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NL's, CFL's, and CF-PSG's

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£. Introduction,*

Consider the following quotations:

> As already mentioned, a context-free phrase structure grammar is not sufficient to describe or analyze the whole range of syntactic constructions which occur in natural language texts <cf. Chomsky 1957). Even if one disregards the theoretical linguist's demand for satisfactory descriptions of the syntactic structure of sentences, there are strong reasons to design a more powerful parser than the one described above. ... Cases in point *are* the phenomenon of agreement within noun phrases, the correspondence in the verb phrase between the form of the main verb and the type of the auxiliary, and subject verb agreement. The argument structure of predicates, that is, their various types of objects and complements, represents another kind of context-sensitivity in natural language. ... The best strategy seems to be to take care of the particular types of context-sensitivity recognized by linguistic theory by means of special procedures which act as a superstructure of the algorithm for context-free analysis. ... In addition to the above-mentioned drawbacks a context-free phrase structure grammar has difficulty handling word order variation in a natural way.
> CWelin 1979: 62-63]

> One significant use of the general context-free methods is as part of a system of processing natural languages such as English. We are not suggesting that there is a context-free grammar for English. It is probably more appropriate to view the grammar/parser as a convenient control structure for directing the analysis of the input string. The overall analysis is motivated by a linguistic model which is not context free, but which can frequently make use of structures determined by the context-free grammar.
> CGraham, Harrison 8 Ruzzo 1980: 415-416]

These two passages have a number of things in common, of which three are relevant here. Firstly, the issue of whether natural languages (NL's) are context-free languages (CFL's) and are susceptible to analysis by context-free phrase structure grammars (CF-PSG's) is one the authors take to be relevant to parsing. Secondly, both passages assume that this issue has already been resolved, and resolved in the negative Thirdly, I did not have to look for them. I merely bumped into them, as it were, in the course of recent reading. However, I am sure that if I had been in the business of finding passages with this kind of flavour in the parsing literature of the past 20 years, then I could have found dozens, probably hundreds.

The purpose of the present paper is simply to draw the attention of computational linguists to the fact that the issue of the status of NL's with respects to the CFL's and CF-PSG's is not resolved, and to the fact that all the published arguments seeking to establish that NL^f^s are not CFL's, or that CF-PSG's are not adequate for the analysis of NL's, are completely without force. Of course, this does not entail that NL's are CFL's or that CF-PSG's constitute the appropriate formal theory of NL grammars. But it does have as a consequence that computational linguists should not just give up on CF-PSG's on the grounds that theoretical linguistics has demonstrated their inadequacy. No such demonstration exists.

In assessing whether some formal theory of grammar is an adequate theory for NL's, at least the following three criteria are relevant, and have been historically. <i> Does it permit NL's qua sets of strings to be generated? <ii) Does it permit significant generalizations to be expressed? (iii) Does it support a semantics, that is, does it provide a basis on which meanings can be assigned to NL expressions in a satisfactory manner?

In the remainder of this paper, I shall consider these three criteria in turn with reference to the adequacy of CF-PS^s as grammars for NL's. The issues are large, and space is limited, so my discussion will take the form, for the most part, of annotated references to the literature where the various issues are properly dealt with.

I* Generating NL string sets.

The belief that CF-PSG's cannot cope with syntactic concord and long-distance dependencies, and hence that NL's are not CPUs, but, say, properly context-sensitive languages, is well entrenched. One textbook goes so far as to assert that 'the grammatical phenomenon of Subject Predicate Agreement is sufficient to guarantee the accuracy of Cthe statement that] English is not a CF-PSG language[1] CGrinder & Elgin 1973: 59]. The phenomenon guarantees no such thing, of course. Nor is the character of the problem changed when agreement is manifested across unbounded distances in strings Cpace Bach 1974: 77, Bresnan 1978: 383. Indeed, finite state languages can exhibit such dependencies Csee Pullum & Gazdar, 19823.

The introductory texts and similar expository works in the field of generative grammar offer nothing that could be taken seriously as an argument that NL's are not CFL's. However, five putatively non-specious arguments to this effect *are* to be found in the more technical literature. These are based on the following phenomena:

(a) English comparative clauses CChomsky 1963: 378-9],
(b) the decimal expansion of pi CElster 1978: 43-44],
<c) 'respectively[1] CBar-Hillel S Shamir 1960: 96, Langendoen 1977: 4-5],
(d) Dutch subordinate clauses CHuybregts 1976],
(e) Mohawk noun incorporation [Postal 1964].

Pullum S Gazdar C1982] show that (a) is based on a false empirical claim and a false claim about formal languages, (b) has no bearing on English or any other natural language since it depends on a confusion between grammar and arithmetic, (c) is based on a false empirical claim, and the facts, such as they are, are relevant to semantics rather than syntax in any case, <d) provides no basis for any string set argument <1>, and <e) Postal crucially failed to take account of one class of permissible incorporations - once these are recognized, the formal basis of his argument collapses.

Thus, Pullum & Gazdar C1982] demonstrate that every published argument purporting to show that one or another NL is not a CFL is invalid, either formally, or empirically, or both. Whether any NL, construed as a string set, falls outside the class of'CFLs remains an open question, just as it was twenty five years ago.

2. Capturing significant generalizations.

Argumentation purporting to show that CF-PSG's will miss significant generalizations about some NL phenomenon has been woefully inadequate. Typically it consists simply of providing or alluding to some CF-PSG which obviously misses the generalization in question. But, clearly, nothing whatever follows from such an exhibition. Any framework capable of handling some phenomenon at at all will typically make available indefinitely many ugly analyses of the phenomenon. But this fact is neither surprising nor interesting. What is surprising, and rather disturbing, is that arguments of this kind (beginning, classically, in chapter 5 of Chomsky 1957) have been taken so seriously for so long.

Capturing significant generalizations is largely a matter of notation. But CF-PSG's, taken as a class of mathematical objects, have properties which are theirs independently of the notations that might be used to define them. Thus they determine a certain set of string sets, they determine a certain set of tree sets, they stand in particular equivalence relations, and so on. An analogy from logic is pertinent here: the truth function material implication just is material implication whether you notate it with an arrow, or a hook, or the third letter of the alphabet, and whether you use prefix, infix, or postfix positioning of the symbol.

Over its 25 year history, transformational grammar developed a whole armoury of linguistically useful notations, and many of these can just as well be used in characterizing CF-PSG's. Three such notational devices merit individual mention: (a) complex symbols, (b) rule schemata, and (c) mappings from one set of rules into another (metarules).

Harman [1963] deserves the credit for first seeing the potential of PSG's incorporating complex symbols. The use of a finite set of complex symbols, in place of the traditional finite set of monadic symbols, leaves the mathematical properties of CF-PSG's unchanged. Every CF-PSG employing complex symbols generates a tree set that is isomorphic to the tree set set generated by some CF-PSG not employing complex symbols. However, complex symbols including features, "X-bar conventions", and "slash categories", etc., allow numerous significant syntactic generalizations to be captured rather straightforwardly.

For example, in Gazdar [1981a, 1981b] and Sag [1982a, 1982b] complex symbols called "slash categories" are shown to be able to capture the generalizations underlying the class of unbounded dependency constructions in English (e.g. relative clauses, wh-questions, topicalization, etc.) including a generalization about the interaction of such constructions with coordination that was never satisfactorily captured in transformational analyses [see Gazdar, Pullum, Sag & Wasow 1982]. And Gazdar & Pullum [1981] show how the use of complex symbols for subcategorization in a CF-PSG can capture generalizations that had had to be stipulated in the standard transformational account employing context-sensitive lexical insertion.

Rule schemata allow generalizations to be captured by collapsing sets of rules with some common property into a single statement. In a CF-PSG, one can capture the familiar generalization that only like-constituents conjoin with a schema along the following lines:

> @ -> @ and @
> where @ is any category.

The generalization that this captures was not captured in classical TG: part of it was expressed in the base rules, and the rest was intendedly expressed in the formulation of a transformation called "Coordination Reduction".

Another example of the power of rule schemata (applied to complex symbols) involves agreement phenomena:

> S -> NP[@] VP[@]
> where @ ranges over permissible
> combinations of agreement features.

This schema, taken together with a widely assumed, and putatively univeral, convention of feature transfer, suffices to capture all the straightforward facts about subject verb agreement in English [see Gazdar 1982].

A metarule is a grammar characterization device (i.e. a clause in the definition of the grammar) which enables one to define one set of rules in terms of another set, antecedently given. Generalizations which would be lost if the two sets of rules were merely listed are captured by the metarule <2>. Note that transformations were mappings from sets of structures to sets of structures, whereas metarules are mappings from sets of rules to sets of rules. Gazdar & Sag [1981] show how metarules can capture the active-passive and reflexive pronoun generalizations in the definition of a PSG for English, and Gazdar, Pullum & Sag [1982] use metarules to provide accurate and nonredundant analyses for "Subject-auxiliary inversion", adverb placement, and VP ellipsis in a grammar of the English auxiliary system.

There is, thus, at the present time, no reason whatsoever to think that the goal of capturing linguistically significant generalizations is in any way inconsistent with the use of CF-PSG's <3>.

3. Support of a semantics.

In asking whether some theory of syntax "supports a semantics", we are asking whether there exists some semantic theory which will interpret the structures provided by the syntax in a manner consistent with our judgments concerning ambiguity, synonymy, entailment, etc. Within linguistics, the key semantic development of the 1970's was the appearance of a model theory for natural languages originating in the work of Montague [see Montague 1974; Dowty et al. 1981]. Before Montague, linguists had been disposed either to do their semantics in the syntax, a practice that reached its apogee in the work of the Generative Semanticists, or not at all, as in Chomsky's oeuvres. But the sophisticated machinery (including lambda abstraction, meaning postulates, higher order quantification, intension and extension operators, etc.) which Montague had made available meant that semantics could now be done as such. This had all kinds of implications for syntax.

Here are some examples. (i) Heny [1970] and Cooper [1975] showed that quantifier scope ambiguities could be handled entirely in the semantics, without the need for quantifier movement in the syntax. (ii) Dowty [1978] showed that the semantic properties of dative, passive, unspecified object, "Raising", and "Equi" constructions could all be provided for directly, without corresponding syntactic operations that moved or deleted NP's. (iii) Also in 1978, three sets of authors independently proposed closely related cross-categorial semantic theories for coordination [Cooper 1979; Gazdar 1980a; Keenan & Faltz 1978]. This work, which is further advanced in Partee & Rooth [1982], completely undercuts all semantic motivation for "Coordination Reduction" transformations or equivalent operations in the syntax. (iv) McCloskey [1979] was able to show that the deep structure/surface structure distinction was irrelevant to giving a semantics for relative clauses and wh-questions: structures of either kind provide a suitable locus for semantic interpretation. (v) Klein [1980, 1981a, 1981b, 1982] has demonstrated that the meaning of all the various comparative constructions found in English can be derived directly from their surface syntactic forms as given by a CF-PSG along the lines of Gazdar [1980b]. (vi) Wasow, Sag, & Nunberg [1982] argue that the proper treatment of idioms is one which semantically interprets them directly and compositionally. Their analysis vitiates all the arguments for syntactic movement rules that depend on the claim that sentences like *tabs were kept on every suspect* cannot be compositionally interpreted. In a similar vein, Sag [1982c] and Sag & Klein [1982] show that the syntactic distribution of the English "dummy subjects" *it* and *there* (as in such sentences as *it appears to be obvious that we lost*, and *there seems to have been a gorilla in the park*) can be made to follow from an appropriate semantic theory of such expressions, without any need for subject-to-subject or subject-to-object raising operations in the syntax. (vii) And, in related work, Klein & Sag [1982] develop a semantic theory for phrase structure grammars for natural languages which largely eliminates the need to stipulate semantic translation rules. Instead, these rules follow from a function which takes as arguments (1) the semantic type of a lexical item, and (2) the phrase structure rule responsible for introducing the lexical item.

Thus there is every reason to believe that CF-PSG's can support appropriate semantic theories for NL's at least as well as multilevel syntactic frameworks <4, 5>. Indeed, there is an ad hominem argument which suggests that they may be preferable. It is noteworthy that almost all the linguists currently working out the implications of Montague's semantic legacy have gravitated towards essentially monostratal syntactic theories <6>, although this concreteness is not obviously presaged in Montague's own, rather abstract, approach to syntax.

4. Conclusions.

In brief, I have tried to make plausible the following three claims. (i) There is no reason, at the present time, to think that NL's are not CFL's. (ii) There are good reasons for thinking that the notations we need to capture significant syntactic generalizations will characterize CF-PSG's, or some minor generalization of them, such as Indexed Grammars. (iii) There are very good reasons for believing that such grammars, and the monostratal representations they induce, provide the necessary basis for the semantic interpretation of NL's. And that, concomitantly, there is no semantic motivation for syntactic operations that move, delete, permute, copy or substitute constituents. The relevance, if any, of these claims to computational linguistics and the parsing of NL's is something that, in the present context, I am content to leave to others <7>.

FOOTNOTES

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1. Whether or not a CF-PSG can generate the correct structural descriptions for the relevant set of Dutch sentences is an intriguing open question. If the structural descriptions are what Bresnan, Kaplan, Peters & Zaenen [1982] assume them to be, then, as they show, the answer is no.

2. The idea of using one grammar to generate another originates in computer science with the work of van Wijngaarden [1969] who used the technique to give a perspicuous syntax for ALGOL68. A good introduction to his work can be found in Cleaveland & Uzgalis [1975]. Janssen [1980] employs a van Wijngaarden-style two-level grammar to define a generalization of Montague's PTQ syntax.

3. So-called "free word order" languages have sometimes been alleged to pose a problem in principle for the generalization-capturing powers of CF-PSG's. That they do not is amply demonstrated in Pullum [1982] and Stucky [1981].

4. This is not to suggest, of course, that all significant semantic problems are solved by the shift to surface structure syntax. One currently interesting puzzle concerns how one binds pronouns that appear in "dislocated" constituents [Cooper, in press; Dahl 1981, 1982; Engdahl 1982a, 1982b]. Another concerns the possibility of multiple wh-type dependencies in Scandinavian languages, and the variable-binding issue that this gives rise to [see Engdahl 1980; Maling & Zaenen 1982]. One promising strategy for getting a solution to both these problems entails grounding the semantics on an indexed grammar [Aho 1968; Hopcroft & Ullman 1979, pp. 389-390] rather than on a CF-PSG. Indexed grammars are similar to CF-PSG's which employ complex symbols, except that there is no finite limit on the number of distinct complex symbols that can be used. This generalization of CF-PSG is potentially relevant to the issue mentioned in footnote 1, above, and to the nesting of equative and comparative clauses [see Klein 1981b]. Cf., also, the tree adjunction defined MCSL's of Joshi [1982] (the MCSL's properly include the CFL's but are properly included by the indexed languages).

5. I assume that this conclusion would carry over to non-Montague approaches to semantics. However, I have restricted myself here to the Montague paradigm since it is by far and away the most detailed and extensive framework for NL semantics available at the present time. That Montague's ideas are compatible with a computational orientation to language is evidenced or argued in a sizeable body of recent work: e.g., Bronnenberg et al. [1980], Friedman [1978, 1981], Friedman, Moran &

Warren [1978], Friedman & Warren [1978], Fuchi [1981], Gunji & Sondheimer [1980], Hobbs & Rosenschein [1978], Indurkhya [1981], Ishimoto [1982], Janssen [1976, 1977], Landsbergen [1981], Matsumoto [1981, 1982], Moran [1980], Nishida et al. [1981], Nishida & Doshita [1982], Root [1981], Saheki [1982], Sawamura [1981], Sondheimer & Gunji [1978], and Warren [1979]. See also Gunji [1981] for a description of the programming language EIL - Extended Intensional Lisp.

6. E.g. Bach, Cooper, Dahl, Dowty, Karttunen, Keenan, Klein, Partee, Peters, and Sag, to name but ten.

7. E.g., Bear & Karttunen [1979], Ejerhed [1980], Fodor [1982a, 1982b], Gawron et al. [1982], Joshi & Levy [1982], Kay [1983], Konolige [1980], Pulman [1983], Robinson [1980, 1982], Rosenschein & Sheiber [1982], Ross [1981], Schubert [1982], Schubert & Pelletier [1982], and Thompson [1981, 1982]. And see Berwick & Weinberg [1982] for a rather extended metatheoretical disquisition.

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