$

An alternative analysis (with the same semantic result) would apply H_{103} to:

sent: *John walks and talks.*

3) tns sent: *A president has walked and will talk*

T: *a president*

tns iv: *have walked and will talk*

past iv: *have walked*

iv: *walk*

fut iv: *will talk*

iv: *talk*

translation

$$\exists u[\underline{president}_*(u) \wedge \mathrm{H}\ \underline{walk}_*(u) \wedge \underline{talk}_*(u)].$$

6. CONCLUSIONS

Two kinds of problems arise in connection with syntactic variables in Montague grammar. The existing proposals for treating these problems are not free of objections, whereas the *variable principle* is able to cope with them. The application of hyperrules, metarules and compound category symbols permits the incorporation of the variable principle as a restriction on possible grammars. These tools are also useful for other purposes (subcategorization, verb tense). The variable principle excludes the complicated NP-S analysis of relative clauses as proposed by Bach & Cooper. Concerning the demonstrative use of pronouns and related phenomena, the principle guides us towards the use of constants as is practised by Bennett.

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7. APPENDIX

Rules for bags.

The aim of this appendix is to demonstrate that is possible to describe the bag manipulations used in section 4 by means of pure grammatical tools. Before to do so, some remarks for experts in van Wijngaarden grammars. The hyperrules presented in this paper do not have the format of hyperrules according to the literature, but they can be transformed to such a format. The hyperrule $S_{14,N}$ then obtains the shape

$$X(S, BAG_1 \cup [BAG_2 - N])Y ::=$$
$$X\ F_{10,N}((T, BAG_1), (S, BAG_2 \underline{w}\ N))Y.$$

The metanotions X and Y stand for arbitrary contexts (cf. VAN WIJNGAARDEN 1970). The syntactic operation $F_{10,N}$ has to be described by means of other hyperrules. The phrase '<u>unless</u> N_1 <u>is</u> N_2' (used below) is to be considered as a separate hypernotion. The rules below use the rotation technique of VAN WIJNGAARDEN 1974 and the blind alley technique of Sintzoff as practised in VAN WIJNGAARDEN 1975.
The metarules are (λ denotes the empty string)

$$\begin{array}{ll}
BAG & \to \{SEQ\} \mid \{\ \} \\
SEQ & \to N \mid N,SEQ \\
N & \to 1 \mid 2 \mid 3 \mid 4 \mid 5 \mid 6 \mid 7 \mid 8 \mid 9 \mid NN \mid N0. \\
LSEQ & \to SEQ, \mid \lambda. \\
RSEQ & \to ,SEQ \mid \lambda.
\end{array}$$

The hyperrules for union are

$$\begin{array}{ll}
\{SEQ_1\} \cup \{SEQ_2\} & \to \{SEQ_1, SEQ_2\} \\
\{SEQ_1\} \cup \{\ \} & \to \{SEQ_1\} \\
\{\ \} \cup \{SEQ_2\} & \to \{SEQ_2\}\ .
\end{array}$$

For with

$$\{LSEQ\ N\ RSEQ\}\ \underline{w}\ N \rightarrow \{LSEQ\ N\ RSEQ\}$$

For minus

$$\{SEQ\} - N \rightarrow \{*,SEQ\} - N$$
$$\{\ \} - N \quad \rightarrow \{\ \}$$
$$\{LSEQ * RSEQ,N_1\} - N_2 \rightarrow \{N_1,LSEQ * RSEQ\} - N_2\ \underline{\text{unless}}\ N_1\ \underline{\text{is}}\ N_2$$
$$\{LSEQ\ *\} - N_2 \rightarrow \{LSEQ\}.$$

Hyperrules concerning the unless phrase are

$$\underline{\text{unless}}\ \underline{\text{false}} \rightarrow \lambda$$
$$0\ \underline{\text{is}}\ 0 \rightarrow \underline{\text{true}};\quad 0\ \underline{\text{is}}\ 1 \rightarrow \underline{\text{false}};\quad 0\ \underline{\text{is}}\ 2 \rightarrow \underline{\text{false}}\ \ldots$$
$$N_1N_2\ \underline{\text{is}}\ N_3N_2 \rightarrow N_1\ \underline{\text{is}}\ N_3;\ N_1N_2\ \underline{\text{is}}\ N_1N_3 \rightarrow N_2\ \underline{\text{is}}\ N_3.$$

So the phrase 'unless N_1 is N_2' reduces to the empty string just in case N_1 is not equal to N_2, otherwise one cannot get rid of the phrase and thus the rule cannot be used in an actual derivation.

REFERENCES

BACH, E. & R.H. COOPER (1978), The NP-S analysis of relative clauses and compositional semantics, *Ling. and Phil.* 2, 145-150.

BENNETT, M. (1976), Variation and extension of a Montague fragment, in: *Partee 1976*, pp. 119-163.

BENNETT, M. (1977), A guide to the logic of tense and aspect in English, *Logique et Analyse* 80, 491-518.

BENNETT, M. (1978), Demonstratives and indexicals in Montague grammar, *Synthese* 39, 1-80.

CHOMSKY, N. (1965), *Aspects of the theory of syntax*, The MIT Press, Cambridge (Mass.).

COOPER, R.H. (1975), *Montague's semantic theory and transformational syntax,* unpublished dissertation, Univ. of Massachusetts, Amherst.

DOWTY, D.R. (1978), Governed transformations as lexical rules in a Montague grammar, *Ling. Inq.* 9, 393-426.

FRIEDMAN, J. (1979), An unlabelled bracketing solution to the problem of conjoined phrases in Montague's PTQ, *Jour. of Phil. Log.* 8, 151-169.

GROENENDIJK, J. & M. STOKHOF (1976), Some notes on personal pronouns, reflexives and sloppy identity in a Montague grammar, in: K. Braunmüller & W. Kürschner (eds.), *Akten des 10 linquistischen Kolloquiums, Tübingen 1975,* Max Niemeyer verlag, Tübingen, pp. 301-315.

GROENENDIJK, J. & M. STOKHOF (1979), Infinitives and context in Montague grammar, in: S. Davis & M. Mithun (eds.), *Proc. of the conf. on Montague grammar at SUNY Albany,* University of Texas Press (to appear).

HAUSSER, R.R. (1979), How do pronouns denote?, in: *Heny & Schnelle 1979.*

HENY, F.W. & H.S. SCHNELLE (eds.) (1979), Selections from the third Groningen round table, *Syntax and Semantics 10,* Academic Press, New York (to appear).

JANSSEN, T. (1976), A computer program for Montague grammar: Theoretical aspects and proofs for the reduction rules, in: J. Groenendijk & M. Stokhof (eds.), *Proc. of the Amsterdam coll. on Montague grammar and related topics,* Amsterdam papers in formal grammar I, Centrale Interfaculteit, University of Amsterdam, pp. 154-176.

KARTTUNEN, L. (1977), Syntax and semantics of questions, *Ling. and Phil.* 1, 3-44.

MONTAGUE, R. (1970), Universal grammar, *Theoria* 36, 373-398. Reprinted in: *Thomason 1974*, pp. 222-246.

MONTAGUE, R. (1973), The proper treatment of quantification in ordinary English, in: J. Hintikka, J. Moravcsik and P. Suppes (eds.), 1973, *Approaches to natural language,* Synthese library, Reidel, Dordrecht, pp. 221-242, reprinted in: *Thomason, 1974,* pp. 247-270.

PARTEE, B. (1976), *Montague grammar,* Academic Press, New York.

PARTEE, B. (1979), Montague grammar and the well-formedness constraint, in: *Heny & Schnelle 1979.*

RODMAN, R. (1976), Scope phenomena, "Movement transformations", and relative clauses, in: *Partee 1976,* pp. 165-176.

THOMASON, R.H. (1974), *Formal philosophy, selected papers of Richard Montague,* Yale University Press, New Haven.

VAN WIJNGAARDEN, A. (1970), On the boundary between natural and artificial languages, in: B. Visentini et al., *Linguaggi nella società e nella tecnica,* Edizioni di comunita, Milan, pp. 165-176.

VAN WIJNGAARDEN, A. (1974), The generative power of two-level grammars, in: J. Loeckx (ed.), *Automata, languages and programming, 2nd coll.* (*Saarbrücken*), Lect. Notes in Comp. Sc. 14, Springer, Berlin, pp. 9-16.

VAN WIJNGAARDEN, A. et al. (1975), Revised report on the algorithmic language Algol68, *Acta Informatica* 5, 1-236.

ONTVANGEN 3 0 AUG. 1979