SOME TRANSFORMATIONAL EXTENSIONS OF MONTAGUE GRAMMAR[1]

Barbara Partee

0. Introduction

Richard Montague's work on English, as represented in Montague (1970a), (1970b), (1972), represents the first systematic attempt to apply the logician's methods of formal syntax and semantics to natural language. With few exceptions,[2] linguists and logicians had previously been agreed, although for different reasons, that the apparatus developed by logicians for treating the syntax and semantics of artificially constructed formal languages, while obviously fruitful within its restricted domain, was not in any direct way applicable to the analysis of natural languages. Logicians seem to have felt that natural languages were too unsystematic, too full of vagueness and ambiguity, to be amenable to their rigorous methods; or if susceptible to formal treatment, only at great cost.[3] Linguists, on the other hand, emphasize their own concern for psychological reality, and the logicians' lack of it, in eschewing the logicians' approach: linguists, at least those of the Chomskyan school, are searching for a characterization of the class of possible human languages, hoping to gain thereby some insight into the structure of the mind, and the formal languages constructed by logicians appear to depart radically from the structures common to actual natural languages.

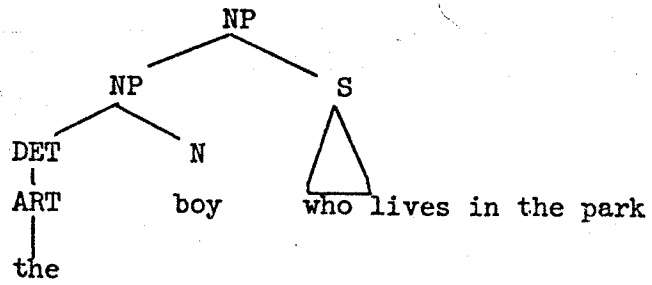
Montague's claim, as represented in the title of one of his papers, "English as a Formal Language," is that English can be treated in a natural way within the logical tradition in syntax and semantics. A few remarks about that tradition are in order here. Since Tarski (see, e.g., Tarski (1944)), the concept of truth has played a key role in semantics. It is held that an essential part of the semantic interpretation of any sentence is a specification, given in a metalanguage antecedently understood, of the conditions under which the given sentence is true. Thus an essential part of semantics is the construction of a theory of truth for a language. The mechanism for doing this involves syntax in a fundamental way: first, a set of recursive syntactic rules are given defining the set of wffs (well-formed formulas), starting with the smallest, primitive elements and specifying how units of various categories can be combined to form larger units. Then the task of the semantics is to assign interpretations to the

smallest units and then to give rules which determine the interpretation of larger units on the basis of the interpretation of their parts. A key feature of this approach is that the part-whole analysis should be the same in the syntax and the semantics; the syntactic analysis should build up larger units from (or equivalently, analyze them into) just those parts on the basis of which the meaning of the larger unit can be determined. (This one-one correspondence between syntactic and semantic structure is not an absolute condition on the construction of formal languages, and some treatments of the semantics of the two standard quantifiers, for instance, violate it;[4] languages constructed in accordance with it are often called "logically perfect languages").

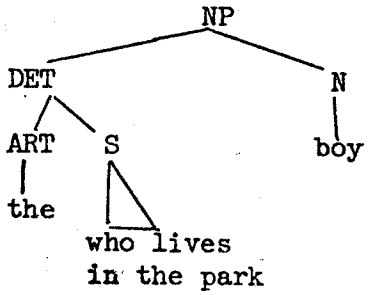
Note that the logical tradition involves a bottom-up view of both sentence construction and semantic interpretation. In the case of purely context-free phrase structure rules and something like a Katz-Fodor-Postal semantics of the 1963-1965 period, it is easy enough to see a close correspondence between linguistic and logical practice, since CF-rules can be equally well interpreted as starting at the bottom (with the lexical units) and applying to build up larger and larger phrases. Then the only gross divergence between the Katz-Fodor view of semantics and that of the logical tradition is in the nature of the output of the semantic rules (see Vermazen (1967)); the idea of a fundamental connection between the syntactic and semantic rules is preserved. But transformational grammar in general has gotten away from that, and semantics was never developed far enough within the "standard theory" to reach the point of influencing the syntax in any systematic way. What we find now in linguistics are two main approaches which depart radically, in different ways, from the principle of a one-one correspondence between syntactic and semantic rules. One approach, generative semantics, was founded in part on the conviction that semantic and syntactic rules could not be separated in any principled way, and that "semantic-interpretation" and "deepest structure" could be identified.[5] The other, interpretive semantics, maintains the distinction between syntactic rules as formation rules and semantic rules as interpretive rules, but does not posit any systematic relation between them.[6]

Within the logical tradition, there are just two criteria of adequacy for syntactic rules: (i) that they define the set of wffs of the language (which is not an empirical constraint for constructed languages, unless some independent characterization of the set of wffs is already given), and (ii) most importantly, that they provide a basis for the rules of semantic interpretation. To illustrate the consequences of the second condition, consider the long-standing disputes among linguists as to the heirarchical constituency relations within noun phrases containing a determiner, a noun, and a relative clause, e.g., "the boy who lives in the park". There have been at least three basically different alternatives suggested in the literature, schematically represented below[7] as (1), (2), and (3).

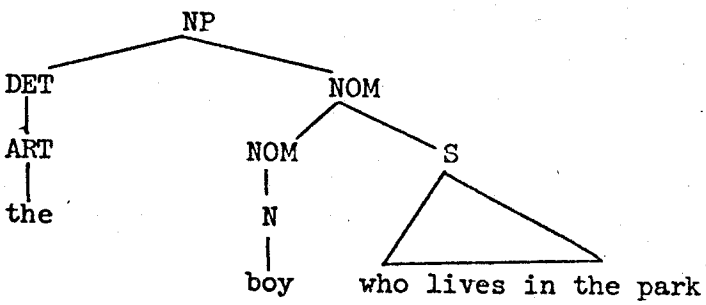
(1)



(2)



(3)



There are syntactic arguments pro and con in each of these structures[8], but semantic arguments have entered in only peripherally, because no systematic attempt was ever made in any of the linguistic treatments to find rules to determine the interpretation of the whole NP on the basis of its parts. But the following informal sketch of the relevant semantics[9] shows that a structure like (3) can provide a direct basis for the semantic interpretation in a way that (1) and (2) cannot. The construction has three parts: the, a noun, and a relative clause. Each analysis makes two binary subdivisions, and in fact, apart from linear order the three analyses exhaust the possible binary sub-groupings. The semantic consequences of the differences can be seen most clearly by focussing on the interpretation of the. Ignoring controversial details, the general principle for interpreting singular phrases of the form the α will include an assertion or presupposition that the class denoted by α has one and only one member. The noun boy denotes a class (the class of boys), and so does the relative clause who lives in the park (the class of entities which live in the park.[10]) Under analysis (3), the two class-denoting phrases are first combined to form a complex class-denoting phrase, which can be interpreted as denoting the intersection of the two classes[11], namely the class of entities which both live in the park and are boys;

combining the with the result leads to the correct assertion that it is that class that has one and only one member. On analysis (1), on the other hand, the is first combined with boy, which would lead to an assertion that there is one and only one boy, and only a non-restrictive interpretation of the relative clause could naturally be gotten by combining that assertion with the interpretation of who lives in the park. Similarly, the first stage in the interpretation of (2) would lead to an assertion that there is one and only one entity that lives in the park, leaving no natural way to add the interpretation of boy. Put another way, the problem with trying to use structure (1) for semantic analysis is that the meaning of the phrase the boy is not a part of the meaning of the phrase the boy who lives in the park. The problem for structure (2) is analogous. Only by making the major syntactic sub-division between the and boy who lives in the park can a uniform semantic treatment of the be given.[12]

The example just discussed shows that the requirement that semantic interpretation rules correspond structurally to the syntactic rules can put very strong constraints on possible syntactic analyses. This point is worth emphasizing because Montague offers virtually no constraints on syntactic rules themselves; it is only in the connection between syntax and semantics that the grammar is constrained, but that constraint is strong enough that I think it is a serious open question whether natural languages can be so described.

1. Montague's "The Proper Treatment of Quantification in Ordinary English"

In this section I will sketch some of the key features of the last (and to a linguist the most interesting) of Montague's three treatments of fragments of English, that in Montague (1972) (henceforth PTQ). Since the syntactic rules work bottom-up, I will start with the grammatical categories and the lexicon, then mention the rules most like CF-rules, and finally discuss the treatment of quantification. (The fragment also includes relative clauses, about which I will say no more than the few informal remarks above.)

1.0 Categories and lexicon

The categories are defined as in a categorial grammar,[13] though the rules that combine them are not limited to simple concatenation (categorial grammars are a subclass of CF grammars, but Montague's syntax is not.) The two basic categories are t, the category of sentences (t for truth-bearing), and e, the category of "entity-expressions". The category e seems quite mysterious if one looks only at the syntax, since it turns out that no words or phrases of English are assigned to that category. But it, along with the category t, is used in defining the remaining categories, and in the language of intensional logic into which the English expressions are translated, there are expressions of category e, and they are interpreted as denoting entities in a straightforward way.

The remaining categories are defined categories; for instance, the category of intransitive verb phrases, abbreviated as IV (the linguist's VP) is defined[14] as t/e: something that could combine with an e-phrase (if there were any) to form a t-phrase (sentence). In this case, since there are no e-phrases in the object language, there is no syntactic rule combining an IV-phrase with an e-phrase to make a sentence, but the definition nevertheless has consequences in the semantics. The category of common noun phrases, abbreviated CN, is defined as t//e, another category of the same categorial (henceforth CAT) type as IV. (The use of single vs. double slashes is simply a device for distinguishing two syntactic categories of the same CAT type; a larger fragment of English might require triple slashes or more.)

The category of term-phrases, abbreviated T (the linguist's NP) is defined as t/IV something that combines with an IV-phrase to make a t-phrase (sentence). In this and all the remaining cases, since the constituent categories are non-empty, there are syntactic rules which specify just how the constituent categories combine. The following chart gives all the categories of the grammar.

Category	Abbreviation	PTQ name	Nearest linguistic equivalent
t	(primitive)	truth-value expression; or declarative sentence	sentence
e	(primitive)	entity expression; or individual expression	(noun phrase)
t/e	IV	intransitive verb phrase	verb phrase
t/IV	T	term	noun phrase
IV/T	TV	transitive verb phrase	transitive verb
IV/IV	IAV	IV-modifying adverb	VP-adverb
t//e	CN	common noun phrase	Noun or NOM
t/t	none	sentence-modifying adverb	same
IAV/T	none	IAV-making preposition	locative, etc., preposition
IV/t	none	sentence-taking verb phrase	V which takes that-COMP
IV//IV	none	IV-taking verb phrase	V which takes infinitive COMP

Most of the categories have both lexical members and derived phrasal members; the category t contains only derived phrases, and the categories t/t, IAV/T, IV/t, and IV//IV contain only lexical members. The complete lexicon for the fragment is presented in the listing below; B_A means "basic expression of category A".

B_t = ∧
B_e = ∧
B_{IV} = { run, walk, talk, rise, change }
B_T = { John, Mary, Bill, ninety, he_0, he_1, he_2, ...}
B_{TV} = { find, lose, eat, love, date, be, seek, conceive }
B_{IAV} = { rapidly, slowly, voluntarily, allegedly }
B_{CN} = { man, woman, park, fish, pen, unicorn, price, temperature }
$B_{t/t}$ = {necessarily}
$B_{IAV/T}$ = { in, about }
$B_{IV/t}$ = { believe that, assert that }
$B_{IV//IV}$ = { try to, wish to }

1.1 Rules of functional application

The syntactic component of the grammar is a simultaneous recursive definition of the membership of the sets of phrases P_A for each category A, with the set of sentences being the members of P_t. Each syntactic rule has the general form "If $\alpha_1 \in P_{A_1}$, $\alpha_2 \in P_{A_2}$, ..., $\alpha_n \in P_{A_n}$, then $F_i(\alpha_1, \ldots \alpha_n) \in P_B$" where F_i is a specification of the syntactic mode of combination of the constituent phrases and B is the category of the resulting phrase. Some of the syntactic functions F_i are simply concatenation or concatenation plus some morphological adjustments and are hence very much like CF-rules; others of the F_i bear more resemblance to transformations. All of the syntactic rules build up larger phrases from smaller ones. The semantic interpretation rules operate in two stages. First, for every syntactic rule there is a corresponding rule of translation into an expression of intensional logic; these rules also apply "bottom-to-top", paralleling the syntactic derivation, so that the translation of any given sentence into intensional logic is built up via translations of each of its subphrases, starting from the basic expressions. (Most of the basic expressions, e.g., John, walk, slowly, are translated into constants of appropriate categories in the intensional logic; a few, such as be, necessarily, and he_0, he_1, etc., receive special translations reflecting their special logical roles.) The second stage of the semantic interpretation consists of a possible-worlds semantics defined for the given intensional logic. An independent syntactic characterization of the wffs of the intensional logic is given, and the semantic rules for the intensional logic are based on the structure given by those syntactic rules. In some of Montague's earlier work, the possible-worlds semantics was defined directly on the English syntax; the change to two-stage semantics may reflect some measure of agreement with Quine's remarks cited in footnote 3.

We will concentrate on the relations between the syntactic rules and the rules of translation into intensional logic; the semantics of the intensional logic is developed in a way familiar to logicians and will not be discussed here. Among the syntactic rules there is a subset which relate directly to the CAT definitions, and whose corresponding rules of translation follow a uniform pattern. For every category A/B or A//B there is a syntactic rule of the form (4):15

(4) If $\alpha \in P_{A/B}$ and $\beta \in P_B$, then $F_i(\alpha,\beta) \in P_A$.

For each such rule, the corresponding rule of translation into intensional logic is (5):

(5) If $\alpha \in P_{A/B}$ and $\beta \in P_B$, and α,β translate into α', β', then $F_i(\alpha,\beta)$ translates into $\alpha'(\hat{}\beta')$.

The notation $\hat{}\beta'$ means "the intension (or sense) of β'". Thus each member of a complex category A/B is interpreted as denoting a function which takes as argument intensions of expressions of category B; applying that function to that argument gives the interpretation of the resultant A-phrase. For example, the function corresponding to "rapidly" applied to the sense of "run" gives the interpretation of "run rapidly"; the function corresponding to "in" applied to the sense of the T-phrase "the park" gives the interpretation of "in the park".

Linguists lost interest in CAT grammar when it was shown to be a subcase of CF-grammar, since at that time the focus was on pure syntax. The original point of CAT grammar, however, was to connect syntactic and semantic structure in a certain way. David Lewis (1971) suggests using a pure (i.e. CF) CAT grammar for the base component of a transformational grammar. Montague, who has no base component per se, makes use of the basic CAT notions in a system of syntactic rules not restricted to CF rules, and keeps the close correspondence between syntactic and semantic rules as the central feature of the CAT idea. The CAT rules, which he calls rules of functional application because of their semantic interpretation, do not exhaust the grammar, however, they may be viewed roughly as those rules which define the basic grammatical relations among the parts of simple sentences; there are additional rules for conjunction, relative clauses, quantification, tenses, and negation, to which we now turn.

1.2 Other rules of PTQ: quantification

To illustrate the workings of the rest of the grammar of PTQ, we will describe Montague's treatment of quantification.

Probably the most novel feature of Montague's treatment is that quantifier phrases such as every man, the unicorn, a woman are analyzed as

term phrases along with John and Mary. Although such an analysis is not linguistically novel (both sorts have been traditionally called NP), it goes against the treatment of quantifier expressions, first suggested by Frege, that opened up the way for the development of quantificational logic and has become standard in logic. The standard logical analysis of, say, every man runs would be written as (6):

(6) $(\forall x)\,(Mx \longrightarrow Rx)$.

What looked like a term phrase in the English sentence does not appear as a constituent in the logical expression, but is rather reanalyzed into the whole frame in which "R" appears. A proper name, on the other hand, does show up as a simple term-expression in standard logical notation; thus John runs would be simply Rj.

The way Montague manages a uniform treatment of every man and John is to interpret both as denoting sets of properties of individual concepts. The individual concept of John is the function which picks out John at each possible world and time. The constant j in the intensional logic is of category e and simply denotes the individual John (assuming we have fixed on a particular interpretation of the constants of the intensional logic.) The individual concept of John is denoted by $\wedge j$, where "$\wedge$" means "intension of". The term-phrase John in the English fragment is not translated simply as j or as $\wedge j$, however, it is translated as $\hat{P}\ P\{\wedge j\}$, the set of all properties of the individual concept of John. There is a one-one correspondence between individuals and the set of all properties of their individual concepts; the only reason for giving such a "higer-order" treatment of the proper nouns is that phrases like every man can also be interpreted as sets or properties of individual concepts, and in this way the desired unification of term-phrases can be achieved. The syntactic rule which creates quantifier phrases is given below as (7):

(7) If $\alpha \in P_{CN}$, then $F_0(\alpha)$, $F_1(\alpha)$, $F_2(\alpha) \in P_T$, where

$F_0(\alpha)$ = every α

$F_1(\alpha)$ = the α

$F_2(\alpha)$ = a/an α

The corresponding translation rule is (8).

(8) If α translates into α', then

$F_0(\alpha)$ translates into $\hat{P}[(\forall x)(\alpha'(x) \longrightarrow P\{x\})]$

$F_1(\alpha)$ translates into $\hat{P}[(\exists y)((\forall x)[\alpha'(x) \longleftrightarrow x=y] \wedge P\{y\})]$

$F_2(\alpha)$ translates into $\hat{P}[(\exists x)(\alpha'(x) \wedge P\{x\})]$.

Thus every man is interpreted as denoting the set of all properties which every man has; the king as denoting the set of all properties such that there is a unique entity which is a king and he has those properties; a fish as denoting the set of all properties which some fish has (the union of all the properties of all the fish there are).

A related innovation of Montague's treatment is that when a term-phrase and an IV-phrase are combined to form a sentence, it is the term-phrase which is viewed as function and the IV-phrase as argument. Thus the translations of John runs and every man runs come out schematically as (9) and (10) respectively:

(9) John' ($\hat{}$ run')
(10) every man' ($\hat{}$ run')

What (9) says is that the property of running is in the set of properties of (the individual concept of) John, which is logically equivalent (at least given certain of the meaning postulates of PTQ regarding the extensionality of run, etc.) to saying that John has the property of running. Expression (10) says, in a parallel manner, that the property of running is in the set of properties shared by every man, which is likewise equivalent to the usual logical formulation. The ultimate logical interpretations of these sentences are thus just the standard ones; what is new is being able to get to those interpretations from a syntax that assigns proper names and quantifier phrases to the same syntactic category.

In the sentences just discussed, the term-phrases were introduced into the sentence directly by the CAT rules; but they may also be introduced via substitution for free variables, a mechanism necessary to account for ambiguities of scope. The rule for sentence-scope quantification is given in a rough form in (11):

(11) 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 illustrated below:

Let α = every unicorn, ϕ = $\underline{\text{he}_0}$ seeks a woman such that she loves $\underline{\text{him}_0}$

Then $F_{10,0}(\alpha,\phi)$ = every unicorn seeks a woman such that she loves it

What the rule does is combine on a term phrase and a sentence (an open sentence in all the non-vacuous cases) with respect to a given free variable in the sentence (the subscript n of the syntactic-operation-schema $F_{10,n}$), by substituting the term phrase for the first occurrence of the variable and appropriate pronouns for the subsequent occurrences. The corresponding translation rule is (12):

(12) If α, ϕ translate into α', ϕ' respectively, then $F_{10,n}(\alpha,\phi)$ translates into $\alpha'(\hat{x}_n\phi')$.

This interpretation comes out just like the interpretation of John runs or every man runs described above, except that instead of the simple property of running we have whatever property of x_n (which corresponds,

albeit indirectly, to $\underline{he}_n$) is expressed by the sentence ϕ.

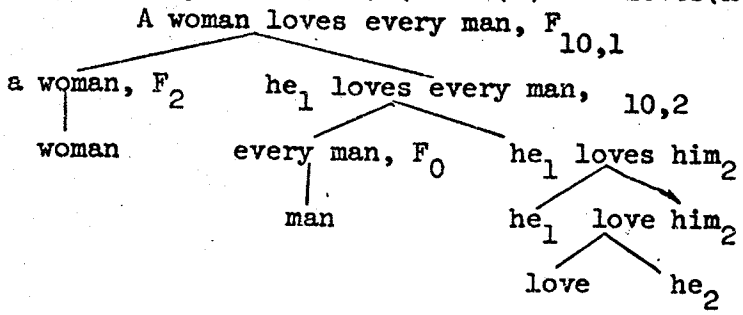
To illustrate the treatment of scope ambiguity we will show two analysis trees for sentence (13) below. An analysis tree is a graphic representation of the steps by which a sentence has been constructed (more like a T-marker in pre-1965 transformational theory than like a P-marker), with each node labelled by an expression and an index indicating the structural operation that was applied to form it, the nodes immediately beneath indicating the expressions from which it was formed. The two analysis trees (13a') and (13b') correspond to the interpretations given as (13a) and (13b). The only structural operations labelled in the trees are those that have been presented here.

(13) A woman loves every man.

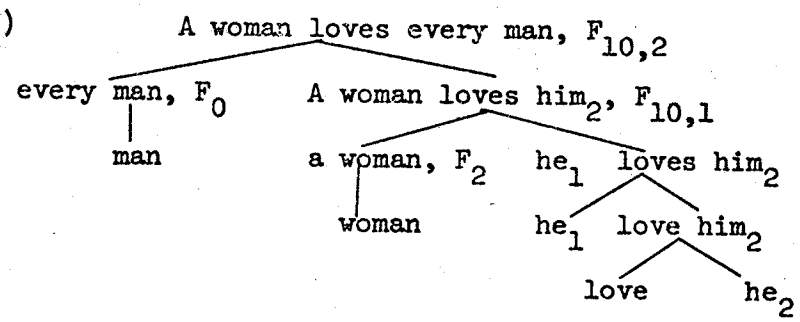
(13a) $(\exists x)\ (\text{woman}(x) \wedge (\forall y)\ (\text{man}(y) \longrightarrow \text{loves}(x,y)))$

(13b) $(\forall y)\ (\text{man}(y) \longrightarrow (\exists x)\ (\text{woman}(x) \wedge \text{loves}(x,y)))$

(13a')



(13b')



Such trees bear a striking resemblance to the abstract trees found in generative semantic treatments of quantifiers; in particular, a higher position in the tree indicates wider scope, and the quantificational substitution rule is analogous to quantifier-lowering. On the other hand, since the trees are not P-markers, they do not represent constituent structure, and no grammatical relation is said to hold between a quantifier phrase and the sentence with which it is combined. The syntactic rules generate well-formed ("surface") expressions directly without ill-formed "deeper" structures, with the sole exception of the occurrence of the free variables he_0, he_1 etc. The "abstractness" which is needed for the semantic rules to correctly interpret the expressions is provided not by a labelled bracketing assigned to the generated expressions themselves (Montague doesn't assign any, although it is a natural extension

to make), but by the analysis tree which is in a sense a partly temporal representation. For instance, the two analyses of sentence (13) differ not in their parts or the grammatical relations between them, but in the order in which those parts were put together.

This point may be clarified by anticipating the first addition to the system to be proposed in the next section, namely the addition of labelled bracketing. If we assign to each generated expression a labelled bracketing, or P-marker, then at each node of the analysis tree there will be a P-marker, not simply a string. Then the analogy between an analysis tree and a T-marker becomes even stronger: each generated expression is given a P-marker which shows its internal constituent structure and to which subsequent syntactic rules may be sensitive, while the analysis tree shows its derivational history, and it is to the latter that the semantic interpretation rules correspond. Note that there is no single level corresponding to "deep structure" in anybody's sense, since PS-like rules and transformation-like rules are not distinguished and there is no extrinsic rule ordering.

There is much more that could be said about the grammar of PTQ, but I want to turn now to some suggestions for extending it to include transformations.

2. Transformational extensions

2.0 Introduction

The fragment Montague chose to develop was semantically a very rich one, including as it did quantification, verbs of propositional attitude, verb-phrase adverbs, be, and necessarily; but syntactically it was quite simple,[16] and the rules given provide no basis for conjecturing what Montague would have done about such classic constructions as passive sentences, reflexive pronouns,[17] or the easy-to-please construction. The rest of the paper is concerned with the question of whether and how such constructions can be accommodated within Montague's framework. I will suggest two additions to the framework itself, labelled bracketing and a "starred variable convention", additions which seem to me natural and helpful although I have no proof that they are indispensable. With these two general additions and a few grammar-specific departures from the usual ways of stating certain transformations, I will sketch a way to add to Montague's grammar rules for reflexive, passive, "tough-movement" (= "easy-to-please"), subject-raising, object-raising, and derived verb phrases in general. I will also discuss some problems raised by apparent dialect differences with respect to various types of scope ambiguity.

2.1 Labelled bracketing. In addition to the generally acknowledged need for labelled bracketing in the statement of transformational rules, there is some internal evidence in PTQ that the addition of labelled bracketing would be helpful, if not indispensable.[18] One of Montague's rules adds a

subject-agreement morpheme to the first verb of a verb phrase when the verb phrase is combined with a subject to make a sentence. Thus John plus walk becomes John walks. But PTQ also contains a verb-phrase conjunction rule, so the grammar, incorrectly, generates John walks and talk, with talk instead of talks. The problem that arises in attempting to correct the agreement rule is with verb phrases like try to walk and talk, which are ambiguous. The ambiguity shows up in the analysis tree, of course, and can be represented by labelled bracketing as $_{IV}[_{IV}$[try to $_{IV}$[walk]] and $_{IV}$[talk]] vs. [try to $_{IV}[_{IV}$[walk] and $_{IV}$[talk]]]. A rule sensitive to the bracketing could assign subject-agreement correctly, giving John tries to walk and talks and John tries to walk and talk, respectively, while a rule operating only on strings could not make such a discrimination.

I will thus assume that labelled bracketing is a desirable addition to the theory; as for implementing it, it is straightforward for all the rules which are analogous to PS-rules, and I will just leave open for the time being the details of what labelled bracketing to assign in cases where the rules add grammatical morphemes which are not themselves assigned to any category, or in other ways lead to indeterminacies of bracketing. I assume that either some general principles can eventually be found to cover such cases, or the derived structure will have to be determined for each such rule on the basis of the requirements of subsequent rules, and explicitly stated (as in current transformational practice, or an idealization thereof.)

2.2 Semantic constraint. The constraint which Montague's theory imposes on the addition of transformational rules is that, as for all syntactic rules, there must be a single uniform translation rule for each T-rule. The translation rule must be such that the translation of the input expression(s) must occur intact in the translation of the output; translation rules cannot change the interpretation of expressions which have already been built up by preceding rules. In the case of meaning-preserving transformations, this requirement presents no problem, since the corresponding translation rule will just be the identity mapping. So now that labelled bracketings have been added, any "purely stylistic" transformations can be added to the grammar in essentially their usual form. (For consistency, they would be worded as follows: "If $\phi \in P_t$ and ϕ is of the form ..., then ... $\in P_t$", where the first"..." would be filled by the structural description and the second by the structural change.)

But the semantic constraint does pose a problem for the statement of rules that involve deletion, such as all the rules which include equi-NP deletion, since the translation rules must always preserve what has been built up so far, and can never delete anything. In the rules sketched below, there are two grammar-particular innovations introduced to accommodate rules which have traditionally involved deletion: in the agentless passive, what is usually called agent-deletion is expressed as a

rule which syntactically deletes a free variable but semantically adds an existential quantifier over that variable; for derived verb phrases in general, a rule is introduced which syntactically deletes a free variable $\underline{he}_i$ from subject position but semantically adds an "abstraction operator" $\hat{x}_i$ to the translation of the input expression. Thus in both cases the problem is solved by finding a way of interpreting syntactic deletion as semantic addition, and it seems to me that the resulting semantic interpretations are indeed correct. It is of course an open question whether such an approach is the best in the long run, but at least the first major obstacle to synthesizing the two theories has been overcome.

2.3 Six transformations

In this section I sketch, not completely rigorously, rules for reflexivization, passivization, passive agent deletion, tough-movement, subject-raising, and object-raising. Most of these rules can be stated in essentially their classical forms; I include them primarily to show their interaction with the derived verb-phrase rule presented in section 2.4 below. Several of the rules are given in two forms, a "strict form" and a "loose form", which I will relate to the questions of conflicting judgments of scope ambiguity.

1. Reflexive. If $\phi \in P_t$ and ϕ is a simplex sentence[19] of the form $\alpha\ \underline{he}_i\ \beta\ \underline{him}_i\ \gamma$, then $F_{100}(\phi) \in P_t$, where $F_{100}(\phi) = \alpha\ \underline{he}_i\ \beta\ \underline{him}_i\ \underline{self}\ \gamma$.[20]
   Example. he_3 sees $him_3 \longrightarrow he_3$ sees him_3 self.
   Translation rule: identity mapping.

2. Passive. If $\phi \in P_t$ and ϕ has the form:
   (a) strict form: $_t[_T[\alpha]_{IV}[_{TV}[\beta]_T[\underline{him}_i]\ \gamma]]$
   (b) loose form: $_t[_T[\alpha]_{IV}[_{TV}[\beta]_T[\delta]\ \gamma]]$
   then $F_{101}(\phi) \in P_t$, where $F_{101}(\phi)$ is:
   $$_t[_T[\ \left\{\begin{array}{l}\text{(a) } \underline{he}_i \\ \text{(b) } \delta\end{array}\right\}\ ]_{IV}[\underline{is\ EN}_{TV}\ [\beta]_\gamma\ [\underline{by}_T\ [\alpha]]\ ]]]$$
   Example: John sees $him_2 \longrightarrow he_2$ is seen by John.
   Translation rule: identity mapping.

3. Passive agent deletion. If $\phi \in P_t$ and ϕ has the form:
   $_t[_T[\underline{he}_i]\ _{IV}\ [\underline{is\ EN}_{TV}[\beta]\ [\underline{by\ him}_j]]]$
   then $F_{102}(\phi) \in P_t$, where $F_{102}(\phi)$ is:
   $_t[_T[\underline{he}_i]_{IV}\ [\underline{is\ EN}_{TV}\ [\beta]]]$

Example. he_1 is loved by him_3 ⟶ he_1 is loved.

Translation rule. If $\Phi \in P_t$ and Φ translates into Φ', then $F_{102}(\Phi)$ translates into $(\exists x_j)\ \Phi'$.

4. Tough-movement. (In stating this rule I have to make the contrary-to-fact assumption that the fragment already contains a syntactic category AP (adjective phrase), a subcategory of adjectives A_E, containing easy, tough, etc., and infinitive phrases in subject position.)

If $\Phi \in P_t$ and Φ has the form:
$t[_{INF}[\beta\ \underline{him}_i\ \gamma]\ _{IV}[\ \underline{is}_{AP}[A_E\ [\alpha]]]]$
then $F_{103}(\Phi) \in P_t$, where $F_{103}(\Phi)$ is:
$t[\ _T\ [\underline{he}_i\ ]\ _{IV}\ [\ \underline{is}_{AP}\ [A_E[\alpha]]_{INF}\ [\beta\ \gamma]]]$.

Example. to please him_7 is easy ⟶ he_7 is easy to please.

Translation rule: identity mapping

N.B. The above is the strict version; the loose version would have δ in place of $\underline{him}_i$.

5. Subject raising

Here I will just indicate the rule by an example. The strict version requires the moved T-phrase to be a variable, the loose version does not.

Example. it seems that he_6 is happy ⟶ he_6 seems to be happy

Translation rule: identity mapping.

6. Object raising. Same comments and translation rule as above.
John believes that he_3 is a fool ⟶ John believes him_3 to be a fool.

Aside from the question of which constituents are required to be free variables, the only innovation in the rules above is in the treatment of passive agent deletion. There have been two main proposals in the previous transformational literature, one that what is deleted is the word someone and the other that it is an "unspecified NP". I have nothing to say about the latter because its semantic interpretation has never been made explicit, but some comparisons can be made between the treatment above and someone-deletion. There is a minor problem with someone-deletion in that the deleted agent need not always be animate, but that could be rectified. The problem I am interested in lies in the interpretation of the relative scope of the existential quantifier associated with the deleted agent and any other quantifiers that may occur in the sentence. In the rule as stated above I have only dealt with the subject and object term-phrases, but the

treatment could be extended to cover all the term-phrases in the same simplex sentence, or whatever the actual restrictions should be. Consider the following sets of sentences.

(14) (a) Someone has reviewed all of John's books.
(b) All of John's books have been reviewed by someone.
(c) All of John's books have been reviewed.

(15) (a) Someone caught three fish.
(b) Three fish were caught by someone.
(c) Three fish were caught.

Judgments differ as to how many readings the (a) and (b) sentences have, but the (c) sentences are uniformly judged to be unambiguous, with the deleted quantifier having narrower scope than the remaining quantifier. If the (c) sentences were derived from (b) sentences, then those speakers who allow a wide-scope reading for someone in the (b) sentences should also do so for the (c) sentences, but they don't. The analysis presented above captures this fact by requiring deletion to occur while both term-phrases are free variables, and existentially quantifying over the deleted variable in the translation of the result. Thus the remaining variable, the derived subject, has to be quantified after the deleted variable, and therefore will necessarily be interpreted as having wider scope.

The other matter to be discussed before going on to the derived verb phrase rule is the question of interpretations of scope and the strict vs. loose forms of the rules. The sorts of examples we are concerned with here include, for instance the (a)-(b) pairs of sentences (14) and (15) above, and sentences (16 a-b) below, which were discussed in Chomsky (1957) and more extensively in Katz and Postal (1964).

(16) (a) Everyone in this room speaks two languages.
(b) Two languages are spoken by everyone in this room.

Now although the problem of the order of interpretation of quantifiers has many ramifications and undoubtedly involves a large number of interacting factors,[21] I want to focus on two idealized "dialects" and their implications for whether the movement rules given above should be restricted to free variables or not. In what I will call the "loose dialect", the (a)-(b) pairs are fully synonymous, each having two readings. (Factors such as left-right order may make one reading preferred over the other, but I am only concerned with how many readings should be generated at all.) In the "strict dialect", each sentence has only one reading, with the subject quantifier having wider scope.

For the loose dialect, the unrestricted form of the transformations is a meaning-preserving rule; the active sentence is generated as ambiguous and can be transformed into the passive on either reading. For the strict

dialect, constraints will have to be added to block one of the readings of the active sentence, which is generated as ambiguous in Montague's system. One kind of constraint might be an analog to Lakoff's derivational constraints, which could be easily added to Montague's rules (it would represent an extension of the theory, but would be no harder to formulate than for a generative semantics theory); if that were done, it would not be necessary to restrict the individual rules. But what leads me to posit the restriction of movement rules to the movement of free variables is that I suspect there may be a correlation between quantifier scope interpretation and "dialect differences"[22] in two other phenomena. One is the breaking up of idioms, as in (17) and (18), which some but not all speakers accept:

(17) Track was kept of the proceedings.
(18) Little heed was paid to my warnings.

The loose form of the passive rule would permit such sentences while the tight form would not, since the superficial term-phrases track and little heed should presumably not be allowed to substitute for free variables. The other related phenomenon is opacity: sentence (19a) below has both a specific and a non-specific (or referential and non-referential, or de re and de dicto) reading, but judgments differ as to whether (19b) is likewise ambiguous or allows only the specific reading.

(19a) John is looking for a green-eyed woman.
(19b) A green-eyed woman is being looked for by John.

Again the two forms of the rule would make different predictions: the loose form would give (19b) both of the readings of (19a), while the strict form would predict (19a) to be ambiguous but (19b) to have only a specific reading.

Now if (a big if) judgments on these three phenomena were found to correlate strongly, that would suggest that there really might be a difference in people's grammars in whether moved T-phrases were restricted to variables or not. Even if matters are not this simple, as they undoubtedly are not, there still might be some psychological reality to both forms of the rules, with the strict form of the rule its fundamental form, providing the main reason why such a rule is in the grammar at all (see especially the next section, where moved free variables are crucially involved in derived verb-phrase formation), and the loose form a "surface structure analog" of the strict rule, involved mainly for stylistic variation. This is all much too vague to form an empirical hypothesis of any sort yet, however.

The examples above all dealt with the passive rule, but the same phenomena are to be found in connection with the other rules as well. Consider, for instance, tough-movement: since almost no one interprets (20a) and (20b) as synonymous, it might seem that only the strict form of the rule should be allowed, but the usual interpretation of (21) can be gotten only with the loose form.

(20a) It is hard to catch every cockroach.
(20b) Every cockroach is hard to catch.
(21) A good man is hard to find.

In the case of subject-raising, sentences (22a,b) illustrate the quantifier scope problem and sentences (23a,b) the opacity problem. In my (unsystematic) experience, there are considerable differences of judgment here, plus plenty of "undecided's".

(22a) It appears that a unicorn is approaching
(22b) A unicorn appears to be approaching.
(23a) It seems that some man loves every woman.
(23b) Some man seems to love every woman.

(Montague in PTQ accepts (22a) and (22b) as synonymous, with two readings each, although he does not give rules to derive them.)

For object-raising, the data is particularly slippery, partly because there is a third construction whose syntactic relation to the other two is not clear.

(24a) John believes that a woman robbed the bank.
(24b) John believes a woman to have robbed the bank.
(24c) John believes of a woman that she robbed the bank.

While (24a) pretty clearly allows both a specific and a non-specific reading, and (24c) only a specific one, (24b) seems to be hard to get clear judgments on. For the loose dialect it should be the case that not only does (24b) share the ambiguity of (24a), but so should (25), the passive of (24b).

(25) A woman is believed by John to have robbed the bank.

If others share my intuition that it is twice as hard to get a non-referential reading of a woman in (25) as in (24b) or a simple passive like (19b), that would be further evidence that this is not really a simple matter of dialect split nor a matter of restrictions on individual rules.

Having reached no conclusions as to the correct version of the rules given above, let us turn to the next section, for which the only crucial thing is that what gets moved may be a free variable, which is the case under either formulation.

2.4 Derived verb phrases: abstraction

The rule to be given below provides a way to account for the occurrence in verb-phrase conjunction and in infinitives of verb phrases that are not built up directly in the CAT part of the grammar. It will thus allow us to provide for sentences like (26) and (27), which could not be generated in PTQ.

(26) Few rules are both explicit and easy to read.
(27) John wishes to see himself.

The rule requires the addition of a syntactic metarule, which is given below.

Derived verb phrase rule.

If $\phi \in P_t$ and ϕ has the form ${}_t[\ {}_T[\underline{he}_i\ ]\ {}_{IV}\ [\alpha]]$, then $F_{104}(\phi) \in P_{IV}$, where $F_{104}(\phi) = \alpha'$, and α' comes from α by replacing each occurrence of $\underline{he}_i$, $\underline{him}_i$, $\underline{him}_i\underline{self}$ by $\underline{he}^*$, $\underline{him}^*$, $\underline{him}^*\underline{self}$ respectively.

Examples. F_{104} ($\underline{he}_0$ sees $\underline{him}_0$ self) = see him*self.

F_{104} ($\underline{he}_7$ is easy to please) = be easy to please.

Translation rule: If $\phi \in P_t$ and ϕ translates into ϕ', then $F_{104}(\phi)$ translates into $\hat{x}_i\phi'$.

Starred variable convention (syntactic metarule):

> Whenever any syntactic rule applies to two (or more) arguments such that one is a T-phrase and one contains a starred variable, replace all occurrences of the starred variable by pronouns of the appropriate gender.

Example: Mary + try to see him*self ⟶ Mary tries to see herself.

The derived verb phrase rule transforms a sentence into a verb phrase; the resulting verb phrase can then be used just like any other verb phrase in building up larger phrases. It can, for instance, enter into verb-phrase conjunction, as in (26); it can serve as a complement to verbs such as wish and try;[23] it can combine with verb-phrase adverbs. The derived verb phrase rule is incompatible with the usual transformational framework, either standard or generative semantic, since the transformationally derived verb phrase is permitted to recombine with new elements via essentially CF rules. However, it seems to offer a maximally simple way to reconcile the syntactic arguments for deriving certain phrases from whole sentences with the semantic arguments against doing so (as discussed, for instance, in Partee (1970).)

The semantic interpretation of the derived verb phrase makes use of an abstraction operator. If the translation of $\underline{he}_0\ \underline{sees\ him}_0\underline{self}$ is $\underline{see}'(x_0,x_0)$ (a rough approximation to the PTQ translation), then the translation of its derivative $\underline{see\ him}^*\underline{self}$ will be $\hat{x}_0(\underline{see}'(x_0, x_0))$, i.e. the property of seeing oneself. Since the abstraction operator binds the free variables, there is no further semantic need to keep track of the variables in the underlying sentence; but syntactically the pronouns must be made to agree with whatever term-phrase that property is eventually connected with, and that

is the function of the starred variable convention.

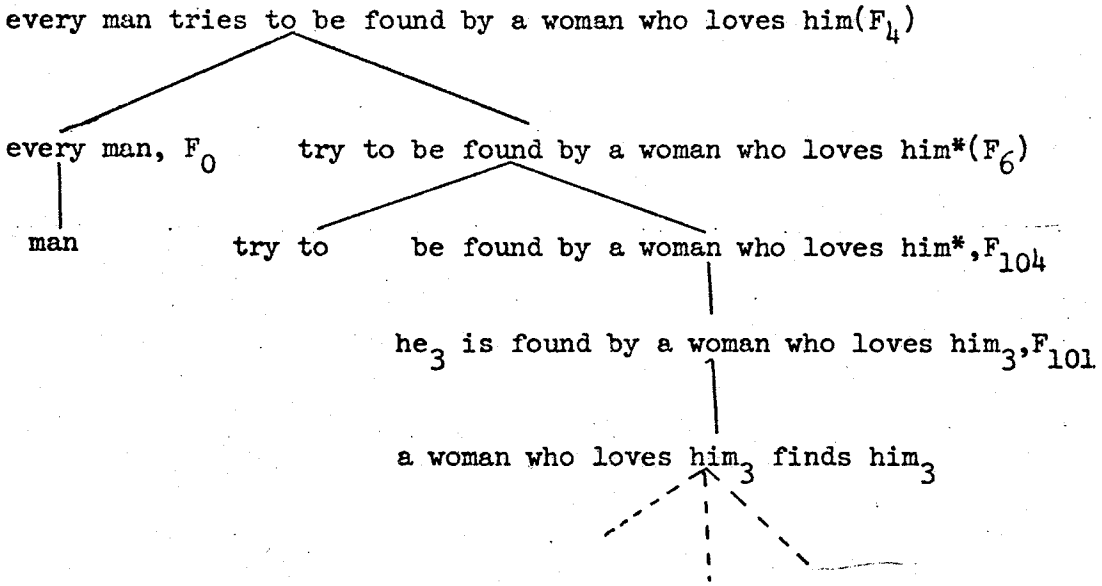
The starred variable convention is closely analogous to Rosenbaum's minimum distance principle, except that topographical nearness is replaced by a relation which centers on the analysis tree: the term-phrase that picks up the starred variable is the first term-phrase to be combined as a constituent with the phrase containing the derived verb phrase. If persuade to is added to the fragment as TV/IV, then persuade to would combine with see him*self to form a TV-phrase persuade to see him*self; then the TV + T-phrase $\longrightarrow$ IV rule would combine that with Mary and the result would be (with appropriate reordering) persuade Mary to see herself since the starred variable convention would apply. Richmond Thomason (personal communication) has pointed out that if promise is assigned to the category (IV//IV)/T, the difference between promise and persuade will be correctly represented with this starred variable convention; the correct predictions will be made about sentences (28) and (29) below.

(28) John persuaded Mary to shoot $\begin{Bmatrix} *\text{himself} \\ \text{herself} \end{Bmatrix}$

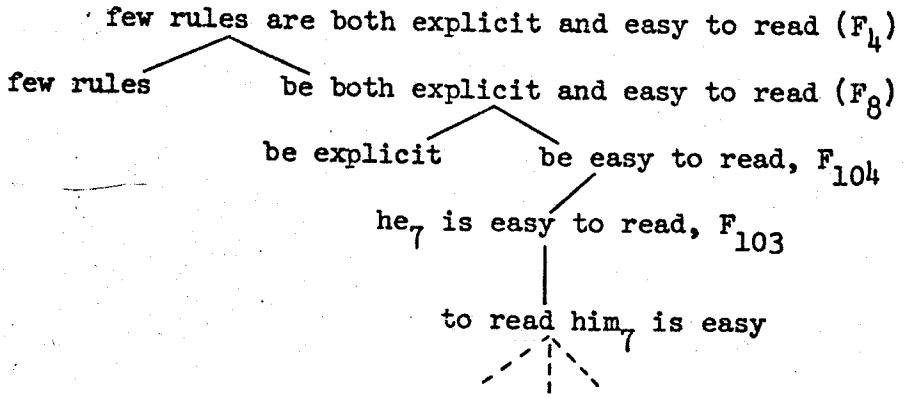
(29) John promised Mary to shoot $\begin{Bmatrix} \text{himself} \\ *\text{herself} \end{Bmatrix}$

In conclusion, I will sketch the analysis trees for some sentences whose derivations involve the derived verb phrase rule.

(30) Every man tries to be found by a woman who loves him



(31) Few rules are both explicit and easy to read



FOOTNOTES

[1]This paper is a written version of a talk given in April, 1972, in the Linguistics and Semantics Workshop at the University of Western Ontario. A preliminary version was given in March at the University of Massachusetts at Amherst, and a version was also given at a colloquium at UC San Diego. The first part of the paper, like the first part of the talks, is a condensation of a talk which I gave in various forms and places in the fall and winter 1971-72. A fuller treatment of the same subject can be found in my "Montague Grammar and Transformational Grammar." My debts to others in this work are too numerous to list here, but I must at least mention Richmond Thomason, whose suggestions about the abstraction operator helped me get my first ideas about how to accommodate transformations in the Montague framework; Michael Bennett, whose continuing extensions of Montague's work have fertilized and challenged my own; David Kaplan, who has given me constant encouragement and taught me a great deal about philosophy and logic; and of course Richard Montague and Noam Chomsky, without whom I wouldn't have had a starting point. I am also grateful to all the students and other audiences who have given me helpful comments and criticisms, particularly the linguistics and philosophy students in my Montague seminar at UCLA, Winter-Spring, 1972.

[2]The exceptions include the work of Reichenbach (1947) and the exhortation to collaboration made by Bar-Hillel (1954), rebuffed by Chomsky (1955).

[3]"Simplification of theory is a central motive likewise of the sweeping artificialities of notation in modern logic. Clearly, it would be folly to burden a logical theory with quirks of usage that we can straighten. If we were to devise a logic of ordinary language for direct use on sentences as they come, we would have to complicate our rules of inference in sundry unilluminating ways." (Quine (1960), p. 158) As an example: "Our ordinary language shows a tiresome bias in its treatment of time...[T]he form that it takes - that of requiring that every verb form show a tense - is peculiarly productive of needless complications... Hence in fashioning canonical notations it is usual to drop tense distinctions."

[4]Tarski pointed out to me (pers. communication, 1971) that the substitutional view of quantification, as found in the work of Ruth Barcan Marcus, is an example of a departure from the scheme described above.

[5]Actually, it appears that this principle is being abandoned, and generative semanticists are coming to view their work more as "abstract syntax", a view that would make their approach compatible with the traditional logical approach.

[6]Some central references for the two approaches are Lakoff (1971), (1972), Chomsky (1971), Jackendoff (1969).

[7]I am purposely ignoring here the question of the deep structure of the relative clause itself, although that also makes a great difference to the semantics.

[8]For a review of a number of such arguments, see Stockwell et al. (1968).

[9]The semantics here is basically from Montague; the discussion of alternatives is my own.

[10]This view of the semantics of restrictive relative clauses is not unique to Montague; it can also be found in Quine (1960).

[11]The syntactic and semantic details of such an analysis can be found in Montague (1972).

[12]I realize that negative arguments such as those given here against analyses (1) and (2) can never be fully conclusive; the discussion should be construed as a semantic defense of (3) plus a challenge to proponents of (1) or (2) to provide a semantic analysis that supports their syntax. The argument against (2) is weaker than that against (1), since only in (1) is the intermediate constituent called an NP.

[13]The originator of categorial grammar was the Polish logician Ajdukiewicz; for exposition see Lewis (1971).

[14]Although in one sense it is correct to speak of the categories as being defined by these specifications, it should be borne in mind that in another sense the categories are defined only implicitly, by the totality of the rules of the grammar.

[15]The two exceptions are IV and CN, since the set of expressions of category e is empty.

[16]The syntactic simplicity was intentional since Montague's interest was in semantics. In the opening paragraph of PTQ he says, "For expository purposes the fragment has been made as simple and restricted as it can be while accommodating all the more puzzling cases of quantification and reference with which I am acquainted."

[17]An earlier paper, Montague (1970a), does have a footnote suggesting a treatment of reflexive pronouns to which the one proposed here is almost identical; essentially the same treatment is found in earlier works by generative semanticists. What Montague did not have was a way to generate infinitive phrases containing reflexive pronouns.

[18]The reason I am not prepared to claim that labelled bracketing is indispensable is that in Montague's system rules can, in principle, refer to the derivational history of a string, and I have no clear cases where that would not suffice. But with labelled bracketing added, one would be free to investigate the possibility of constraining the rules so that only the bracketing, and not arbitrary aspects of the derivational history, could be used by the (syntactic) rules.

[19]This condition needs to be made precise; a first approximation would be to say ϕ contains only one verb (i.e. one basic expression of category IV, TV, IV/t, or IV//IV.)

[20]As presented, this rule would have to be obligatory, which would be the first such rule in the grammar. An alternative might be to build reflexivization into the rule that combines subject and verb phrase to make a sentence.

[21]These matters have been discussed extensively in the literature; see, for example, Lakoff (1971), Jackendoff (1969). Among the factors I think are involved are not only the structural factors of dominance and left-right order, and stress, but also individual differences in "strength" or "precedence" among the various quantifiers, and, to complicate matters, non-linguistic judgments of absurdity vs. plausibility of the different structurally possible interpretations.

[22]I am very hesitant to call any of these differences dialect differences because I have no conviction that what is going on is to be accounted for in terms of differences in grammatical rules, and I also have no evidence that these "dialects" are related to speech communities. See Gleitman and Gleitman (1970) for a study of similar problems relating to the interpretation of noun compounds.

[23]We have several choices as to the handling of infinitival complements. The derived verb phrase rule gives approximate inputs to the PTQ rule which combines try to with an IV-phrase; or we could add a rule forming infinitives from IV-phrases by systematically adding to and semantically taking the intension of the IV-phrase translation, and let try take an infinitive-phrase. We could also let try take as complement a sentence with a free variable as subject, with infinitive-formation part of the rule for combining them.

REFERENCES

Bar-Hillel, Yeshoshua. 1954. "Logical syntax and semantics", Language 30. 230-237

Chomsky, Noam. 1955. "Logical syntax and semantics: their linguistic relevance", Language 31. 36-45.

---------- 1957. Syntactic Structures. The Hague

---------- 1971. "Deep structure, surface structure, and semantic interpretation" in Steinberg and Jakobovits. 1971. 183-216

Gleitman, Lila and Henry Gleitman. 1970. Phrase and Paraphrase. New York.

Harmon, Gilbert and Donald Davidson. 1971. Semantics of Natural Languages. Dordrecht.

Hintikka, Jaakko, Julius Moravcsik, and Patrick Suppes. 1972. Approaches to Natural Language. Dordrecht, forthcoming.

Jackendoff, Ray. 1969. Some Rules of Semantic Interpretation for English. MIT dissertation.

Katz, Jerrold. 1966. The Philosophy of Language. New York.

Katz, Jerrold and Paul Postal. 1964. An Integrated Theory of Linguistic Descriptions. Cambridge.

Lakoff, George. 1971. "On generative semantics" in Steinberg and Jakobovits. 1971. 232-296.

---------- 1972. "Linguistics and natural logic" in Harmon and Davidson. 1971. 545-665.

Lewis, David. 1971. "General semantics" Synthese 22. 18-67.

Montague, Richard. 1970a. "English as a formal language", in Visentini et al. 1970. 189-224

---------- 1970b. "Universal grammar" Theoria 36. 373-398.

---------- 1972. "The proper treatment of quantification in ordinary English" in Hintikka, Moravcsik and Suppes.

Partee, Barbara. 1970. "Negation, conjunction, and quantifiers: syntax vs. semantics", Foundations of Language 6. 153-165

Quine, W.V. 1960. Word and Object. Cambridge.

Reichenbach, Hans. 1947. Elements of Symbolic Logic. New York.

Steinberg, Danny and Leon Jakobovits. 1971. Semantics. Cambridge (England).

Stockwell, Robert, Paul Schachter, and Barbara Partee. 1968. Integration of Transformational Theories of English Syntax. Los Angeles.

Tarski, Alfred. 1944. "The semantic conception of truth" Philosophy and Phenomenological Research 4. 341-375.

Vermazen, Bruce. 1967. A review of Katz and Postal (1964) and Katz (1966). Synthese 17. 350-365.

Visentini, Bruno, et al. 1970. Linguaggi nella societa e nella tecnica. Milan.