

**Constraining Transformational Montague Grammar:
A Framework and a Fragment***

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1. Introduction: three types of constraints.

1.1. The need for constraints.

Montague's theory of grammar^{1/} imposes strong constraints on the correspondence between syntactic rules and semantic interpretation rules, but virtually no constraints on the form of syntactic or semantic operations. His theory has been of interest to linguists even without further constraints, I think in large part because it provides an explicit and rigorous semantic framework within which elegant solutions have been provided to many classically difficult semantic problems. Another point of particular interest to linguists is the compositionality constraint, which is a strong and interesting constraint whose soundness can to some degree be confirmed or disconfirmed without formal constraints on the operations, just by following some implicit standards for what constitute reasonable rules. Nevertheless, I think linguists are agreed that the task of imposing further constraints is imperative if some form of Montague grammar is to be taken seriously as a candidate for a theory of natural languages, insofar as one of the linguist's chief goals in constructing such a theory is to characterize the class of possible natural languages as narrowly as possible.

This emphasis on the need for additional constraints is not meant as a criticism of Montague's own work, since it stems from goals not shared by Montague. On the one hand, he clearly wanted a theory which would

account equally well for natural languages and the artificial languages constructed by logicians.^{2/} On the other hand, he wanted a mathematically elegant theory, and while a linguist would of course welcome formal elegance if it is attainable within the limits set by empirical constraints, the linguist is obligated to put higher priority on the facts of natural languages. For example, if it could be shown to hold universally that languages with sentence-initial complementizers had only leftward unbounded movement rules, and those with sentence-final complementizers only rightward ones, the linguist would want to constrain his theory so as to rule out the non-occurring possibilities, even though doing so would probably make the theory less "elegant". Considerations of elegance or simplicity do come in, of course, particularly in trying to extrapolate from the universal properties of the finite set of actual natural languages to the universals of language that have a principled and not an accidental basis.

Insofar as constraints on grammars are hypotheses about universals, it could be argued that it is premature to begin proposing any for Montague grammar, and that many more "fragments" of many more languages should be written first. My response would be that it is certainly too early to have much confidence in any proposed constraints, but never too early to start proposing and investigating potential constraints. The fruitfulness of constraint-inspired research within transformational grammar has been enormous, and it should be neither surprising nor discouraging that there are nevertheless still fundamental disagreements about almost all the constraints that have so far been proposed. So I will emphasize

at the outset that all the constraints suggested herein are highly tentative; my hope is that they may stimulate others to find better ones.

1.2. The compositionality constraint.

The main constraint in Montague's theory, and the one that makes it so interesting semantically, is the compositionality constraint, i.e., the requirement that there be a semantic interpretation rule corresponding to each syntactic formation rule, so that the interpretation of each expression is determined by the interpretation of its syntactic subparts and the rule by which they were combined. If we adopt the two-stage semantics of Montague (1973) (henceforth PTQ), in which the first stage consists of translation from the natural language into a formalized language of intensional logic and the second stage consists of a model-theoretic semantics for that language, then the compositionality constraint can be represented in part by the requirement that syntactic and semantic rules come in pairs of the following form:

- (1) Syntactic rule \underline{n} : If $\alpha \in P_A$ and $\beta \in P_B$, then
 $\gamma \in P_C$, where $\gamma = F_1(\alpha, \beta)$.
- (2) Semantic rule \underline{n} : If α, β translate into α', β' , respectively, then
 $F_1(\alpha, \beta)$ translates into $G_k(\alpha', \beta')$.

The parameters to be specified for the particular rules are the following:

- (i) the categories A and B of the input expressions and the category C of the resulting expression; (ii) the syntactic operation F_1 , which may be as simple as concatenation or as complex as a transformational operation;

and (iii) the 'semantic' operation G_k , which is actually a syntactic operation mapping two expressions of the intensional logic onto an expression of the intensional logic; but I shall continue to refer to it as a semantic operation to distinguish it from the natural language syntactic operation F_1 .

The compositionality constraint further requires that all expressions of a given syntactic category be translated into expressions of a single type, or semantic category, in the intensional logic. It does not, however, require any correspondence between the form of the syntactic operation F_1 and the form of the semantic operation G_k of the corresponding semantic rule, other than what is required by the correspondence between categories of expressions and the logical types of their translations.

I said at the beginning that the compositionality constraint is a strong one; but in fact that assessment presupposes some constraints on the syntactic operations F_1 and the semantic operations G_k . Otherwise, I believe it puts virtually no constraint on either the syntactic or semantic analysis of a given possible language.^{3/} Hence an additional reason to look for constraints on the form of the rules is to give more substance to the compositionality constraint. And with a more explicit statement of the permissible forms of rules, one could propose ways of tightening the compositionality constraint itself, by imposing correspondences between the form of the syntactic operation F_1 for a given syntactic rule and the semantic operation G_k of the corresponding semantic rule.

1.3. The well-formedness constraint.

What I mean by the well-formedness constraint is given in (3):

- (3) The well-formedness constraint. Each syntactic rule operates on well-formed expressions of specified categories to produce a well-formed expression of a specified category.

This constraint comes from Montague, but not in quite as strong a form as I would like to propose. For any ambiguous language, such as any natural language, Montague's general theory as specified in Montague (1970b) (henceforth UG) calls for giving the syntax in two parts: a set of syntactic rules of the form given in (1) above for a disambiguated language, and the specification of an 'ambiguating relation' R which pairs expressions of the disambiguated language with expressions of the actual ambiguous language. The well-formedness constraint within Montague's theory holds only for the syntax of the disambiguated language, which is in effect a construct of the Montague grammarian, much as are the deep structures of the transformational grammarian. The disambiguated language L' 'underlying' a given natural language L could, if no additional constraints are imposed, differ from the natural language in quite arbitrary ways, which would rob the well-formedness constraint of empirical content. If we could eliminate the ambiguating relation completely, then the well-formedness constraint would require that the inputs and outputs of all syntactic rules be well-formed surface expressions of the given language, which is presumably what we have empirical data about.

In an earlier paper,^{4/} I suggested that the following limited differences between the disambiguated language L' and the surface language L

be tolerated, and no others: (i) L' contains labelled brackets, L does not, and the ambiguating relation simply deletes the brackets; (ii) L' contains "variables" like he₃, L does not, and the ambiguating relation simply deletes the subscript; (iii) L' contains morphological representations such as see + Past or she, which the ambiguating relation maps into the surface forms saw and her. From the point of view of Montague's theory, these are constraints on the form of the ambiguating relation R. From a linguistic perspective, they might better be viewed as eliminating R completely but adding the specific devices of labelled bracketing, indexed pronouns, and a morphological component to the theory to take over some of the intended functions of R. Taken either way, my aim is to make the well-formedness constraint empirically as strong as possible without giving up descriptive adequacy.

The strength of the well-formedness constraint can be illustrated best by showing some of the sorts of analyses it disallows. For example, Siegel (1976b) presents syntactic and semantic arguments in favor of a dual categorization of adjectives in English (and in Russian), with some adjectives classified as applying directly to common nouns (CN/CN in PTQ terminology) and others classified as one-place predicates (t//e). If the well-formedness constraint is taken seriously as part of the syntax, the analysis of at least some adjectives as common noun modifiers is independently selected on purely syntactic grounds over the classic transformational derivation of all pronominal adjectives from predicate adjectives in relative clauses, since the classic analysis requires the generation of ill-formed expressions as part of the derivation of well-formed ones, as in (4).

- (4) *a convert who is recent → a recent convert

Although the analysis of all adjectives as common noun modifiers as in Montague (1970a) (EFL) cannot be completely ruled out by the well-formedness constraint^{5/}, the constraint does rule out any analysis which would syntactically generate such expressions as (5a) as part of the derivation of (5b).

- (5) (a) *be an asleep entity
(b) be asleep

As this example illustrates, one effect of the well-formedness constraint is to automatically disallow obligatory rules.

I will briefly mention some further examples of analyses ruled out by the well-formedness constraint; these are discussed further in Partee (forthcoming).

(1) Analyses of the easy-to-please construction like that of Lasnik and Fiengo (1974) would be ruled out because of the ill-formedness of the source structure as exemplified in (6), and like that of Chomsky (1978) by the ill-formedness of the source as shown in (7).

- (6) *John is easy to please John → John is easy to please
(7) *John is easy whom to please → John is easy to please

Chomsky's classical analysis of the easy to please construction, illustrated in (8), does not violate the well-formedness constraint; an analogous rule in a Montague framework was proposed in Partee (1973).

- (8) To please John is easy → John is easy to please

(ii) There have been many analyses proposed in the transformational literature for pseudo-cleft sentences like (9); of the hypothesized sources listed below as (10 a-e), only (10a) and (10b) satisfy the well-formedness constraint.

- (9) What John ate was the meat

- (10) (a) $S[John\ ate\ the\ meat]$
(b) $NP[what\ John\ ate]\ was\ NP[the\ meat]$
(c) $NP[S[John\ ate\ the\ meat]]\ was\ NP[the\ meat]$
(d) $NP[S[John\ ate\ wh-something]]\ was\ NP[S[John\ ate\ the\ meat]]$
(e) $NP[S[John\ ate\ the\ meat]]\ was\ NP[\Delta]$

(iii) The constraint would also rule out all cases of lexically governed obligatory extraposition, as illustrated by the widely accepted transformational derivation of (11b) from (11a).

- (11) (a) *That Susan is asleep appears
(b) It appears that Susan is asleep

It may be that the well-formedness constraint is too strong and needs to be weakened somewhat; I believe that its effects are good ones in the cases cited, but I do not want to try to argue for that here. The examples were included primarily to illustrate that the constraint does indeed have quite strong effects on the class of grammars compatible with given data about the well-formed surface expressions of a given natural language. If it is correct, it could have important effects for theories of first-language acquisition, since it places rather severe limitations on the abstractness of the relation between surface forms and the structures that need to be posited for their derivation.

1.4. The need for constraints on the form of rules.

The compositionality constraint limits the possible pairings of syntactic and semantic rules, and the well-formedness constraint indirectly limits the class of syntactic rules for a given language by constraining their outputs to be well-formed expressions of that language. But neither of these kinds of constraints puts any limits on the syntactic operations F_1

or the semantic operations G_1 that occur in the rules, and without some constraints on these as well, the class of grammars available within a Montague framework still includes infinitely many grammars that are incompatible with strongly supported linguistic universals. Consider, for example, a hypothetical rule that formed the conjunction of two sentences by a syntactic operation F_1 that interleaved the successive words of the first sentence with the successive words of the second sentence, so that F_1 (John went to the store, Mary raked the leaves) would yield "John Mary went raked to the the leaves store". Compositionality does not rule out any particular choice of F_1 ; as long as the rule is uniformly interpreted, say as conjunction, the compositionality requirement is met. The well-formedness constraint can eliminate such a rule from English, or any other known natural language, since its output is clearly ill-formed, but the well-formedness constraint does not furnish us with a basis for predicting that no possible human language could have such a rule. Clearly the potential of Montague grammar as a theory of human linguistic competence would be strengthened by the inclusion of constraints on the form of the rules in addition to compositionality and the well-formedness constraint. In the remainder of the paper I will consider a number of possible constraints of this sort on the syntactic rules and suggest ways of incorporating them into a tightened format for writing syntactic rules in a (modified) Montague framework.

2. Constraints on the form of rules.

2.1. The nature of Montague syntax.

Since a Montague syntax consists of rules which work "bottom-up", combining well-formed expressions to produce new well-formed expressions, many of Montague's rules have the effect of what would normally be expressed as two or more rules in a transformational grammar. Montague's PTQ has many

examples of such rules: S4, the simple subject-predicate rule, for instance, is analogous to a phrase-structure rule ($t \rightarrow T IV$) plus a transformation of subject-verb number agreement. One immediate concern to the linguist is whether it will be possible to find a constrained form of syntactic rules when one rule may have to incorporate a number of diverse operations into a single operation F_1 . I will propose that each syntactic operation F_1 must be stutable as a composition of subfunctions,^{6/} where each subfunction is itself a composition of certain primitive operations (to be specified below, section 3.). The intuitive idea is that the factors that should make one grammar preferable to another in this framework should be reflected in the simplicity of the definition of each subfunction together with the simplicity of expressing each full syntactic operation F_1 as a composition of subfunctions.

The fact that Montague syntax works "bottom-up" also has certain effects on the possible form of rules. Suppose we want the rules to operate on and produce labelled bracketed structures^{7/} as in transformational grammar (TG). One plausible constraint in TG is that no "structure-building" be allowed: transformations must operate on the tree structure^{8/} of the input expression but not create new labelled nodes except by operations such as copying or Chomsky-adjunction which do so uniformly. This prohibition would rule out, for instance, the "extraction analysis" of pseudo-clefts which derives sentences (9) from (10a) (repeated below), building a number of new nodes in the process.

(9) What John ate was the meat.

(10a) John ate the meat.

In a Montague syntax with labelled bracketing, some structure-building is inevitable because of the absence of a separate phrase structure component.

Consider a syntactic rule of the form (1) above, in which F_1 is simple concatenation. The interpretation of such a rule in a labelled bracketed system is that it operates on a pair of inputs as shown in (12) and produces an output as shown in (13): concatenation then amounts to sister-adjunction plus creation of a parent node.

(12) $A[\alpha], B[\beta]$

(13) $C[A[\alpha] B[\beta]]$

While one cannot absolutely prohibit structure-building in a bottom-up system, a comparable effect would be achieved by adopting the following:

(C1) No Internal Structure Building: The only new node that can be added by a rule is a single parent node labelled to indicate the category of the resulting expression. (The pair of brackets labelled "C" in (13) represent such a node.)

(As in TG, certain primitive operations may be defined to create duplicates of existing nodes; the constraint in effect prohibits node-addition from being a separate primitive operation.) I am in favor of this constraint in part because it can help to tighten the notion of syntactic category and strengthen the degree to which surface structure facts provide evidence for deeper structure. The free insertion of new labelled nodes into derived structures would seem to weaken the empirical import of the labelled nodes in both these respects.

A second constraint which is built into the Montague syntax is that there is no extrinsic rule ordering:

(C2) No Extrinsic Rule Ordering:

There is a high degree of intrinsic rule ordering because every category is recursively defined, so that the domains of the rules are sets of n-tuples

of categories and not just the single category S .^{9/} So one cannot, for example, apply the relative clause rule until one has built up a common noun phrase and a sentence to apply it to, and one cannot apply that rule after a determiner has been added to the common noun phrase to produce a term phrase.

2.2 Consequences of the well-formedness constraint.

Suppose we adopt the well-formedness constraint in the form proposed in section 1.3 above, where the only exceptions to surface well-formedness to be tolerated are (i) the inclusion of labelled brackets, (ii) the inclusion of indexed variables, and (iii) the inclusion of abstract morphological representations that can be mapped into actual phonological forms by morphological and morphophonemic rules. Then two immediate constraints follow, both of which I want to accept.

(C3) No Obligatory Rules

(C4) No Purely Abstract Morphemes

The first of these is clear enough; note that what standardly happens to rules considered obligatory in TG is that they get incorporated as subfunctions in rules that do more besides, in the way that number-agreement is incorporated into subject-predicate rules. Not everyone working in the MG framework has accepted this constraint; my own reflexive rule in Partee (1973) violates it, as do several of the rules involved in Rodman's analysis of relative clauses in Rodman (1976). My proposal that late obligatory morphological rules should be permitted reflects the judgment that the complexity of doing all the morphology as one builds expressions up (with the concomitant need to "undo" some of it at later stages) is so great as to outweigh the appeal of the well-formedness constraint in such cases; advocacy of a larger class of obligatory rules would presumably involve similar considerations for other cases.

The class of elements that (C4) is intended to prohibit are those which never have a phonological realization. This would permit a present tense morpheme which is sometimes phonologically null, but rule out such elements as Bennett's \$ and # (Bennett 1974), or morphemes such as Q and IMP which are sometimes used in TG to "trigger" certain rules before being obligatorily deleted.

2.3 Transformational modifications of Montague syntax.

Since Montague himself put no constraints on the syntactic operations F_1 , not even that they be limited to recursive functions (a minimal constraint if the grammar is to be learnable), his rules already have at least as much power as transformational rules. So although the introduction of labelled brackets is in one sense an extension rather than a restriction of his system, my motivation in adding the brackets to the generated expressions is to make it possible to restrict the class of rules by making the labelled bracketing (which represents the derived constituent structure) one of a limited set of properties of expressions to which the rules may refer, and in particular to disallow reference to previous stages of the derivational history.

(C5) No Appeal to Derivational History.

Labelled bracketing will not be the only property of expressions to which rules may be sensitive, however; see the discussion of recursively defined properties in section 2.4 below.

Another modification I am introducing into Montague's system, one which does represent an extension rather than a restriction, is to allow the syntactic operations to be partial functions. This corresponds to the inclusion of "structural analysis" statements in transformations, and requires a modification in the basic form of the syntactic rules:

- (14) Syntactic rule \underline{n} : If $\alpha \in P_A$ and $\beta \in P_B$ and α, β are of the form SA_n , then $\gamma \in P_C$, where $\gamma = F_1(\alpha, \beta)$.

The addition of the structural analysis clause means that a given syntactic rule will not necessarily apply to all expressions of the input categories. The requirement that the functions always be total functions is linguistically unnatural, and its abandonment does not, as far as I am aware, have any undesirable consequences for the rest of the system.^{10/} Restrictions on the allowable form of the structural analysis statement will be specified in later sections, and will be in part borrowed from transformational theory. It may be noted that transformational rules in the framework of Chomsky (1957) have the form of (14), with the restriction that the category of both input(s) and output is always S.

2.4. Features as recursively defined properties.

In Partee (forthcoming) it is proposed that Montague's bottom-up form of syntax, in which the syntactic rules take the form of a recursive definition of the set of expressions of each category, provides a natural way to unify the linguists' use of features on lexical items and features on non-terminal nodes if both kinds of features are viewed as properties of expressions.^{11/} Consider syntactic gender, for example, in languages like those of the Romance family.^{12/} Each lexical common or proper noun has a specified gender, and for each syntactic rule which creates a common noun phrase or a term phrase, one can write a rule specifying the gender of the resulting phrase, given the gender of each constituent CN or T phrase. For endocentric constructions, such a recursive property specification rule will simply state that the gender of the resulting phrase is the gender of one of the constituent phrases (the head); this corresponds to the notion of "feature-climbing" in the linguistic literature. For non-endocentric constructions, the rules will be less uniform. The gender of a term phrase formed from a sentence,

such as a that-clause, will always be a certain fixed gender, such as neuter or masculine, and the gender of a conjoined term phrase will be a specifiable function of the genders of the constituent term phrases. What I propose, then, is a set of property specification rules that accompany the formation rules, recursively defining properties to which syntactic rules may refer, starting with lexically specified properties and specifying properties of derived expressions on the basis of the properties of the constituents and the rule that is combining them.

In addition, it appears to be necessary to allow some of the syntactic formation rules themselves to add or change property specifications, either by copying, as in the case of agreement rules, or by stipulation, as in the case of government rules, e.g. the addition of case marking when a verb is combined with its object. This last case represents something of a problem for this approach for languages in which there is a rich case morphology, since addition of a case specification to a full term phrase would seem to require top-down rather than bottom-up transmission of the case specification to the appropriate subconstituents of the term phrase. (The problem is not so great for English where only pronouns show case, so I have been able to make do with an ad hoc treatment of case in this fragment. But I do not see any way to give a satisfactory treatment for the general case within this framework, so further modification seems inevitable.)

One must of course seek constraints on the set of permissible properties in this framework, just as one must constrain the use of features in a transformational framework, if one wishes to forbid the encoding of arbitrary aspects of derivational history.^{13/} Although I do not have specific constraints to offer at this point, I will list here the properties used in the fragment of section 4 below, which can be grouped into four types. Further

work will be needed to see whether these types can be narrowly defined by some formal means, whether some can be eliminated, and whether others need to be added.

Type 1: Morphological properties.

- (i) GENDER (α) is defined recursively for term phrases and common noun phrases, and is copied by rules onto pronouns. The values for this property are Masc(uline), Fem(inine), Neut(er), and Com(mon). Common gender is the gender assigned to conjoined terms whose constituents differ in gender; in various dialects it is realized as he, he or she, or they (the latter creating problems for the treatment of number which are ignored here.)
- (ii) PERSON (α), a feature whose values are 1, 2, and 3, is defined recursively for term phrases, copied by rule onto pronouns, and referred to in the subject-verb agreement operation (subfunction AGR in the fragment). The PTQ fragment has only third person term phrases, but the person property is included here to illustrate the more general case.
- (iii) NUMBER (α), with values Sg and Pl, is also defined recursively for term phrases and referred to in the subject-verb agreement rule as well as in the rules of quantification and relativization. In this fragment, all term phrases are singular; in an extended fragment, a treatment of plural along the lines of Bennett (1974) could be given by referring to the property specification "NUMBER (α) = Pl" where Bennett has " α is of the form $\$ \beta$ ".
- (iv) CASE (α) is a property whose values are Nom and Acc; it is not an inherent property of expressions in this fragment, but is assigned to term phrases by the subfunction ACC(α), which occurs in the rules combining term phrases with transitive verbs and prepositions.

Type 2: Categorial properties.

There is just one property of the sort I am calling categorial in this fragment, namely $VERB(\alpha)$, whose values are + and -. This property is not a particularly attractive one, since it is simply a reflection of the absence of the grammatical category "verb" in the PTQ fragment. However, recent work on cross-categorial generalizations within the X-bar theory has led to a number of suggestions for decomposing even the more traditional categories like Verb into complexes of features (e.g. Verb as [+V, -N], Adjective as [+V, +N], etc.^{14/}), so there may be independent justification for features of this sort. At any rate, such properties do not significantly increase overall expressive power, since they are (at worst) replaceable by finite disjunctions of category membership statements.

Type 3: Relational properties.

Following a suggestion of Friedman (1974),^{15/} we introduce two recursively defined relational properties: $MAINVERB(\alpha, \beta)$ (" α is a main verb of β ") and $MAINTERM(\alpha, \beta)$ (" α is a main term of β "), each of which has the values + and -. The principal need for such relational properties is the existence of rules which apply to full term phrases or verb phrases in ways that require identifying the head (or heads in the case of conjoined phrases), such as the attachment of the present tense morpheme to the head verb(s) of a verb phrase in sentence-formation. It is well known that PTQ incorrectly generates (15a) instead of (15b) because Montague's rule S4 changes only the leftmost basic verb of the verb phrase to its present tense form.

(15) (a) *John walks and talk

(b) John walks and talks

The introduction of the relational property $MAINVERB(\alpha, \beta)$ represents a

choice of one among four possible ways of solving this and related problems. The other three are (i) appeal to derivational history, which we wish to exclude generally; (ii) the introduction of abstract morphemes like Bennett's "#", which we also wish to exclude generally; and (iii) defining the tense-attachment operation in terms of the labelled bracketing of the verb phrase. The first two of these are in a sense notational variants of the relational property solution,^{16/} since both the relational property and the introduction of Bennett's "#" can be viewed as encoding the relevant aspects of the derivational history (as a property of the derived string in one case and as an overt marker in the derived string in the other.) My preference for the recursively defined property solution derives largely from the expectation that only a small set of such relational properties like MAINVERB will be needed and that they will be universally definable. Thus even if the three solutions (Friedman's (i), and (ii)) are equivalent with respect to the PTQ fragment, I would expect to find evidence that they are not equivalent in terms of predictions about the class of possible grammars of natural language. (The remaining approach, (iii), was one I advocated in introducing labelled bracketing into the Montague framework in Partee (1973, 1975), but I have not found any way of implementing it without defining the attachment subfunction itself recursively, which in effect is just another form of the derivational history solution.)

Type 4: Indexed pro-form properties.

The two properties $PRO(\alpha)$ and $INDEX(\alpha)$ are of a somewhat special kind, and perhaps would better be treated in an entirely separate component of the grammar.^{17/} The PRO property value is + for both subscripted and unsubscripted pronouns (and - for all other basic terms and term phrases) and is used to identify term phrases to be put into the accusative as well as in the operations

affecting subscripted pronouns. The INDEX property is the only property with infinitely many values: ω , 0, 1, 2, The substitution of a "real pronoun" for an indexed one is viewed, partly following Bach (1976, 1978), as just "desubscripting" the indexed pronoun (changing a numerical value of the INDEX property to " ω "), with accompanying addition of gender and number features as specified in the particular rule. This treatment fits in with the constraint suggested in Partee (forthcoming) that indexed elements be permitted in the syntax only as indexed forms of actually occurring pro-forms (such as pronouns, there, then, do so, etc.)

One respect in which the PRO and INDEX properties differ from the other properties is that they are lexically determined and not modified recursively in the way that properties like GENDER, MAINVERB, etc., are (except in the trivial respect that the value of PRO is specified as ω for all recursively built up, non-basic, term phrases.)

2.5 Bound variables and "everywhere substitution".

Both the relative clause rule and the quantification rules in PTQ include the operation of substituting an appropriate pronoun for every occurrence of he₁ in a certain domain. This operation, because of the "every occurrence" clause, cannot be defined in any natural way as a transformational rule, since the structural description of a transformation must partition the input structure into a fixed finite number of factors. Attempts to reproduce such rules as transformations (e.g. in the Cooper-grammar of Cooper and Parsons (1976)) involve innovations such as allowing "iterable" factors such as (16):

$$(16) (X \text{ he}_1 Y)^*$$

The introduction of such terms into transformations not only makes the structural description non-finite but raises questions about the interpretation of the structural description, since what is intended is to allow for multiple

occurrences of the same he₁ surrounded by different X's and Y's. Allowing iterated application of a single finitely stated transformation won't work either, unless some way could be found to insure that the same he₁ is chosen for each successive application.^{18/}

Rather than make the primitive operations powerful enough so that such an operation of "everywhere substitution" could be defined in terms of them, I have chosen to make "everywhere substitution" itself one of the primitive operations; with constraints on its use designed to limit its application to cases where the elements substituted for are interpreted as bound variables. I believe that an operation of this sort is needed in some component of the grammar in any framework. An explicit statement of the generative semanticists' rule of quantifier-lowering requires such an operation, and an analogous operation is needed in the interpretive rules if it is not included in the syntactic rules.^{19/ 20/}

2.6 Functions, subfunctions, and primitive operations.

The fact that the output of each rule must be a syntactically well-formed expression appears to require a loss of generalization with respect to what in a transformational grammar would be treated as obligatory transformations. For example, in PTQ, person and number agreement of the tensed verb with the subject is stated separately for each tense as it is introduced; accusative-marking must be stated separately as part of each rule that combines a verb or preposition with a term-phrase object. If reflexivization is not to be a single obligatory rule (which it cannot be if the well-formedness constraint is correct), reflexivization must be built into the subject-predicate rule(s) and additionally into one or more verb-phrase creating rules (to handle cases where the antecedent of a reflexive is in the verb phrase.) The significance of this loss of generalization is that we then have no basis

for predicting that, say, reflexivization should operate in the same way in each rule in which it is introduced.

To remedy this shortcoming, I will follow a suggestion made by Emmon Bach and require that each syntactic operation F_i be specifiable as a composition of "subfunctions", where each subfunction is itself defined as a composition of certain primitive operations (to be specified below.) A frequently recurring operation, specific to a particular language, that is smaller than a whole rule but bigger than a primitive operation will be defined just once in the grammar, given a name, and then simply referred to by that name in the statement of each rule in which it is used. For example, one useful subfunction for PTQ is the subfunction PROFORM(α), which defines the pronoun agreeing in gender and number with the common noun or term phrase .

$$(17) \text{ If } \alpha \in P_{CN} \cup P_T, \text{ PROFORM}(\alpha) = \tau \left[\begin{array}{l} \underline{he} \\ \text{GENDER}(\alpha) \\ \text{NUMBER}(\alpha) \\ \text{PRO: +} \\ \text{INDEX: --} \end{array} \right]$$

(The bracketed feature specifications represent the composition of four primitive operations of property specification.)

Using this subfunction, we can define further a subfunction PROSUB(α, i, δ) which substitutes for every occurrence of \underline{he}_i or \underline{him}_i in δ a pronoun which is the appropriate proform of α (see the fragment in section 4.) This subfunction shows up in the relativization and quantification rules of PTQ, and would show up in other rules as well in extensions of PTQ.

"Capturing generalizations" depends not only on the form of grammars but on the evaluation metric as well. It is intended here that the evaluation metric should count a defined subfunction as a single operation within a large function definition, but should also take into account for the grammar as a whole the number and complexity of the defined subfunctions. Intuitively,

this use of subfunctions is analogous to the use of subroutines in complicated computer programs. There is no advantage to separately defining a subroutine if it will be used only once; there may be if it recurs at several different points in the program. A sharper definition of the evaluation metric, incorporating appropriate tradeoff values among complexities in different parts of the grammar, is eventually needed but is probably not within reach in the near future.

The initial motivation for defining the rule-size operations F_i in terms of intermediate-level subfunctions was to capture a kind of generalization that is normally captured in transformational grammar by a single transformation; in this respect it may appear simply to be a "patch" on MG to enable it to reach a level of adequacy already attained by TG. Recent work by Bach (ms. a, ms. b) suggests, however, that the subfunction notion may have fruitful application to cases not representable as single transformations;^{21/} it may turn out, for instance, to provide a helpful tool for expressing some of the kinds of typological generalizations about families of rules that tend to cluster together in languages (e.g. Greenberg (1963)).

The particular primitive operations to be taken as basic will be specified in section 3 below; some of them have already been discussed above (e.g. "everywhere substitution"). The choices are quite tentative at this point, since the primitives should be universal (unlike the language-particular functions and subfunctions), and there has not been very much work done so far in the MG framework on languages other than English.^{22/}

2.7. Conjunction and "across-the board" rules.

Several of the errors in PTQ involve failure of rules to apply correctly when one of the input expressions is a conjoined phrase (Friedman (1974)).

For example, as Friedman notes, PTQ generates all of the following:

- (18) Bill seeks John and find he or Mary.
- (19) John has talked and walk.
- (20) Mary or John finds a fish and she eats it.

The last example has both a reasonable derivation, on which she is coreferential with Mary, and an inappropriate derivation, on which she is coreferential with Mary or John. The error responsible for the second derivation is that the pronoun corresponding to a given term phrase is determined by considering just the gender of the first basic term or common noun in the term phrase. In PTQ, the first basic term or common noun phrase is the head of the term phrase in all cases except conjoined term phrases.

Sentence (18) illustrates two errors: present tense marking applies only to the first verb of the verb phrase (again appropriate for all cases except conjoined verb phrases), and accusative marking applies only when the term phrase to be marked is a single pronoun. Sentence (19) illustrates another tense-marking failure: a verb phrase is put into the present perfect by prefixing has and putting the first verb of the verb phrase into the past participle form.

In the fragment below, these errors are corrected by a means similar to that employed by Friedman. The device of recursive property specification described in section 2.4 is used to define the notions "main verb of a verb phrase" and "main term of a term phrase"; whenever conjunction is involved, there will be more than one main verb or main term, and subfunctions such as tense-attachment and accusative marking are defined to apply to all main verbs or main terms of the affected phrases. The recursive definition of the gender property provides for the appropriate specification of the gender of conjoined

phrases, so that a pronoun whose antecedent is Mary or John will be given common gender (he or she or they, depending on dialect^{23/}).

These corrections solve most of the problems connected with conjunction in PTQ (some remaining ones are discussed in section 5), and the devices employed are for the most part independently justifiable. But there seems to be a higher-order generalization that is not reflected in the rules, since it is probably universal that rules like accusative marking should apply to all conjuncts of a conjoined phrase. A similar problem exists in transformational grammar, where the notion of "across-the board rules" (first proposed by Ross (1968)) has been suggested as a solution, though never completely or adequately formalized, as far as I am aware. What is needed, in either framework, is a way of predicting, from the form of a rule as stated for simple non-conjoined input structures, exactly how the rule will apply when one or more of the input structures is or contains a conjoined phrase. I do not have such a formulation to offer; the treatment in section 4 should therefore be regarded as something of a "brute force" solution.

2.8. The separation of morphology and syntax.

The fragment presented in section 4 below incorporates certain working assumptions about the separation of morphology and syntax. I have nothing to offer here about the basis for a principled distinction; this is an area much in need of further research. I assume that the rule for the alternation of a/an does not belong in the syntax (where Montague had it in PTQ), and I generate such terminal strings as (21) (brackets omitted), leaving it to later components to turn this into (22).

(21) Mary believe Pres that HE
 [CASE:NOM] [NUM:Sg] [GENDER: Fem
 NUM: Sg
 PRO: +
 INDEX: -]
 have Pres walk en.
 [NUM:Sg]

(22) Mary believes that she has walked.

How much power the morphological rules have can of course make a difference to the demands placed on the syntax. I assume that morphological rules must follow all syntactic rules and may not operate across-the-board or across variables. Hence I assume, for instance, that the problem of across-the-board case marking noted in the previous section must be solved within the syntax, and that the morphological component can only tell us what the actual case forms of various lexical items are.

3. A formal framework.

The framework proposed here is tentative; I am sure that neither the form nor the content is optimal. In this framework, the specification of the syntax of a natural language has four parts: (i) a lexicon, (ii) a defined set of syntactic subfunctions, (iii) a set of syntactic rules, and (iv) a set of property-specification rules. The framework specifies the form of all of these as well as the primitive syntactic operations from which the functions and subfunctions are built. Perhaps the framework should also specify the set of properties and property values that may be used in the property-specification rules (and operated on in the other rules), but it seems premature to try to specify such a set universally at this point.

3.1. Primitive operations.

The primitive operations are all operations on labelled bracketed strings

(or trees), although the inputs may also include strings without labelled bracketing. There are five primitive operations: Concatenation/adjunction, simple substitution, everywhere substitution, property specification, and property copying.

(i) Concatenation/adjunction. The concatenation/adjunction operation applies to any number of arguments, concatenates them, and provides a new outermost pair of labelled brackets (in tree terms, it provides a parent node). The label on the added brackets can be specified in one of two ways: (a) by stipulating it to be a particular category symbol; (b) by requiring it to be identical to the category of one of the arguments. For illustration of type (a), see all of the syntactic rules of section 4 except S14 and S15. For illustration of type (b), see the definition of the subfunction ATTACH, whose outputs include such expressions as (23) and (24).

(23) $IV[IV/t[IV/t[believe] en]]_t[that....]$

(24) $IV[TV[TV[find] en]]_T[Mary]$

Since the operation takes any finite number of arguments and includes the addition of outer brackets with a specified label, it is really a family of operations. We could write a given one of these operations as, e.g. $CONCAT_{n,A}$, where n is the number of arguments and A the category label to be added, as illustrated in (25)

(25) $CONCAT_{2,t}(\alpha, \delta) = {}_t[\alpha \delta]$

For perspicuity, however, I have used in the fragment below a notation which more nearly displays the form of the output, as in (26).

(26) ${}_t[\alpha \delta]$

The composition of concatenation operations is illustrated in rule S7 of the fragment; F_6 could be written in the notation of (25) above as (27):

$$(27) F_6(\delta, \beta) = \text{CONCAT}_{2,IV}(\delta, \text{CONCAT}_{2,t}(\text{that}, \beta))$$

(11) Simple substitution. This operation, which is written as $\text{SUB}(\alpha, \beta, \delta)$, substitutes α for β in δ . We require that α and β be constituents of the same category. (The requirement is independent and could be dropped if it turns out to be too strong.) Any properties that have been specified for β that do not conflict with properties of α are preserved as properties of α in the result (e.g. case, if α is unmarked for case.) Deletion results if α is the null string \underline{e}_i ; we assume that the null string counts as a member of any category, so that by fiat deletion does not violate the category-preserving requirement. Additional constraints on deletion should be added; there is no deletion at all in the fragment below.

There is not much use of SUB in the fragment below; it occurs only in the definition of three subfunctions, $\text{NOM}(\alpha)$, $\text{ACC}(\alpha)$, and $\text{ATTACH}(\beta, \delta)$, all of which are slightly atypical in that they are designed as across-the-board rules. Consider $\text{ACC}(\alpha)$, given in (28).

$$(28) \text{ACC}(\alpha) = \text{SUB} \left(\begin{array}{c} \beta \\ \text{[CASE:ACC]} \end{array}, \beta, \alpha \right) \text{ for all } \beta \text{ such that} \\ \text{MAINTERM}(\beta, \alpha) = +.$$

The effect of this subfunction is to add the property specification indicating accusative case to α or to each conjunct of α if α is a conjoined term phrase. The prose quantification in the statement of the subfunction should probably not be permitted; I have used it in the absence of a good general scheme for across-the-board operations.

One place in the grammar where SUB would be expected to turn up is in the quantification rules S14 and S15; the reason it does not is discussed in section 5.

(iii) Everywhere substitution. This operation, discussed in section 2.5 above, is represented as $\text{ESUB}(\alpha, \beta, \delta)$. Its effect is to substitute α for every occurrence of β in δ , retaining any properties of β that do not conflict with properties already specified for α . As in simple substitution, α and β must be of the same category. Further, β must be an indexed pro-form; these are always \underline{he}_i in the fragment, but an extended fragment might have pro-forms for additional categories. This restriction reflects the hypothesis that ESUB is always associated with variable building.

In the fragment below, ESUB is used in the definition of the subfunction PROSUB : $\text{PROSUB}(\alpha, i, \delta)$ substitutes the pronominal form of α for every occurrence of \underline{he}_i in δ . (In an interpretive variant of Montague grammar such as that in Cooper and Parsons (1976), in which no indexed pro-forms occur in the syntax, ESUB would be eliminated from the syntax completely.) The retention of non-conflicting properties has the effect that whatever case properties have been assigned to the various occurrences of \underline{he}_i will be carried over to the pronouns that are substituted for them. Without this convention, it is hard to see how one could write a uniform rule that has the same effect as Montague's complex condition involving "...for \underline{he}_i or \underline{him}_i respectively" in his rules S3, S14 - S16.

(iv) Property specification. In addition to the property specification rules themselves, to be discussed below, the syntactic operations can include the addition of properties with particular values. Properties can be added to individual lexical items or to constituents, but not to strings which are not constituents. Property specification is illustrated in the definition of

the subfunction ACC, given above in (28). The notation adopted here is much like standard feature notation: property names and specified values are put in brackets under the constituent to which the property is added.

(v) Property copying. This operation is similar to property specification, except that instead of specifying a particular value for the added property, we write, e.g., [GENDER (α)] to mean that the gender value to be assigned is whatever the gender value of α is. This operation is used for agreement rules, and is illustrated in the fragment in the definition of the subfunction AGR. Both kinds of property operations are illustrated in the subfunction PROFORM. Both property specification and property addition are to be understood as overriding any previously specified values for the mentioned properties, but leaving intact the values of any properties not mentioned in the rule.

This completes the inventory of the primitive operations.

3.2. Syntactic rules. Each syntactic rule is to be of the form given in (29).

(29) If $\alpha_1 \in P_{A1}, \dots, \alpha_n \in P_{An}$, and $\alpha_1, \dots, \alpha_n$ are of the form SA, then $F_i (\alpha_1, \dots, \alpha_n) \in P_B$, where $F_i (\alpha_1, \dots, \alpha_n) = \dots$.

What is further required is a specification of the form of the "structural analysis" conditions SA, and of the form of the syntactic operations F_i . With respect to the former I do not have a clear set of criteria, and there is more prose in that part of the rules of the fragment than I would like. I permit reference to labelled bracketings much as in standard transformational grammar, reference to specified properties, reference to lexical items, and both quantification and negation (see S14 and S15).

The operations F_i are more tightly constrained: these must be definable

as a composition of primitive operations and subfunctions, where the subfunctions themselves are language-specific operations defined as compositions of primitive operations. The only violations of the requirement in the fragment occur in the definitions of the subfunctions NOM, ACC, and ATTACH, which have been complicated to make them operate across the board in conjunctions.

One important respect in which the framework is still deficient is in the connection between the specification of the structural analysis SA and the specification of the operands of the subfunctions used in F_i . In standard transformational grammar, the SA of a transformation is always a specification of a finite partition of a tree, and the rule operates on the pieces of tree determined by the partition. But as noted above, the operation ESUB cannot be formulated in this way, because there may be no fixed limit on the number of occurrences of the form to be substituted for in the string. I have not found any fully satisfactory formalism for integrating ESUB with the other operations (see section 4.2 for some particular problems); this may eventually lead to an argument for leaving all ESUB operations out of the syntax and following an interpretive variant of Montague grammar, such as Cooper (1975). The problem may be only in devising a suitable notation; there is no difficulty that I can see in stating rules involving ESUB as well as other operations explicitly in prose while obeying all the constraints on operations suggested in the previous sections.

3.3. Rules of property specification.

For each syntactic formation rule S_n , there are zero or more associated rules of property specification (PS_n). If S_n combines α and β to form a new expression γ , the rules of PS_n will specify values for properties of γ in terms of values for properties of α and β . A typical set of property

specifications can be seen in PS2. A more problematic use of the property specification mechanism is its use to specify the "MAINVERB" of a verb phrase (the lexical item(s) to which tense or other affixes should be attached): when two verb phrases are conjoined, each of their main verbs becomes a main verb of the result (PS12), and since an adverb may be applied to conjoined as well as simple verb phrases, the property specification rule PS10 must have a quantifier in it to guarantee that all of the main verbs of the input verb phrase become main verbs of the resulting verb phrase. (Bennett's device of using "#" to mark main verbs does not need any additional stipulation when adverbs are added; the main verbs are automatically still main verbs unless some rule deletes the "#".)

Because of this and related problems, I suspect it may be a mistake to permit "binary properties" like MAINVERB (of) to be treated in the same way as ordinary properties like gender. The binary properties used in this fragment are all devices for identifying heads of phrases, and that task should probably have a separate device of its own, with universal principles for such predictable cases as the fact that the addition of adverbs and adjectives does not affect what is the main verb or main noun of a phrase. This in turn relates to larger questions of the representation of categories (since IV/IV adverbs are "modifiers", while IV//IV verbs like try to do become new heads of verb phrases; hence the relevant universals are not directly statable in PTQ terms.)

3.4. The lexicon.

A full theory of the lexicon is beyond the scope of this paper; see Dowty (1976) and Dowty (forthcoming) for interesting and extensive treatment

of the lexicon and its relation to syntax within a Montague framework. The only addition I propose here is the addition of certain property specifications to lexical items, to serve as initial inputs to the property specification rules. I have used an abbreviated feature-like notation in the lexicon of the fragment; an entry such as (30) is to be understood as an abbreviation for (31).

(30) John

MASC
PRO: <small>PRO</small>

(31) GENDER (John) = Masc.
PRO (John) = -

I have also specified in the fragment that all members of B_{IV} , B_{IV} , $B_{IV/t}$ and $B_{IV//IV}$ have the value + for the feature "V"; this is a makeshift device for recapturing the lexical category "verb", which I believe should rather be accomplished by a modification of the categorial notation (see, e.g. Bach (ms. a)).

This completes the presentation of the framework. The main innovations are the decomposition of syntactic operations into subfunctions, the proposals for particular primitives, and the inclusion of property specification rules. The main deficiency, in my opinion, is that prose has not been more fully eliminated from the writing of the rules.

4. A fragment.

4.0. Introductory remarks.

The fragment of English treated here is almost identical to that generated by PTQ, and the rules are virtually identical in effect with exceptions as noted below. The semantics is unchanged and has been omitted. Property specification rules have been added.

The fragment differs from that of PTQ in the following ways:

- (1) Conjunction errors noted in section 2.7 above have been corrected.
- (2) Relative clause formation requires at least one occurrence of the variable being relativized on, so vacuous relativization (unicorn such that John loves Mary, etc.) is eliminated.

(3) The CN-scope quantification rule is eliminated (see Partee (1975) for discussion; the marginal evidence cited there in favor of such a rule now appears to be spurious.^{24/})

(4) In the sentence-scope and IV-scope quantification rules, vacuous quantification is eliminated (see Cooper and Parsons (1976) for discussion), and the term phrase quantified in may not be a subscripted pronoun or a disjunction including a subscripted pronoun.

Some discussion of the rules follows in section 5.

4.1. The fragment.

Lexicon.

$B_{IV} = \{run, walk, talk, rise, change\}$ all [V: +]

$B_T = \{John, Mary, Bill, ninety, he_0, he_1, \dots\}$ all[Number: Sg]

Masc PRO:-	Fem PRO:-	Masc PRO:-	Neut PRO:-	PRO:+ INDEX:0	PRO:+ INDEX:1
---------------	--------------	---------------	---------------	------------------	------------------

$B_{TV} = \{find, lose, eat, love, date, be, seek, conceive\}$ all [V: +]

$B_{IAV} = \{rapidly, slowly, voluntarily, willingly\}$

$B_{CN} = \{man, woman, park, fish, pen, unicorn, price, temperature\}$

[Masc]	[Fem]	[Neut]	[Neut]	[Neut]	[Neut]	[Neut]	[Neut]
--------	-------	--------	--------	--------	--------	--------	--------

all[Number: Sg]

$B_{t/t} = \{necessarily, allegedly\}$

$B_{IAV/T} = \{in, about\}$

$B_{IV/t} = \{believe, assert\}$
 [V:+] [V:+]

$B_{IV//IV} = \{try, wish\}$
 [V:+] [V:+]

$B_{T/CN} = \{every, the, a\}$

Defined subfunctions

1. $PROFORM(\alpha) = T[HE]$ (for $\alpha \in P_{CN} \cup P_T$)

GENDER NUMBER PRO: + INDEX: -	(α)
--	--------------
2. $PROSUB(\alpha, i, \delta) = ESUB(PROFORM(\alpha), he_i, \delta)$ (for $\alpha \in P_{CN} \cup P_T$, any δ)
3. $AGR(\alpha, \beta) = \beta$ (for $\alpha \in P_T$, $\beta = Pres$)

NUMBER	(α)
--------	--------------
4. $NOM(\alpha) = SUB(\beta, \beta, \alpha)$ for all β such that

[CASE:NOM]	MAINTERM(β, α) = +
------------	---------------------------------
5. $ACC(\alpha) = SUB(\beta, \beta, \alpha)$ for all β such that

[CASE:ACC]	MAINTERM(β, α) = +
------------	---------------------------------
6. $ATTACH(\beta, \delta) = SUB(CAT\gamma[\beta\gamma], \gamma, \delta)$ for all γ such that

MAINVERB(γ, δ) = +.	(for β an "affix", $\delta \in P_{IV}$)
-----------------------------------	--

Syntactic Rules and Property-Specification Rules

S1. If $\alpha \in B_A$, then $F_0(\alpha) \in P_A$, where $F_0(\alpha) = A[\alpha]$, for every category A.

PS1. (Property-specification 1).

(i) For all properties P which are defined for lexical items,
 $P(F_0(\alpha)) = P(\alpha)$.

(ii) If $V(\alpha) = +$, then $MAINVERB(\alpha, F_0(\alpha)) = +$

(iii) If $\alpha \in B_T$, then $MAINTERM(\alpha, F_0(\alpha)) = +$

S2. If $\alpha \in P_{T/CN}$ and $\beta \in P_{CN}$, and $NUMBER(\beta) = Sg$, then $F_1(\alpha, \beta) \in P_T$,

where $F_1(\alpha, \beta) = T[\alpha \wedge \beta]$

PS2. (i) $GENDER(F_1(\alpha, \beta)) = GENDER(\beta)$

(ii) $NUMBER(F_1(\alpha, \beta)) = Sg$

(iii) $MAINTERM(F_1(\alpha, \beta), F_1(\alpha, \beta)) = +$

(iv) $PRO(F_1(\alpha, \beta)) = -$

S3. If $\alpha \in P_{CN}$ and $\varphi \in P_t$ and φ is of the form $t[\beta \text{ he}_n \gamma]$, then

$F_{2,n}(\alpha, \varphi) \in P_{CN}$, where $F_{2,n}(\alpha, \varphi) = CN[\alpha \text{ such that } \text{PROSUB}(\alpha, n, \varphi)]$

PS3. (i) $GENDER(F_{2,n}(\alpha, \varphi)) = GENDER(\alpha)$

(ii) $NUMBER(F_{2,n}(\alpha, \varphi)) = NUMBER(\alpha)$

S4. If $\alpha \in P_T$, $\delta \in P_{IV}$, then $F_4(\alpha, \delta) = t[NOM(\alpha) \text{ ATTACH}(AGR(\alpha, Pres), \delta)]$

PS4. $MAINVERB(\gamma, ATTACH(AGR(\alpha, Pres), \delta)) = +$ for all γ such that $MAINVERB(\gamma, \delta) = +$

S5. If $\alpha \in P_{TV}$ and $\beta \in P_T$, then $F_4(\delta, \beta) \in P_{IV}$, where $F_4(\delta, \beta) = IV[\delta \text{ ACC}(\beta)]$

PS5. $MAINVERB(\gamma, F_4(\delta, \beta)) = +$ for all γ such that $MAINVERB(\gamma, \delta) = +$

S6. If $\delta \in P_{IAV/T}$ and $\beta \in P_T$, then $F_5(\delta, \beta) \in P_{IAV}$, where $F_5(\delta, \beta) = IAV[\delta \text{ ACC}(\beta)]$

PS6. (none)

S7. If $\delta \in P_{IV/t}$ and $\beta \in P_t$, then $F_6(\delta, \beta) \in P_{IV}$, where $F_6(\delta, \beta) = IV[\delta \text{ that } \beta]$

PS7. $MAINVERB(\gamma, F_6(\delta, \beta)) = +$ for all γ such that $MAINVERB(\gamma, \delta) = +$

S8. If $\delta \in P_{IV/IV}$ and $\beta \in P_{IV}$, then $F_7(\delta, \beta) \in P_{IV}$, where $F_7(\delta, \beta) = IV[\delta \text{ to } \beta]$

PS8. $MAINVERB(\gamma, F_7(\delta, \beta)) = +$ for all γ such that $MAINVERB(\gamma, \delta) = +$

S9. If $\delta \in P_{t/t}$ and $\beta \in P_t$, then $F_8(\delta, \beta) \in P_t$, where $F_8(\delta, \beta) = t[\delta \wedge \beta]$

PS9. (none)

S10. If $\delta \in P_{IV/IV}$ and $\beta \in P_{IV}$, then $F_9(\delta, \beta) \in P_{IV}$, where $F_9(\delta, \beta) = IV[\beta \wedge \delta]$

PS10. $MAINVERB(\gamma, F_9(\delta, \beta)) = +$ for all γ such that $MAINVERB(\gamma, \delta) = +$

S11. If $\varphi, \psi \in P_t$, then $F_{10}(\varphi, \psi), F_{11}(\varphi, \psi) \in P_t$, where $F_{10}(\varphi, \psi) = t[\varphi \text{ and } \psi]$

PS11. (none)

where $F_{11}(\varphi, \psi) = t[\varphi \text{ or } \psi]$

S12. If $\gamma, \delta \in P_{IV}$, then $F_{12}(\gamma, \delta), F_{13}(\gamma, \delta) \in P_{IV}$, where $F_{12}(\gamma, \delta) = IV[\gamma \text{ and } \delta]$

$F_{13}(\gamma, \delta) = IV[\gamma \text{ or } \delta]$

PS12. $MAINVERB(\beta, F_{12}(\gamma, \delta)) = +$ for all β such that

$MAINVERB(\beta, \gamma) = +$ or $MAINVERB(\beta, \delta) = +$. (Same for F_{13})

S13. If $\alpha, \beta \in P_T$, then $F_{14}(\alpha, \beta) \in P_T$, where $F_{14}(\alpha, \beta) = T[\alpha \text{ or } \beta]$

PS13. (i) $MAINTERM(\gamma, F_{14}(\alpha, \beta)) = +$ for all γ such that

$MAINTERM(\gamma, \alpha) = +$ or $MAINTERM(\gamma, \beta) = +$

(ii) $GENDER(F_{14}(\alpha, \beta)) = \begin{cases} GENDER(\alpha) & \text{if } GENDER(\alpha) = GENDER(\beta) \\ COM & \text{if } GENDER(\alpha) \neq GENDER(\beta) \end{cases}$

(iii) $NUMBER(F_{14}(\alpha, \beta)) = NUMBER(\alpha)$ [grammar book dialect]

S14. If $\alpha \in P_T$ and $\varphi \in P_t$ and (i) $PRO(\beta) = -$ for all β such that $MAINTERM(\beta, \alpha) = +$

and (ii) $\varphi = t[\gamma \delta \xi]$, where $\delta = \text{he}_n$ and γ does not contain he_n , then

PS14. $F_{15,n}(\alpha, \varphi) \in P_t$, where $F_{15,n}(\alpha, \varphi) = t[\gamma \text{ PROSUB}(\alpha, n, \xi)]$

PS14. (none)

S15. If $\alpha \in P_T$ and $\delta \in P_{IV}$ and (i) $PRO(\beta) = -$ for all β such that $MAINTEN(\beta, \alpha) = +$ and (ii) $\delta = IV[\gamma \in \theta]$, where $\xi = \underline{he}_n$ and γ does not contain \underline{he}_n , then $F_{16,n}(\alpha, \delta) \in P_{IV}$, where $F_{16,n}(\alpha, \delta) = IV[\gamma \wedge \alpha \wedge PROSUB(\alpha, n, \theta)]$.

PS15. $MAINVERB(\gamma, F_{16,n}(\alpha, \delta)) = +$ for all γ such that $MAINVERB(\gamma, \delta) = +$.

S17.1. If $\alpha \in P_T$ and $\delta \in P_{IV}$, then $F_{17}(\alpha, \delta) \in P_t$, where $F_{17}(\alpha, \delta) = {}_t[NOM(\alpha) \wedge AUX[do] \wedge AGR(\alpha, Pres)] \wedge \underline{not} \wedge \delta$

PS17.1. (none)

S17.2. If $\alpha \in P_T$ and $\delta \in P_{IV}$, then $F_{18}(\alpha, \delta) \in P_t$, where $F_{18}(\alpha, \delta) = {}_t[NOM(\alpha) \wedge AUX[will] \wedge \delta]$

PS17.2. (none)

S17.3. If $\alpha \in P_T$ and $\delta \in P_{IV}$, then $F_{19}(\alpha, \delta) \in P_t$, where $F_{19}(\alpha, \delta) = {}_t[NOM(\alpha) \wedge AUX[will] \wedge \underline{not} \wedge \delta]$

PS17.3. (none)

S17.4. If $\alpha \in P_T$ and $\delta \in P_{IV}$, then $F_{20}(\alpha, \delta) \in P_t$, where $F_{20}(\alpha, \delta) = {}_t[NOM(\alpha) \wedge AUX[have] \wedge AGR(\alpha, Pres)] \wedge ATTACH(\underline{en}, \delta)$

PS17.4. (none)

S17.5. If $\alpha \in P_T$ and $\delta \in P_{IV}$, then $F_{21}(\alpha, \delta) \in P_t$, where $F_{21}(\alpha, \delta) = {}_t[NOM(\alpha) \wedge AUX[have] \wedge AGR(\alpha, Pres)] \wedge \underline{not} \wedge ATTACH(\underline{en}, \delta)$

PS17.5. (none)

5. Problems and alternatives.

5.1. Gender.

No gender is assigned to \underline{he}_i ; as a result, the property specification rule for gender of conjoined term phrases (PS13) is undefined when either conjunct is an indexed pro-form. This should not cause a problem in this fragment because of the prohibition against quantifying in pro-forms (S14, S15) (which extends to pro-forms as conjuncts of term phrases), but it could cause a problem for languages in which predicate adjectives agree in gender with subjects. Perhaps languages in which gender is clearly syntactic (which might not include English) should have separate pro-forms for each gender.

Lauri Karttunen (personal communication) has suggested that gender in English might best be treated entirely as a matter of conventional implicature, and not handled in the syntax at all.

5.2. Case.

As mentioned in section 2.4., there is an asymmetry between the treatment of number and gender on the one hand and case on the other; the former are specified by the recursive property specification rules, the latter assigned by a syntactic rule when a verb or preposition combines with an object. For languages with a rich inflectional morphology, this would seem to imply that number and gender are specified bottom-up, while case is imposed top-down. Given that the same elements (determiners, adjectives) often show agreement in all three features, something seems wrong. The only uniform treatment I can think of is to define case bottom-up as well, generating term phrases of each case separately, and having verbs and prepositions select term phrases of a particular case to combine with rather than combining with un-case-marked term phrases and assigning case to them. The unattractiveness of generating all the cases separately could be lessened by providing a single schema with a

variable ranging over the values of the case property. One interesting consequence of such an approach is that it would render impossible rules like Passive or Raising which entail the reassignment of case. (Dowty (forthcoming) and Bresnan (forthcoming) argue independently that such rules should be eliminated in favor of lexical rules.)

5.3. Problems with the quantification rules.

Rules S14 and S15 do not quite work as they are stated, and what may seem at first like a trivial problem with them is probably a serious one. The crucial part of S14 is repeated below (the problem with S15 is identical).

$$(32) F_{15,n}(\alpha, \varphi) = \tau[\gamma \alpha \text{PROSUB}(\alpha, n, \tau)]$$

The SA part of the rule specifies that δ is the first occurrence of \underline{he}_n in φ ; $\varphi = \tau[\gamma \delta \xi]$. The problem is that in many cases, neither γ nor ξ will be constituents, yet the concatenation operation is defined only on constituents. My intention is that α should simply substitute for δ without affecting the rest of the structure, and that the PROSUB function should make appropriate substitutions in ξ without affecting the rest of its structure. If PROSUB were applying to the entire string φ , there would be no such difficulty (as there is no comparable difficulty with the relative clause rule S3.) But there is no way within the proposed framework to apply PROSUB (or any ESUB operation) to a part of an expression which is not a constituent. I have written the rule almost as if it were a transformation; the substitution of δ for α would be easily expressible in transformational terms (leaving surrounding tree structure intact). But as mentioned earlier, ESUB cannot be a transformation. The problem seems to be that I haven't found any way to have operations apply to specific parts of strings without having either (i) a factorization of the TG sort as SA statement or (ii) a reconcatenation of the

affected parts, violating constituenthood requirements.

An earlier formulation of the quantification rules avoided the concatenation problem but ran into a different one (Stanley Peter, Jr., personal communication). The earlier formulation of S14 was as follows:

$$(33) \text{ If } \alpha \in P_T \text{ and } \varphi \in P_t \text{ and (i) PRO}(\beta) = - \text{ for all } \beta \in \text{MAINTERM}(\alpha) \\ \text{and (ii) } \varphi = \tau[\gamma \delta \xi], \text{ where } \delta = \underline{he}_n \text{ and } \gamma \text{ does not contain } \underline{he}_n, \\ \text{then } F_{15,n}(\alpha, \varphi) \in P_t, \text{ where} \\ F_{15,n}(\alpha, \varphi) = \text{PROSUB}(\alpha, n, F_{16,n}(\alpha, \varphi)) \text{ and} \\ F_{16,n}(\alpha, \varphi) = \text{SUB}(\alpha, \delta, \varphi)$$

In effect, this rule first quantifies the term phrase in for the first occurrence of \underline{he}_n (by $F_{16,n}$), and then uses PROSUB to substitute the appropriate pronoun for all remaining occurrences of \underline{he}_n . Since each operation has the whole string φ as an argument, there is no need to break the string apart and reconcatenate it. This version also conforms more closely to the spirit of the proposal to build up rules by composition of subfunctions than does the final version. The problem, however, is that the quantified-in term phrase, δ , may itself contain occurrences of \underline{he}_n , and these would incorrectly be changed to pronouns by $F_{15,n}$ (they would not be bound semantically, since the semantics is exactly as in PTQ). So in fact I cannot see any way to write the quantification rule within this framework; unless there is a solution I have overlooked, it seems that I must either change the framework in some fundamental way, either by changing the way the rules work or by removing indexed pro-forms (and ESUB) from the syntax.

5.4. The auxiliary system.

I had originally hoped to give a more uniform treatment than Montague did to the auxiliary system; the main obstacle turned out to be the problem of conjoined verb phrases. The need for a better treatment of across-the-board

phenomena was discussed in section 2.7. I will add here only one particular problem that so far as I know has not been solved in any extensions of PTQ, and perhaps not in any other framework either. There are conjoined verb phrases such as "be in the park and walk"; what should happen when such a verb phrase is put into the present tense negative form? PTQ gives (34); Friedman (1974) gives (35); there seems to be no possible form at all.

(34) *John is not in the park and walk.

(35) *John doesn't be in the park and walk.

(For reasons noted by Friedman (1974), (36) would be a semantically incorrect form for this rule to produce, though syntactically acceptable.)

(36) John is not in the park and doesn't walk.

The behavior of copular be greatly complicates the treatment of verb phrase conjunction, since it originates in the verb phrase but behaves like an auxiliary if there are no other auxiliaries present. (This presents problems for many frameworks, not just this one.)

It would be possible to list a number of further problems, but the ones cited include the most serious problems for this framework that I am aware of. Some of them present problems for other frameworks as well; I cannot be sure at this point to what extent the phenomena in question are not yet well enough understood.

Let me add a personal note by way of conclusion. It can be very frustrating to try to specify frameworks and fragments explicitly; this project has not been entirely rewarding. I would not recommend that one always work with the constraint of full explicitness. But I feel strongly that it is important to try to do so periodically, because otherwise it is extremely easy

to think that you have a solution to a problem when in fact you don't. If the failure of this attempt to provide a framework both constrained and descriptively adequate can help to lead toward the construction of a better one, I won't regret the headaches.

Footnotes

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¹See Montague (1970b, 1973).

²Once, when Montague was told about linguists' aim of constructing a theory of language to characterize all and only possible human languages, his response was to ask why linguists wished to disqualify themselves from fieldwork on other inhabited planets.

³This has been pointed out by a number of writers; discussion together with a vivid illustration can be found in Bach and Cooper (1978).

⁴Partee (forthcoming). In PTQ, it is the analysis trees that play the role of disambiguated language. Cooper (1975) suggests a way of dispensing entirely with the level of disambiguated language.

⁵It would be possible to treat all adjectives as common noun modifiers by introducing a syntactic category CN//CN for those Siegel treats as t//e; a meaning postulate could be written to "reduce" them in effect to the type $\langle\langle s, e \rangle, t \rangle$.

⁶The introduction of these 'subfunctions' was suggested to me by Emmon Bach. The notion bears some resemblance to the introduction of subroutines in computer programming.

⁷See Partee (1973, 1975). Friedman (1974) suggests that unlabelled bracketing may be all that is required for the resolution of the particular difficulties with PTQ conjunction.

⁸I refer interchangeably to tree structures and labelled bracketings, since either is easily convertible into the other. (Labelled bracketings are typographically more convenient than trees, but structural relations such as "sister node" and "parent node" are easiest to express in tree terms.)

⁹Within transformational grammar, an increase in the number of cyclic categories similarly leads to a decrease in the need for extrinsic rule ordering. See, for example, Williams (1975).

¹⁰Linguistically unnatural features of PTQ that appear to be consequences of the requirement of total functions include vacuous relativization (where the clause to be relativized contains no occurrence of the relevant he_n), vacuous quantification, and the quantifying in of subscripted pronouns.

¹¹The treatment of "features" as recursively defined predicates was suggested to me by Terry Parsons.

¹²In the fragment presented here I treat gender as syntactic in English to illustrate the idea of recursively defined properties. Such a treatment would be appropriate for a language like French or Russian, but it is likely that English gender should not be treated in the syntax at all (Lauri Karttunen, personal communication).

¹³Ewan Klein pointed out to me the possibility that recursively defined properties potentially have all the power of reference to derivational history; he has shown (unpublished notes) how Thomason's (1976) use of derivational history in the statement of reflexivization can be replaced by a recursively defined property of expressions. Nothing I say here rules out his example; the property he uses bears some resemblance to the "Type 3" properties discussed below.

¹⁴Jackendoff, Bresnan, and others have made various suggestions of this sort.

¹⁵A similar device was employed by Montague (1970a) to identify main verb occurrences in verb phrases.

¹⁶That (i) may be equivalent was pointed out to me by Ewan Klein (see note 13); that (ii) may be was suggested by David Lewis at the conference where this paper was presented.

¹⁷See, for instance, the I-Grammar variant of PTQ in Cooper and Parsons (1976).

¹⁸This effect is achieved by Bach (1976, 1978) by eliminating syntactic gender agreement rules, having all of he_i , she_j , it_k separate from the start and with disjoint subscripts.

¹⁹In the I-grammar of Cooper and Parsons (1976), the selection of an index for a term phrase (and its consequent "quantified-in" interpretation) is followed by the selection all at once of whatever pronouns are to be interpreted as co-indexed to it.

²⁰Variable binding is evidently the only thing that makes the syntax of the set of closed formulas of the predicate calculus non-context-free (personal communication from both Herbert Bohnert and William Marsh, independently.)

²¹See the discussion of passive, complex transitive verbs, and the "right-wrap" subfunction in Bach (ms. a, ms. b).

²²At the time this paper was begun, the only published work in Montague grammar on languages other than English that I knew of was that of Siegel (1976a, 1976b) on Russian and that of Cooper (1975) on Hittite. There were two such papers presented at this conference, one by Thomason and Thomason on Serbo-Croatian and one by Thomason and Mithun on Mohawk. There is also now a dissertation by Marion Johnson on Kikuyu (Ohio State), one by James McCloskey on Irish (University of Texas at Austin), and one in progress in

part on Sanskrit by Dave Davis (University of Massachusetts at Amherst). There is probably more than I am unaware of or have forgotten to mention.

²³"She or he" might be better here, but that would require a more complicated device with the power of the "respectively" transformation.

²⁴Evidence for the rule came from Joan Bresnan (personal communication), whose example was a noun phrase of the following form:

(i) every man who loses a pen who finds it

Subsequent discussion with Emmon Bach has persuaded me that such examples do not involve genuine bound-variable anaphora and are probably better grouped with the problematical "donkey-sentences" like (ii), however these are best treated.

(ii) Every man who owns a donkey beats it.

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