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i-within-i Effects in a Variable Free Semantics and a Categorial Syntax *

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This paper is concerned with a semantics making no essential use of variables as proposed originally in Quine (1966) and explored in recent works such as Szabolcsi (1987, 1992), Hepple (1990), and Jacobson (1991, 1992a, 1992b). In particular, I take the implementation of this proposed in my previous papers and couple it with a Categorial syntax; the aspect of Categorial Grammar which is crucial here is the premise that there is a tight fit between the syntactic and the semantic combinatorics. Given this coupling, the phenomenon of so-called i-within-i effects follows from one independently motivated assumption about the syntax of common nouns.

1. The i-within-i Constraint

By i-within-i effects, I mean the generalization that the pronoun within the complement of a relational noun cannot be "bound" by that noun:[1]

1. a. *The/Every wife$_i$ of her$_i$ childhood sweetheart left.
   b. *The/Every wife$_i$ of the author of her$_i$ biography left.

Notice that (1) contrasts sharply with corresponding cases like (2) which contain a relative clause; this is somewhat mysterious on purely semantic grounds since *every wife of* would seem to mean approximately the same thing as *every woman who married:*

2. a. The/Every woman$_i$ who$_i$ married her$_i$ childhood sweetheart left.
   b. The/Every woman$_i$ who$_i$ married the author of her$_i$ biography left..

Actually, the generalization is somewhat broader than that given above; a pronoun also cannot be within a genitive of either a relational noun (3a-b) or a non-relational noun (3c) (compare (3c) to (3d)):

3. a. *Her$_i$ childhood sweetheart's wife$_i$ came to the party.
   b. *The author of her$_i$ biography's wife$_i$ came to the party.
   c. *Its$_i$ best friend's dog$_i$ bit the mailman.
   d. The dog$_i$ that belongs to its$_i$ best friend bit the mailman.

For the moment, however, however, we will concentrate only on the cases shown in (1); I will return to (3) in Sec. 6.[2]

Before continuing, it is worth considering why these facts are mysterious. So, consider again (1). The common wisdom in most work in formal semantics is that ordinary common nouns like *table* have denotations of type

<e,t>. (Of course it could be that this basic view of common nouns is wrong, but since this view leads to a host of interesting results in generalized quantifier theory, I will assume that it is indeed correct.) Given this, it follows that relational nouns - not surprisingly - have denotations of type <e,<e,t>> - they denote 2-place relations between individuals. There is, then, no obvious reason why, e.g., (1a) should be bad: why can't the complex common noun *wife of her childhood sweetheart* have the meaning represented (roughly) as (4)?:

4. λx[wife-of'(x's childhood sweetheart)(x)]

I will indeed claim that there is nothing in the semantics of relational nouns themselves which preclude this - rather, the unavailability of this meaning stems ultimately from a peculiar syntactic fact about common nouns.

In fact, previous treatments of this effect have arguably been quite stipulative. So, for example, Chomsky (1981) and subsequent work within GB has assumed a constraint to the effect that a pronoun within an NP can't be co-indexed with the entire NP. This, however, is just a stipulation. Moreover, as shown in (2), one can in fact get such co-indexation when the pronoun is within a relative clause. (Indeed, Chomsky (1981) was aware of this, and simply added an additional stipulation to exempt such cases from the domain of the constraint.) A somewhat different account is developed in Higginbotham and May (1979) and Higginbotham (1983); the idea here is to account for (1) by a constraint against so-called circular reference. But it is unclear exactly how to make this notion explicit in a natural way in view of the fact that (1) can be given a perfectly coherent semantics.

Actually, it is not only relative clauses which escape the constraint - a pronoun is also allowed in a variety of other post-nominal modifiers such as participles and adjective phrases:

5. The/Every $woman_i$ married to her_i childhood sweetheart left.
6. The/Every $woman_i$ marrying her_i childhood sweetheart next month left.
7. The/Every $woman_i$ still in love with her_i childhood sweetheart left.

To anticipate part of the conclusion: I will claim that the key difference here is that in the good cases ((2) and (5)-(7)) there is a syntactic subject slot which, in essence, "binds" the pronoun. Moreover, it is the lack of this syntactic subject slot which makes it impossible to get the binding in (1). It should be pointed out that an indexing account could undoubtedly also exploit this difference. (Indeed, the account in Higginbotham (1983) does exploit this difference.) Thus, such an account could maintain that what is blocked is direct co-indexation between the NP and the pronoun within it - (2) is good because the co-indexation is mediated by the relative pronoun (and/or its trace) in subject position. Similarly, one could posit that adjective phrases and participles have a silent subject (PRO, trace, or whatever) which mediates between the co-indexation of the NP and the pronoun within it. Nonetheless, the indexing account remains purely stipulative - there is no obvious reason why direct co-indexation between the NP and the pronoun within it should be blocked. (Incidentally, a notable feature of the account to be developed here is that while I will claim that adjective phrases and participles have subject *slots,* I will not need to posit an actual silent subject.)

2. Variable-Free Semantics

Consider the pair of sentences in (8):

8. a. Every man_i thinks that Mary loves him_i.
   b. Every man thinks that Mary loves Jim.

The standard approach to variable-binding is well-known, and does have two apparent (related) advantages. First, any constituent C which contains a pronoun bound from outside C has the same type of meaning as a corresponding constituent without such a pronoun. Thus here the embedded S in both (8a) and (8b) denotes a proposition relative to some assignment function assigning values to the variables. Put differently, in both cases the embedded S denotes a function from assignment functions to propositions. The same point can be made for the most deeply embedded VPs - both *loves him* and *loves Jim* denote a function from assignment functions to VP-type meanings. This would seem to be a happy result since - modulo the distribution of resumptive pronouns - constituents containing pronouns which are bound from higher up have exactly the same distribution as corresponding constituents without such pronouns. (Note the "modulo" here: the true generalization appears to be that the set of environments sanctioning a constituent with a pronoun bound from higher up is a superset of those sanctioning a corresponding constituent without such a pronoun. I return to this point below.) The second advantage is related - the semantic combinatorics is the same regardless of whether or not the constituents whose meanings are combining contain pronouns. In other words, in both (8a) and (8b) the meaning of the lowest VP combines with the meaning of *Mary* in the same way, and the meaning of the embedded S combines with the meaning of *think* in the same way.

Despite this, there are problems with the standard approach (see Landman and Moerdijk, 1983 for relevant discussion). First, all such accounts that I know of require some sort of indexing conventions in the syntax or a level of LF at which pronouns are translated as variables, or both. Second, if we say that constituents have meanings relative to some way to assign values to the variables, then we are committed to variables being some kind of model-theoretic object or at least to variables as key parts of the semantic machinery. I will argue below that the variable-free account allows for a truly direct interpretation of surface structures without use of mediating things such as variables, without use of indexing conventions, and without use of LF.

The alternative account, then, was proposed in Quine (1966). Here there is no sense in which variables are part of the semantic machinery, and no indexing is required in the syntax. The lowest VP in (8b) does not denote a function from assignment functions to properties, but rather a function from individuals to properties - i.e., it simply denotes the 2-place relation *loves*. Similarly, the embedded S *Mary loves him* denotes a function from individuals to propositions - i.e., it denotes the property $\underline{\lambda x[love'(x)(m)]}$.

One could implement this idea in a variety of ways; the particular implementation here is (with one modification) the one developed in Jacobson (1991, 1992a, 1992b). First, I take a pronoun like *him* to denote the identity function on individuals. (Strictly speaking, it denotes the identity function on male individuals, but for simplicity I will ignore gender here.) The second piece to this approach is to say how it is that *Mary loves him* ends up denoting the property $\underline{\lambda x[love'(x)(m)]}$. In my earlier papers, I suggested that the meaning of *him* function composes with the meaning of *loves* (yielding $\underline{love'}$); this in turn function composes with the (type-lifted) meaning of *Mary* to yield the above property. Here, however, I will assume that function composition should actually be broken down into the Geach rule plus application. There are two reasons for this modification. First, this (as opposed to direct function composition) will allow any number of pronouns to be bound in any order. Space precludes a demonstration of this here; this will be detailed in Jacobson (in preparation). For the present purposes, however, we can note that this treatment will allow the semantics to hook into the syntax in a very natural way, as will be shown in Sec. 4. Thus the semantic combinatorics for the embedded S in (8a) sketched in (9) (here g stands for the Geach rule):

9. love-him' = g(love')(him') = $\lambda f[\lambda x[love'(f(x))]](\lambda y[y])$ = love'
   g(lift(m)) = $g(\lambda P[P(m)])$ = $\lambda R[\lambda x[\lambda P[P(m)](R(x))]]$
   Mary-love-him' = g(lift(m))(love-him') = $\lambda R[\lambda x[\lambda P[P(m)](R(x))]](love')$ =
   $\lambda x[\lambda P[P(m)](love'(x))]$ = $\lambda x[love'(x)(m)]$

(At this point, the reader may wonder what allows these particular combinatorics to apply as opposed to other logically possible ones that give rise to incorrect meanings; we return to this in Sec. 4.)

To complete the account, we need to say how it is that the pronoun eventually gets bound. Here I assume that the meaning of *think* can type-shift by an operation I call z which, in essence, binds the pronoun in the complement of *think* to the subject slot. This is spelled out in (10):

10. Given any expression α with meaning of type <X,<e,t>>, α can shift to a homophonous expression β with meaning of type <<e,X>,<e,t>>, where $\beta' = z(\alpha')$. The definition of z is as follows: For any function g,
    $z(g) = \lambda f[\lambda x[g(f(x))(x)]]$ (for f a variable of type <e,X>)

(In Jacobson (1992a) this is generalized for the case of 3-place verbs.) Thus *think* in (8a) undergoes this shift such that z(think') wants a property as argument. Moreover, to stand in the z(think') relation to some property P is to be an x such that x stands in the think' relation to P(x).. Thus the rest of the derivation of (8a) is shown in (10):

10. think-Mary-loves-him' = z(think')(Mary-loves-him') =
    $\lambda P[\lambda x[think'(P(x))(x)]](\lambda y[love'(y)(m)])$ = $\lambda x[think'(love'(x)(m))(x)]$
    every-man-thinks-Mary-loves-him' = every-man'($\lambda x[think'(love'(x)(m))(x)]$)

To illustrate with one further example, consider (11):

11. Every man_i loves his_i mother.

Since *his* denotes the identity function on individuals, the object NP *his mother* will denote the mother-of function - i.e., that function mapping each individual into that individual's mother. (Actually, to make this precise one needs to give a semantics for the genitive here; see Sec. 6.) The binding is effected by having *loves* undergo the *z* operation; to *z*-love a function f (of type <e,e>) is to be an x who ordinary-loves f(x). Thus in (11), the VP denotes the property of *z*-loving the mother-of function, and this occurs as argument of the subject.

While this does, admittedly, involve a slightly more complex set of combinatorics in the semantics than does the standard account, the payoff is that there is no essential use of variables as part of the semantic machinery, no indexing conventions, and a direct model-theoretic interpretation of each constituent. Moreover, the price would seem to be rather small. The only real combinatoric addition here is the adoption of the Geach rule, and once this is hooked into the syntax this will be fairly natural. Of course we have also made use of one other "trick" here to get the effect of binding - and this is the addition of the *z* type-shift rule. It is, however, worth noting that almost all other accounts of binding also need some extra combinatoric rule in order to effect binding.[3] For example, under an account in which pronouns translate as variables, one might posit that (12a) - which would be the meaning of the VP in (8a) - shifts into the meaning in (12b) and then occurs as argument of the subject:

12. thinks-Mary-loves-him':
(a) thinks'(loves'(x)(m)) ===> (b) λx[thinks'(loves'(x)(m))(x)]

Alternatively, one could pull out the subject and leave a variable in its place, and then λ-abstract over the open proposition *x thinks Mary loves x.* Either way, though, some type-shift rule is needed to effect binding.

There are, then, two ways in which my account differs from the usual accounts with variables. First I am of course not making any essential use of variables. Second - and this point will be crucial in the remarks here - the binding effect is located in a different place. In my account, binding is located in the type-shift rule that applies to some function which wants as argument both the pronoun-containing constituent and the binder. At first glance, these two differences may appear to be independent. That is, one might have a semantics with variables but nonetheless simulate the account here as follows: Translate *Mary loves him* in (8a) as love'(x)(m) and then have a rule which λ-abstracts over x at this point, shifting this into the property λx[love'(x)(m)]. Further, adopt the *z* rule as done here. Such an account, then, is not variable-free, but still locates the binding effect in the same place. However, as far as I can see, this simulation is so close to the variable-free approach that having variables is not doing any real work - in fact, the variables are, in a sense, just "getting in the way" since one needs to convert the propositional meaning of *Mary loves him* into a property. I will thus adopt the variable-free approach over this kind of simulation.

3. Independent Motivation for this semantics

The central claim in this paper is that i-within-i effects follow from three things: (a) this treatment of the semantics of binding; (b) embedding this account into a Categorial syntax; and (c) the claim that common nouns do not have a subject slot. The interest in this is therefore only as strong as is the independent motivation for each of these claims, and so we turn briefly here to some independent motivation for this semantics.

In fact, a good deal of such independent motivation is given in Jacobson (1991, 1992a, 1992b, in preparation). Space precludes repeating the details of those discussions here, but I argue in those papers that this account has the following advantages. (1) It allows the semantics of functional questions proposed in Groenendijk and Stokhof (1983) and Engdahl (1986) to be subsumed under the general mechanism for binding. Thus a functional question like (13) simply asks for the identity of the function f such that *every-Englishman' z*-loves f:

13. Who does every Englishman love? His mother.

(2) Moreover, it allows such questions to be subsumed under the general account of extraction in much of the CG literature. In the Groenendijk and Stokhof / Engdahl analysis, the gap needs to be given a complex translation <u>f(x)</u> which is incompatible with the usual CG assumption that the gap is nothing more than a "missing" argument. Under the account here, the gap is simply like any other gap. Since *love* has shifted by *z* it is expecting not an individual argument but rather an argument of type <e,e>. Thus the gap is again just this missing argument. (3) This account (unlike the usual account with variables) predicts that *his mother* is an appropriate answer to a functional question. Here *his mother* does not denote an "open" individual like <u>the-mother-of-(x)</u> but rather denotes the-mother-of function. (4) This allows for a treatment of unexpected inferences of the type discussed in Chierchia (1990) and Reinhart (1990) and again subsumes these under the general account of binding. (5) This accounts without making use of a level such as LF for some interactions of Bach-Peters sentences with Weak Crossover that were originally discussed in Jacobson (1977); in a semantics with variables these interactions necessitate a level of LF at which the first pronoun in a Bach-Peters sentence is "unpacked" into a complex representation while here no such level is necessary. (6) This allows for an account of certain cases of Antecedent Contained Deletion without positing a level of LF. Some of these arguments (such as that in (3)) will go through under almost any implementation of a variable-free account, but others (e.g., the arguments in (1), (2), (4), (5) and the new argument to be developed below) provide evidence for this particular implementation. In particular, they provide evidence for locating the binding effect in the *z* shift rule.

Thus to these cases, I will add here one more case which centers on binding and coordination. Consider first a run-of-the-mill Right Node Raising sentence such as (14):

14. Every man loves but no man married that woman.

One of the biggest successes of Categorial Grammar combined with the Partee and Rooth (1983) semantics for generalized conjunction is that this allows for a straightforward account of (14) without having to invoke a "Right Node Raising" analysis (Dowty, 1988; Steedman, 1990). Thus, *every man* can function compose with *loves* to yield a constituent looking for an NP to its right and similarly for *no man marries*. These two can thus conjoin and take *that woman* as object. But now consider (15):

15. Every man$_i$ loves but no man$_j$ married his$_{i/j}$ mother.

This is impeccable on the intended reading, which I will refer to as the Across the Board Binding reading.

Under the standard approach(es) to binding, there is no obvious way to get the pronoun simultaneously bound by both NPs. In a nutshell, the problem with the standard account is that the variable-binding effect is located in the wrong place. Consider again, for example how binding occurs in a (roughly) analogous case like (11):

11. Every man_i loves his_i mother

As discussed above, one way to effect binding under the standard approach with variables is to map the meaning of the VP shown in (16a) into (16b) and then take that as argument of the subject:

16. loves-his-mother' = (a) loves'(the-mother-of'(x)) ===>
(b) (λx[loves'(the-mother-of'(x))(x)]

But this will not extend to (15) since here there is no VP of the form *loves his mother.* In other words, in (15) there simply is no constituent whose meaning is of the right form to undergo the binding rule. The same remarks will apply under a theory in which binding is effected via a level at which the subject has been scoped out and replaced by a variable.

In fact, I can see only two ways to get the ATB reading under an approach in which pronouns translate as variables. One is to simulate the variable-free approach; I will postpone discussion of this until I discuss the variable-free approach. The second is to abandon the CG analysis of coordination for this type of case, and to posit instead a Right Node Raising analysis. By this, I mean only any analysis which posits some level at which there are actually two sentences and where the binding thus takes place at this level. Such an analysis, then, will map (15) into (or, derive it from) an LF such as that in (17) or (18) (or something analogous). The key point is that the "Right Node Raised" NP *his mother* is mapped into two separate NPs at LF; for expository purposes I have underlined these in (17) and (18).

17. Every man' (λx[x loves <u>x's mother</u>]) but no man'(λy[y marries <u>y's mother</u>])
18. Every man' (λx[x loves <u>x's mother</u>]) but no man'(λx[x marries <u>x's mother</u>])

But even if one were willing to countenance a Right Node Raising analysis, there is a subtle problem here. Note that if (17) is the LF for (15) then we require only that the single NP which is "unpacked" into two NPs at LF be identical up to the variables. If (18) is the LF for (15) we can place a stronger requirement on the "unpacking" of this NP: it must unpack into two identical copies - where even the variables must be identical. Either way, however, there is a problem with respect to (19):

19. *$John_i$ thinks that every man loves but that no man_j married $his_{i/j}$ mother.

Note that (19) cannot have a reading where *his* is simultaneously bound by both *John* and by *no man.* (In fact, this is just an instance of the more general observation made in Chierchia (1988) that there can never be binding out of just one conjunct.) But if (15) could map into (17), then (19) should be able to map into (20), since here the single NP has "unpacked" into two NPs differing only in the variables (again I have underlined the NPs). Similarly, if (15) must translate into (18) (where the variables within the NPs are identical) then there is no obvious reason why (19) could not translate as (21).[4]

20. John' (λy[y thinks that every man'(λx[x loves y's mother]) but
that no man'(λz[z loves z's mother]))

21. John'(λy[y thinks that every man'(λx[x loves y's mother]) but
that no man'(λy[y loves y's mother]))

Under the variable-free approach, on the other hand, this entire domain is unproblematic. First, take the simple ATB binding case in (15); the semantics for this is shown in (22). Informally, the first conjunct denotes the set of functions f such that every man *z*-loves f, and the second conjunct denotes the set of functions g such that no man *z*-loves g. Both are of type <<e,e>,t> and thus may conjoin. Given the Partee and Rooth (1983) semantics for generalized conjunction, the conjoined material will denote the intersection of these two sets of functions. Moreover, as discussed above, since *his* denotes the identity function on individuals, *his mother* will denote the mother-of function, and so it is of the right type to serve as argument of the conjoined material. Thus no Right Node Raising analysis is needed here.

22. every-man-loves-but-no-man-marries' = (for ∧ the generalized ∧ of Partee and Rooth): every-man' ∘ *z*(love') ∧ no-man' ∘ *z*(marry') =
λf[every-man'(*z*(love')(f))] ∧ λg[no-man'(*z*(marry')(g)] = (by def of ∧)
λf[every-man'(*z*(love')(f)) ∧ no-man'(*z*(marry')(f))] = (by def of *z*)
λf[every-man'(λx[love'(f(x))(x)])∧ no-man'(λy[marry'(f(y))(y)])]

Second, it follows immediately under this approach that there can be no binding out of just one of the conjuncts as illustrated in (19). The basic idea is this. Under *John thinks* we have the conjunction of two expressions: *every man loves* and *no man marries.* Notice that *no man* is trying to bind the pronoun in the object; this means that *marries* has undergone *z*. This in turn means that *no man marries* is of type <<e,e>,t>. Consider now the first conjunct *every man loves.* Here *every man* is not trying to bind into the object, and so we have one of two possibilities regarding the meaning of *every man loves.* It could be something which is looking for an ordinary individual object; in this case its meaning is of type <e,t>. Alternatively, both *loves* and *every man* could have shifted by the Geach rule (in this case, *loves* will shift to type <<e,e>,<e,<e,t>>>and *every man* to type <<e,<e,t>>,<e,t>>). These two can then function compose. What this means is that *every man loves* is indeed looking for something which contains a pronoun but here it also wants the pronoun to remain unbound, and only be bound from higher up (for example, by *John)*. (This, in fact, is what is trying to happen in (19).) But in this case the meaning of *every man loves* is of type <<e,e>,<e,t>>. Thus either way its meaning is not of the right type to conjoin with the meaning of *no man marries.* This is spelled out more explicitly in (23):

23. *no man marries* (in (19)) - is trying to bind; hence its meaning is as follows:
no-man' ∘ *z*(marry') = λf[no-man'(*z*(marry')(f)] of type <<e,e>,t>

every man loves - is not trying to bind; hence its meaning is either:

(a) every-man' $\circ$ loves' $= \lambda x[\text{every-man}'(\text{loves}'(x))]$ of type <e,t>, or
(b) $\mathbf{g}(\text{every-man}') \circ \mathbf{g}(\text{loves}') = \lambda f[\mathbf{g}(\text{every-man}')(\mathbf{g}(\text{loves}')(f))] =$
$\lambda f[\lambda R[\lambda x[\text{every-man}'(R(x))]](\lambda g[\lambda y[\text{loves}'(g(y))]](f))] =$
$\lambda f[\lambda x[\text{every-man}'(\text{loves}'(f(x)))]]$ of type <<e,e>,<e,t>>

Of course one might now object that although this account successfully blocks binding out of a conjunct, it should also block binding into a conjunct as in (24), since here too the conjoined constituents are not of the same type:

24. Every man_i thinks that Mary left and that he_i stayed.

The first conjunct here is of type t, and the second of type <e,t>. But in fact (24) is unproblematic; binding is possible here in the same way that binding is possible in general. If *and* is listed in the lexicon as being of type <X, <X,X>> then it itself could undergo the Geach rule and hence combine with one constituent which contains a pronoun as argument, and with another that doesn't. (The second constituent will type-lift so as to be a function over *and X* and will also undergo the Geach rule.) Analogous points with respect to extraction have been noticed over and over in both the CG and the GPSG literature. Hence (24) is derived as follows:

25. $\text{and}' = \lambda q[\lambda p[p \wedge q]]$ $\mathbf{g}(\text{and}') = \lambda P[\lambda x[\text{and}'(P(x))]] = \lambda P[\lambda x[\lambda p[p \wedge P(x)]]]$
he-stayed' = stay'
$\text{and-he-stayed}' = \mathbf{g}(\text{and}')(\text{stay}') = \lambda x[\lambda p[p \wedge \text{stay}'(x)]]$
lift(Mary-left') (over type <t,t>) $= \lambda S[S(\text{Mary-left}')]$
$\mathbf{g}(\text{lift}(\text{Mary-left}')) = \lambda Z[\lambda x[\lambda S[S(\text{Mary-left}')](Z(x))]]$
(for Z of type <e,<t,t>>)
$\mathbf{g}(\text{lift}(\text{Mary-left}'))(\text{and-he-stayed}') = \lambda x[\text{Mary-left}' \wedge \text{stay}'(x)]$

To return to the simple ATB case in (15), the advantage of the variable free approach is two-fold. First, it seems to locate the binding effect in exactly the right place - by locating it in a type-shift rule which operates on the meaning of *love* and *marry* we don't need a full VP *loves his mother* in order to get the binding effect. Second, *his mother* denotes just the mother function, and so its meaning is right to be the argument of the conjoined material. Of course an approach with variables could, as discussed earlier, simulate this. That is, such an approach could map the "open" individual x's mother into the mother-of function and could also incorporate the *z* rule to do the binding. But again this simulation would seem to be so close to the approach here that it is not clear that the variables are doing any real work.

4. Syntax of the account

Having provided some independent motivation for this semantics, let us now consider the question of how this should be hooked in to the syntax. The variable-free approach claims that the embedded "Ss" in (8a) and (8b) have different semantic types; one is a proposition, the other a property. Given the basic fit between the syntax and the semantics maintained in most versions of Categorial Grammar one might, then, expect some syntactic difference as well.

Aside from the aesthetics of the syntax/semantics match, there is a another reason to tightly couple the syntax with the semantics: we need to somehow regulate the semantic combinatorics. Take again the semantic derivation of *Mary loves him* which was shown in (9). While we have shown one set of combinatorics which provide this with the desired meaning, the question arises as to how to block other combinatoric possibilities which result in impossible meanings. For example, assume that *Mary* is listed in the lexicon as denoting just the individual m. When the subject *Mary* combines with the VP *loves him*, we must block a derivation in which m is simply taken as argument of the VP (which, recall, simply denotes the two-place relation love'). For if m were taken as argument of this VP, then we would mistakenly end up with a meaning for (8a) where Mary is the lovee rather than the lover.

This, however, can be solved perfectly straightforwardly by hooking the semantics into the syntax in exactly the way one might expect. First, assume that constituents which contain a pronoun are marked as such in the syntax; we will use a superscript of the appropriate category on such constituents, where this superscript can be seen as a kind of feature. In other words, the VP *loves him* in (8a) is actually of category VP^{NP} and *Mary loves him* is an S^{NP}. In fact, we will take a pronoun such as *him* also not to be an NP, but also to be an NP^{NP}.[5] Note that any expression of category A^B denotes a function from B-type meanings to A-type meanings.

The next question which arises is how this feature gets transmitted and how the this feature is used to regulate the semantic combinatorics. The answer here is straightforward - just as we allowed expressions to undergo the Geach rule in the semantics, so will we allow the corresponding syntactic operation. That is, we will posit the rule in (26), which we will refer to as **g**:

26. For any expression α of category A/B and for any category C, there is a homophonous expression β of category A^C/B^C, where $\beta' = \lambda V[\lambda c[\alpha'(V(c))]]$ (for V a variable of type <C',B'> and c a variable of type C'.

Thus the semantics of (26) is just the Geach rule and the syntax is similar - it allows the function to combine not with an ordinary B but rather with a B^C and the result inherits the superscript feature. This is, of course, reminiscent of the sort of feature passing conventions which have been developed within GPSG, and it is being used here for a similar purpose (except that here it is used for the case of pronouns rather than gaps).

Notice that we now have a ready answer to the question of why it is that a constituent containing a pronoun can occur in any environment where a corresponding constituent without a pronoun can occur. If a constituent of category B can occur as argument of something of category A/B, then a B^C can also occur as argument of a homophonous expression. Thus, one of the apparent advantages of the standard approach with variables disappears: the fact that constituents with pronouns occur wherever constituents without pronouns do follows equally naturally under this approach. In fact, as noted earlier, the generalization holds true only in one direction - the existence of resumptive pronouns shows that there are environments where a pronoun-containing constituent can occur where a corresponding constituent without a pronoun cannot occur. This too is easily accounted for here; we need say only that relative pronouns want as arguments either an S with a gap (I leave open the status of the category of such constituents) or an S^{NP}. More importantly, the semantic combinatorics are now hooked into the syntax in such a way that no wrong meaning can result for (8a). The full derivation of the embedded S in (8a) is now sketched in (27), but the main point is rather simple. In order for *Mary* to combine with *loves him* it has to have undergone **g**, and since **g** has both a syntactic and a semantic side this ensures that the subject can only combine with the meaning of the VP in the right way.

27. him; NP^{NP}; him' = $\lambda x[x]$

loves; $(S/_L NP)/_R NP$; loves' $\Longrightarrow_{\mathbf{g}}$ loves' $(S/_L NP)^{NP}/_R NP^{NP}$; $\lambda f[\lambda y[loves'(f(y))]]$

loves him; $(S/_L NP)^{NP}$; g(love')(him') = $\lambda f[\lambda y[loves'(f(y))]](\lambda x[x])$ = loves'

Mary (lifted); $S/_R(S/_L NP)$; $\lambda P\{P(m)]$ $\Longrightarrow_{\mathbf{g}}$

Mary; $S^{NP}/_R(S/_L NP)^{NP}$; $\lambda R[\lambda x[\lambda P[P(m)](R(x)]]$

Mary loves him; S^{NP}; g(Mary') (loves') = $\lambda R[\lambda x[\lambda P[P(m)](R(x)]](loves')$ = $\lambda x[loves'(x)(m)]$

Having hooked the semantics into the syntax in this way, we now also need to make one modification to the *z* rule; this was given in (10) where I gave only the semantic side. However, this too will need a syntactic side, and this is for two reasons. The first is again aesthetic - we would again expect the semantic shift to be coupled with a corresponding syntactic shift. Aesthetics aside, a corresponding syntactic shift is now forced by the entire system. Consider, for example, *thinks* in (8a), which has undergone *z*. It is combining not with an ordinary S but rather with an S^{NP}, and thus its syntactic category must have shifted as well as its semantic type. (Note that in the case that the subject of *think* does not bind the pronoun, then *think* undergoes **g** rather than **z**, where **g** also shifts its category.) Thus, we can now explicitly spell out the binding rule as follows; we will call the full rule **z**:

28. For any expression α of category (A/NP)/B and semantic type <X.<e,Y>>, there is a homophonous expression β of category $(A/NP)/B^{NP}$ of semantic type <<e,X>,<e,Y>>, where $\beta' = z(\alpha')$ (i.e., $\beta' = \lambda f[\lambda x[\alpha'(f(x))(x)]]$)

We are now ready to see an interesting pay-off to this approach. By adopting a parallel treatment of the syntax and the semantics, we predict that the only expressions which can undergo the **z** operation are those which <u>syntactically</u> expect at least two arguments - they must have an argument slot of category B and a later argument slot. Since this is crucial to the account of i-within-i effects, it is worth reiterating that adding this syntactic requirement to expressions undergoing **z** is not just a stipulation designed for the problem at hand. It is necessitated first by the general premises of Categorial Grammar, and second by the need to ensure that no wrong semantic combinatorics ensue. Of course we are assuming that for the most part there always is a tight correspondence between the syntactic category of an expression and its semantic type, and so adding the syntactic part to (28) might at first glance appear to have no real effect. Suppose, however, we were to find a bit of mismatch on this score say, in the lexicon. In other words, suppose that there are lexical items with meanings of type <e,<e,t>> which never syntactically combine with two NP arguments. Then even those these have the right semantic type to undergo **z** they do not have the right type syntactically, as they are not syntactic 2-place functions. And indeed, I will suggest directly that relational nouns are just this - i-within-i effects, then, will follow from exactly this peculiar property of nouns.

5. i-within-i effects

We now have all of the pieces needed to account for the mysterious i-within-i effects. First, consider the cases in (2) and (5)-(7), where the pronoun is bound within a relative clause, a participle, or an adjective phrase. These are all perfectly straightforward; *marry* in (2), *married* in (5) and *marrying* in (6) all undergo **z**, and so the pronoun is "bound" by the subject slot. Similarly, *in love* undergoes **z** in (7). (It should be pointed out that the indexing shown in these examples is thus a bit misleading; there is no actual sense in which the entire NP nor the head is "binding" the pronoun. Rather, the pronoun is actually being bound by the subject slot via the **z** operation, and the entire phrases are modifiers of the head noun.) Note that we are assuming here that participles and adjectives have actual syntactic subject slots - thus the adjective *in love* takes two arguments (the *with-PP* and a subject), and a participle like *marrying* or *married (to)* also takes two arguments. This will be justified below. But note further that we do not need any silent subject to appear in these "slots", since binding has nothing to do with co-indexation between actual NPs.

Now let us return to an i-within-i case such as (1). In fact, if we consider only the semantic part of the *z* operation then the ungrammaticality of this is indeed a mystery. Since *wife* is a relational noun its meaning is presumably of type <e,<e,t>>, and there is then no obvious reason why it couldn't undergo *z* to give (4), as shown in (29):

29. wife' ==> z(wife') = λf[λx[wife-of'(f(x))(x)]]

Given the variable-free approach, *her childhood sweetheart* will have as its meaning (roughly) λy[the-childhood-sweetheart-of'(y)] and this should be able to occur as argument of z(wife') with the result that *wife of her childhood sweetheart* will have the i-within-i violating meaning shown earlier in (4).

The solution to the mystery, however, lies in the syntactic side. Although common nouns are usually assumed to have meanings of type <e,t>, it is also quite standard in most recent Categorial Grammar literature not to treat these as syntactically functions. Rather, contra Montague (1974), N is usually considered just to be a basic category rather than an abbreviation for some function category. If this is right, this means that relational nouns are syntactically just one-place functions; they are just of category $N/_{R}PP$. In that case, then, these are not of the right syntactic category to undergo the **z** rule. Put differently, nouns contrast with adjective phrases, VPs, participles etc. in that they don't contain a syntactic subject slot, and so there is no slot to bind the pronoun. Thus the fact that *wife* cannot shift in (29) follows from this peculiarity of the syntax of common nouns.

At this point, one might raise the following objection. We have indeed accounted for the facts, but only by adopting one key stipulation - this stipulation being that even though common nouns denote functions of type <e,t> they are syntactically not functions. Consequently, although relational nouns denote functions of type <e,<e,t>> they are syntactically only one-place. (Moreover, the claim here is that we do have to live with the fact that there occasional mismatch between semantic and syntactic types, at least in the lexicon.) Indeed, this is just a stipulation, but the important point here is that it is a stipulation which has independent motivation, quite apart from i-within-i effects. Moreover, the claim that adjective phrases and participle phrases do in fact have syntactic subject slots also has independent motivation.

Let us consider the second claim first. The fact that (5)-(7) are good relies on the assumption that *in love, marrying,* and *married* are all syntactically two-place and have syntactic subject slots. This assumption is justified by the observation that - although these rarely directly combine with their subjects - there are environments where they do; these have gone under the rubric of "small clauses". Thus, for example, Buekema and Hoekstra (1985) note cases like (30):

30. a. With Barbara marrying John next month, you'll need a new suit.
b. With John married to Sue, he'll finally be happy.
c. With Sue in love with John, they'll have to rethink the job situation.

Presumably, then, a participle phrase like *marrying John next month* is actually of some category X/NP, where *with* can combine with an X to give an adverbial (see Jacobson, 1990 for further discussion). Similarly for passive VPs like that in (30b); these too must have some category of the form Y/NP which can occur as argument of *with;* the same remarks apply to the adjective phrase in (30c). This in turn means that *marrying, married,* and *in love* are all syntactically 2-place. It thus follows that they can undergo the **z** rule in (28), and from this it follows that (5)-(7) are possible.

A second environment which sanctions such "small clauses" is the complement of verbs like *like* and *prefer* as in (31):

31. I would prefer him marrying Sue / married to Sue / in love with Sue.

One can show that these are genuine small clauses rather than being a "Raising to Object" configuration by noting that the entire constituent can occur in copular sentences:

32. What I would prefer is him marrying Sue / him married to Sue / him in love with Sue.

Again, then, we can assume that participles and adjective phrases have subject slots, and can take these subjects to give constituents of some category or categories which can in turn occur as the complement of *prefer.*

But now compare this to common nouns (by which I mean both ordinary 1-place nouns and relational nouns coupled with their complements). The most striking piece of evidence for the claim that these in fact do not have syntactic subject slots is the fact that they never combine with subjects, even in these configurations:

33. a. *With that piece of wood table, we'll have a place to eat.
b. *With Barbara friend of yours, you're certain to win the election.

34. a. *I would prefer that piece of wood table.
b. *I would prefer Barbara friend of yours.

(There is actually a class of apparent common nouns like *president* which do occur predicatively and thus do directly take subjects: *With Barbara president,....* etc. I assume, with Partee (1985), that these are actually NPs occurring predicatively, and not common nouns.) Thus the fact that ordinary common nouns do not occur with "subjects" provides very strong evidence for the claim that N is not a functional category - it is not an abbreviation for something of the form X/NP. This in turn means that relational nouns only have one syntactic slot.

There is a second - albeit only suggestive - piece of evidence that common nouns differ from other predicative expressions in not having syntactic subject slots; this centers on so-called Principle A effects. Recent work by Pollard and Sag (1992) has suggested that the correct descriptive generalization concerning locally bound anaphors like reflexives and reciprocals is that given in (35) (I am ignoring one complication concerning the precise descriptive statement which arises from the existence of 3-place verbs; this will not affect the point at hand):

35. Take some anaphor X. If this occurs within the complement of some function Y such that Y has a higher NP argument slot, then X must be bound to the higher slot. If not, then it can remain free.

I have no account of what this descriptive generalization follows from, nor how best to treat such locally bound anaphors within the treatment of binding here. But for the present purposes, the important point is that (35) does seem to be descriptively correct, and thus we get the well-known fact that reflexives and reciprocals, for example, must be locally bound if they have a higher co-argument slot, as in (36):

36. Mary_m said that John_j likes himself_j/ $^*\text{herself}_m$

However, it is also well-known that when these anaphors occur within the complement of an ordinary noun, they can be bound from indefinitely far away, as in (37a). In fact, as has been shown by Kuno (1975), Zribi-Hertz (1989), Pollard and Sag (1992) and others, they can in fact remain free, as in (37b):

37. a. John_j thought that it was obvious that the picture of himself_j was ugly.
b. John_i was upset. That beautiful picture of himself_i that had hung in the museum was destroyed in the fire.

What Pollard and Sag suggest is that the difference between (36) and (37) lies in the fact that there is no higher co-argument slot in (37). In other words, it is precisely because common nouns do not have a subject slot that the binding requirement is "off". Of course this argument is not entirely conclusive without being hooked in to a theory of why we find this distribution of anaphors, but if at least the descriptive generalization in (35) is correct then it provides one more piece of evidence that nouns indeed have no subject slot.

The conclusion, then, is that common nouns appear to have a mismatch between their semantic type and their syntactic category.[6] Ordinary common nouns are just of category N and have no additional subject slot; relational nouns are just of category N/PP and have only a slot for the PP complement. Given this fact, given the variable-free semantics in which binding is located in the *z* type-shift rule, and given the coupling of this semantics with a syntax which also requires that the shifting expression have two syntactic slots, i-within-i effects follow immediately, with no additional stipulations.

Finally, there is is one further interesting piece of evidence for the claim that i-within-i violations do indeed stem from the lack of a subject slot with common nouns. I have found some speakers who do allow apparent i-within-i violations with nouns which are transparently agentive nominalizations, as in (38) (I myself do not find these impeccable and thus have marked them with my own judgments, but they are better than (1)):

38. a. ?*The/Every builder$_i$ of his$_i$ house left.
 b. ?*The/Every builder$_i$ of her$_i$ mother's house left.
 c. ?*The/Every owner$_i$ of his$_i$ mother's condo left.

Similarly, there is a contrast between (39a) and (39b) (again, I indicate my own judgments here):

39. a. *The/Every author$_i$ of her$_i$ mother's biography left.
 b. ?*The/Every writer$_i$ of her$_i$ mother's biography left.

Under the proposal here, it is not surprising to find that these are good for some speakers. Presumably for such speakers what is being nominalized is **z**(*build*), **z**(*own*), etc, where the verbs are, of course, two-place in the lexicon. Moreover, it is not entirely surprising to find speaker variability on these (we might also expect to find variability according to the lexical item here). I assume that such nominalizations are lexical processes and such semi-productive lexical processes are exactly an area where we tend to find variability - both across speakers and across lexical items. Thus speakers who do not allow (38) allow only the unshifted verbs to nominalize.

6. <u>Genitives</u>

To complete the account, we return to the case of genitives as in (3). It is obviously beyond the scope of this paper to give a thorough treatment of genitive NPs; I will thus sketch just one possible account, and I suspect that the same point will hold under any other plausible account. Consider first the case of a genitive with a relational noun, such as *John's mother. John* here fulfills the same semantic slot as in an NP such as *the mother of John('s).* This can be accounted for by supposing that any relational noun can shift its syntactic category and its meaning as follows:

40. Given a relational noun α (of category $N/_R PP$), it can shift to be of category $NP/_L$ NP[GEN], with meaning $\lambda x[\iota y[\alpha'(x)(y)]]$.

As to genitives with ordinary NPs (such as *John's book)* we might assume that common nouns in general can shift in such a way as to augment their argument structure. Thus they can shift to be of category $NP/_L$NP[GEN] with the meaning shown in (41):

41. $\lambda x[\iota y[N'(y) \wedge R(y)(x)]]$ (for R any contextually salient two-place relation)

Whether or not there is some way to collapse (40) and (41) will be left open here.

Note that under this analysis, genitive NPs are arguments. Again, however, a noun which is waiting to take a genitive NP to give an NP is still syntactically only 1-place. Thus again such a noun cannot shift by **z**, and so the ungrammaticality of cases like (3) is accounted for.

7. Conclusion

In this paper, I have argued for three things. (1) There are no variables in the semantics nor indexing in the syntax. The binding effect is located in a type-shift rule which applies to the meanings of expressions which want (at least) two arguments: the binder, and the pronoun-containing constituent. Independent evidence for this view of binding is developed in Jacobson (1991, 1992a, and 1992b), and further independent evidence is given here centering on the interaction of coordination and binding. (2) This semantic type-shift rule is coupled with a corresponding syntactic category changing rule. Coupling the syntax with the semantics in this way is independently motivated both by the central premises of Categorial Grammar, and by the need to have the syntax regulate the semantic combinatorics. Given this coupling, the only expressions which can shift are those which are syntactically (at least) two place. (3) Common nouns have no syntactic subject slot, and hence relational nouns are syntactically only one-place. The independent evidence for this comes from the fact that nouns (including relational nouns with their PP complements) never actually take subjects, even in environments where other predicative expressions (adjective phrases and participles) do. Given these three claims, i-within-i effects follow immediately, with no stipulations. On the other hand, the standard account of binding, making use of variables and/or indexing conventions, appears to have no non-stipulative way to account for this effect.

Footnotes

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[1] An apparent counterexample to this generalization concerns NPs in predicative position:

i. Every woman$_i$/Mary$_i$ is the wife$_i$ of her$_i$ childhood sweetheart.

However, this is not a genuine counterexample; in this case *her* is actually bound by the subject NP and hence need not be analyzed as being "bound" by the head noun.

[2] There are two further points regarding the domain of the constraint. First, it has often been noted that sentences like (1) improve if the pronoun is *her own* rather than *her* (although these are still not impeccable):

i. ??The/?*Every wife$_i$ of her$_i$ own childhood friend left.

I have no explanation for this. Second, Higginbotham (1983) notes the ungrammaticality of (ii), and subsumes this under i-within-i effects:

ii. *John$_i$/Every man$_i$ is his$_i$ cook$_i$.

As noted in fn. 1, pronouns are generally possible in predicative position - as is to be expected since here they need not truly be "bound" by the noun but are rather "bound" by the subject. Given this fact, the ungrammaticality of (ii) is mysterious, and my explanation for i-within-i effects will not generalize to this case. I do not, however, think that this is a problem for this explanation; arguably (ii) simply is not an instance of the same phenomenon. Note that, for example, cases like (ii) are fine if the pronoun is sunk further down:

iii. John$_i$/Every man$_i$ is his$_i$ mother's cook$_i$.

But classic i-within-i cases do not improve (at least not substantially) when the pronoun is sunk further down as shown, for example, in (1b) and (1c). Because the phenomena in (ii) thus exhibits a locality effect it is, perhaps, actually an instance of so-called Principle B effects,which I will not deal with.

[3]The one notable exception to this that I am aware of is the account in Szabolcsi (1992), where she builds the binding effect into the meaning of the pronoun. This appears to be attractive at first blush since under any account the pronoun must have some meaning and thus Szabolcsi, as it were, kills two birds with one stone. Nonetheless, there are problems with this account. First, and perhaps most serious, Szabolcsi (personal communication) points out that there appears to be no way on this account to get two different pronouns "bound" by the same binder, as in (i)

i. Every boy$_i$ thinks that his$_i$ mother likes his$_i$ dog.

This is unproblematic in the present account; the details of this are sketched in Jacobson (1992a) and involve double application of the *z* rule. Second, this account does not extend naturally to cases discussed in Jacobson (1992a) concerning functional questions and unexpected inferences; this point is discussed in more detail there.

[4] One could undoubtedly adopt additional stipulations to rule out these LFs, but it would appear that additional stipulations would be necessary. For example, one might require exact identity in the two NPs (and hence rule out (20) as a possible LF), and further posit that (21) is an ill-formed LF on the grounds that it is ambiguous; y can be bound by either John' or by no-man'. But even this stipulation will not solve the general problem. Consider (i) which cannot have the reading indicated in (ii), where *his* is bound in the second conjunct by *no man* but is free in the first conjunct:

i. Every man$_i$ loves but no man$_j$ marries his$_{j/k}$ mother.
ii. Every man$_i$ loves his$_k$ mother but no man$_j$ marries his$_j$ mother.

The stipulation above will not rule out (iii) as an LF for (i):

iii. every-man'(λx[x loves y's mother]) but no-man'(λy[y loves y's mother])

[5]Actually it would be wrong to think of this feature as always meaning that the constituent in question contains a pronoun of the appropriate type. Space precludes a full discussion of this here, but I will assume that expressions such as *the local bar* (as discussed in Partee, 1991) are also of category NP^{NP} since they undergo binding just as expressions with overt pronouns do. Thus this feature actually does nothing more than record the semantic type of an expression; anything of category A^B denotes a function from B-type meanings to A-type meanings.

[6] Of course it could be that we need to rethink the semantic type of common nouns. If it turns out to be incorrect to treat common nouns as being of type <e,t> and relational nouns as being of type <e,<e,t>> then the i-within-i effects will still hold under the account of binding that I am proposing; it would simply mean that the syntactic side is irrelevant in the account.

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