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Binding and Control in CCG and Its Relatives

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The CCG account of the unbounded constructions - in particular, relativization and coordination-generalizes the notion of surface structure in a way that disrupts traditional notions of dominance and command. This has led researchers in other frameworks to suggest that the theory is fundamentally incompatible with a coherent theory of binding and control - the bounded constructions. The present paper offers a theory of binding in CCG which preserves the original account of the unbounded dependencies, and which renders it immediately compatible with other theories, TAG in particular. The theory requires the abandonment of one assumption that has been traditional (though not essential) in other categorical approaches. The significance of this move is discussed.

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The CCG account of the unbounded constructions – in particular, relativisation and coordination – generalises the notion of surface structure in a way that disrupts traditional notions of dominance and command. This has led researchers in other frameworks to suggest that the theory is fundamentally incompatible with a coherent theory of binding and control – the bounded constructions. The present paper offers a theory of binding in CCG which preserves the original account of the unbounded dependencies, and which renders it immediately compatible with other theories, TAG in particular. The theory requires the abandonment of one assumption that has been traditional (though not essential) in other categorial approaches. The significance of this move is discussed.

Categorial Grammar is usually presented as a system of types, such as $(S\backslash NP)/NP$, the type of a transitive verb in the notation used here. However, it is often convenient to identify the particular function in question, by associating a specific interpretation or logical form with the type. One computationally convenient way to do this is exemplified by the following:

(1) eats :- $(S : eat'\ np_2\ np_1 \backslash NP_{3s} : np_1)/NP : np_2$

(Expressions like $eat'\ np_2\ np_1$ are "left associative" – that is, equivalent to $(eat'\ np_2)\ np_1$).

Such categories have the advantage of being directly compatible with various unification-based realisations, which allow the grammar to build interpretations – that is, canonical function-argument structures – in the course of a derivation. This is shown in the following example, in which we assume, following previous work, that argument categories such as NP are always type-raised, possibly via the lexicon, via the rule schemata shown.

(2) (Lexical?) Type-raising:

a. $X \Rightarrow_{\mathrm{T}} \mathrm{T}/(\mathrm{T}\backslash X)$ $(>\mathrm{T})$

c. $X \Rightarrow_{\mathrm{T}} \mathrm{T}\backslash(\mathrm{T}/X)$ $(<\mathrm{T})$

where X = NP, PP, etc

(3)

```
      Keats                     eats                          apples
   -----------    ---------------------------------        ----------
   NP3s:keats'    (S:eat' np2 np1\NP3s:np1)/NP:np2          NP:apples'
------------------>T                                  ------------------<T
T/(T\NP3sg:keats')                                    T\(T/NP3pl:apples')
                  ---------------------------------------------------------<
                           S:eat' apples' np1\NP3s:np1
-------------------------------------------------------------->
                  S:eat' apples' keats'
```

This property is useful, not only when building parsers, but also for coping with the proliferation of semantically equivalent surface structures characteristic of CCG, since they all deliver the same interpretations. Such interpretation structures are of course commonly used in other Categorial frameworks, although it is generally assumed (following Montague – cf. Dowty 1982) that, since such structures are not necessary intermediaries between syntax and the model, they should not do any real theoretical work. This is the assumption that we shall question here.

To develop a theory of binding in such a system, it is natural to follow Szabolcsi 1989 in assuming that the various pronouns, like all other NPs are type raised categories. Since we are interested in binding, we will realise the interpretation of the argument itself as a special term $pro'\ x$ or $PRO'\ x$, which we can refer to as "pro-terms". The pronoun *him* will then be a simple raised category a, but the anaphor *himself* will be responsible for binding the variable in the pro-term, as in the derivation below.

(4) PRONOMINAL CATEGORIES:

a. *him* := $T\backslash(T/NP_{3sm} : pro\ x)$

b. *himself* := $(S : tv\ (PRO\ x)\ x\backslash NP_{3sm} : x)\backslash((S : tv\ (PRO\ x)\ x\backslash NP_{3sm} : x)/NP_{3sm} : PRO\ x)$

(5)

```
       Keats                          saw                                 himself
 ------------------    --------------------------------   --------------------------------
 T/(T\NP3sg:keats')    (S:see' np2 np1\NP3s:np1)/NP:np2   (S:tv (PRO x) x\NP:x)/NP:PRO x)
                       ----------------------------------------------------------------<
                                   S:see' (PRO np1) np1\NP3s:np1
 ------------------------------------------------------------------->
                      S:see' (PRO keats') keats'
```

Whether or not this is a *good* way to do binding remains to be seen. (For example, we may need quite a lot of these categories, even to capture subject controlled anaphora alone. And we have not yet said how its clause-boundedness is captured (although the form of the interpretation means the anaphor can only apply to lexical verbs). But it is clear from the fact that the arguments in the function-argument structure, as well as the corresponding elements in the derivation, conform to the "thematic" or "obliqueness" hierarchy, subject dominating object, that we could if we wished define a fairly traditional binding theory upon function-argument structures, rather than on derivations.

Similar remarks apply to control. Let us assume the following "base-generative" category for the verb *tried*:

(6) tried := $(S\backslash NP)/(S_{to-inf}\backslash NP)$

Our first attempt at a semantically explicit category might be the following:

(7) $(S : try'\ s\ x\backslash NP : x)/(S_{to-inf} : s\backslash NP : x)$

However, on the assumption that the category of the infinitive is as in 8, the result of combining with it would be the Condition C-violating 9:

(8) $S_{to-inf} : go'\ y\backslash NP : y$

(9) $S : try'\ (go'\ z)\ z\backslash NP : z$

A traditional way out of this problem would be to assume the following category for *tried* instead:

(10) tried := $(S : try'\ s\ x\backslash NP_{agr} : x)/(S_{to-inf} : s\backslash NP_{agr} : PRO\ x)$

This reduces to give the following Condition C-obeying category.

(11) $S : try'\ (go'\ (PRO\ z))\ z\backslash NP_{agr} : z$

Control verbs like *persuade* raise a related problem. The following category will similarly avoid a Condition C violation at the level of interpretation, as shown by the succeeding derivation:

(12) persuades $:= ((S : persuade'\ s\ x_1\ x_2\backslash NP_{agr_2} : x_2)/(S_{to-inf} : s\backslash NP_{agr_1} : PRO\ x_1))/NP_{agr_1} : x_1$

(13)

```
                           persuades                                Keats        to go
----------------------------------------------------------------- --------- ------------------
((S:persuade' s x1 x2\NP:x2)/(Sto-inf:s\NP:PRO x1)/NP:x1 NP:keats' Sto-inf:go' y\NP:y
---------------------------------------------------------------------------->
        (S:persuade' s keats' x2\NP:x2)/(Sto-inf:s\NP:PRO keats')
        ---------------------------------------------------------------------------------->
                              S:persuade'(go' (PRO keats')) keats' x2\NP:x2
```

However, careful inspection will reveal that, if we do assume this category, it is now *only* at the level of interpretation that we can define a binding theory. The surface derivation is one in which the infinitive is c-commanded by *Keats*. It is clear that this solution in some sense makes intrinsic use of function argument structure. Indeed the system as a whole bears a distinct resemblance to a "synchronous" TAG (Shieber & Schabes 1992), albeit of a very restricted kind.

Of course, that is not to say that such a solution is a forced move. Almost every other categorial approach except the present one has followed Bach in assuming that derivation must be made consistent with the obliqueness hierarchy, via "WRAP" operations (cf. Dowty, Jacobson, Szabolci, and Hepple, among others), in which the order of combination of arguments defined by the category is not the same as their linear order in the string. This expedient conserves the Montagovian property, that any expositorily convenient use of interpretation structures remains non-essential.

There is no denying the mathematical appeal of the Montagovian position. The jury is still out on its empirical truth. However, there are two empirical reasons for thinking that the other alternative should be explored in a categorial framework, as it is in virtually every other. The first is that much previous work has shown that categorial theories which eschew such operations offer dramatically simple accounts of certain "non-constituent" coordination. No-one has yet shown how wrapping can be made consistent with a comparably simple account.

The second reason is psychological. Nobody could seriously believe that the child learning language is a model-theoretical *tabula rasa*. Children clearly come to language-learning with a very rich conceptual structure. The semantic nature of the thematic hierarchy makes it reasonable to hypothesise that it is a property of these prelinguistic structures, and that the child at least begins the process of acquiring a specific grammar by hanging (possibly order-specific) categories onto these (unordered) functional categories, according to the following simple prescription:

(14) Irrespective of the linear position of the functor, the linear order of the arguments determined by a verbal syntactic category should reflect the thematic hierarchy.

The combinatory rules of CCG will necessarily correctly project arguments from the lexicon, including bound and controlled anaphors, under such a theory. For example:

(15)

```
                      might                                           eat
-------------------------------------------------- -------------------------------------
(S:might' s np1\NPagr:np1)/(Sinf:s\NPagr:PRO np1)  (Sinf:eat' np2 np3\NPagr:np3)/NP:np2
----------------------------------------------------------------------------------------->B
                (S:might'(eat' np2 (PRO np1)) np1\NP:np1)/NP:np2
```

(16)

```
   Keats                       cooked
------------       ---------------------------------
NP3sm:keats'       (S:cook' np1 np2\NPagr:np2)/NP:np1
-------------------->T
S:s/(S:s\NP3sm:keats')
------------------------------------------------------>B
               S:cook' np3 keats'/NP:np3
```

(17)
```
             file                                         without reading
 -------------------------------  ----------------------------------------------------------
 (Sinf:file' x2 x1\NP:x1)/NP:x2  ((Sx:without'(read' x5 x3) s2\NP:x3)\(Sx:s2\NP:x3))/NP:x5
 ------------------------------------------------------------------------------------------<Sx
                  (Sinf:without'(read' x2 x1)(file' x2 x1)\NP:x1)/NP:x2
```

As a consequence, the existing combinatory analyses of relativisation and coordination would remain unaffected, apart from correct interactions with the binding conditions. For example, the notorious "anti- C-command" condition on the other rightward variety of parasitic gap (involving the forward $>$ **S** rule), revealed in the assymetry between a and b below, would be a necessary consequence of Condition C.

(18) a. *A man who I persuaded to dislike
b. A man who I persuaded every friend of to dislike

This result follows from the fact that the syntactically legal composition of the non-standard constituent *persuaded to dislike* generates a violation, while *persuaded every friend of to dislike* (which has an identical type) does not:

(19) *persuades to dislike := $(S : \underline{persuade'\ (dislike' z\ (PRO\ z))\ z\ w)}\backslash NP : w)/NP : z$

(20) $((S : persuade'\ s\ (every'(friend'z))\ w\backslash NP : w)/(S : s\backslash NP : (PRO\ (every'(friend'z))))/NP_{+wh} : z$

(21) $((S : \underline{persuade'\ (dislike'\ z\ (PRO\ (every'(friend'z))))\ (every'(friend'z))\ w}\backslash NP : w)/NP_{+wh} : z$

The following pattern of parasitic gapping (from Bennis 1986 and Koster 1987), with the same anti- C-command condition, is also immediately predicted on the basis of the verb-final lexicon which we are forced to assume for Dutch.

(22) Welke boeken heb je [zonder te lezen]$_{(VP/VP)\backslash NP}$ [weggezet]$_{VP\backslash NP}$
Which books have you without t reading t away-put?
"Which books did you put away without reading?"

(23) Dutch Forward Crossed Substitution
$(X/Y)\backslash Z \quad Y\backslash Z \quad \Rightarrow_{\mathbf{S}} \quad X\backslash Z \quad (>\mathbf{Sx})$
where $Y = S_x\backslash NP$

(24) Jan heeft deze boeken [zonder te lezen]$_{(VP/VP)\backslash NP}$ [weggezet]$_{VP\backslash NP}$
Jan has these books without t reading away-put
"Jan put away without reading these (very heavy) books"

(25) *Jan heeft [zonder te lezen]$_{(VP/VP)\backslash NP}$ [deze boeken weggezet]$_{VP}$
Jan has without t reading these books away-put
"*Jan put away these books without reading"

(26) Waar heb je [na twee jaar over nagedacht te hebben]$_{(VP/VP)\backslash NP_{er}}$ [een oplossing voor gevonden?]$_{VP\backslash NP_{er}}$
What have you after two years having thought t_{er} about a solution t_{er} to found?
"What have you found a solution to after two years having thought about?"

(27) Dit is het artikel waar ik [over zei]$_{(VP/S)\backslash NPer}$ [dat Hendrik een reactie op moest schrijven]$_{S\backslash NPer}$
This is the article which I t_{er} about said that Harry a reaction t_{er} to should write.
"*This is the article which I said of that Harry should write a reply to."

(28) * Dit is de man die ik [t vertelde]$_{(VP/S)\backslash NP}$ [dat Hendrik t zou bezoeken]$_{S\backslash NP}$
? This is the man who I told that Harry would visit.

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