


Why Variables?*

Uli Sauerland

Kanda University of International Studies

This paper addresses the question of how sentence-internal semantic dependencies are computed? The kind of semantic dependency I am looking at is that between a so called ‘bound (variable) pronoun’ and its binder illustrated in (1), where the dependency is indicated by a connecting line. With all the literature on the topic (see for example Partee 1973, Percus 1998), I assume that this case is the prototype of all semantic dependencies, and therefore any result for this case generalizes to all types of sentence-internal semantic dependencies.¹

- (1) Every boy likes his father.
- 

The specific issue I address is whether two instances of a bound pronoun differ in meaning if their binders are different. This seems an important question to me, since the two major formal models for semantic dependencies, variable binding and combinatorial logic, give different answers to this question. Recall that in the variable-binding model of semantic dependencies, pronouns are represented by indexed variables, where the index may differ between one occurrence of a bound pronoun and another. On the ‘variable-free’ combinatorial view, on the other hand, pronouns are assumed to be semantically vacuous and, therefore, all occurrences of a pronoun identical in meaning. Exploring these issues in more detail, I argue in section 3 that the evidence discovered here lends support to the variable-binding model of dependencies.

In the sections 1 and 2, I argue that the meaning of two instances of a bound pronoun can be different under certain circumstances. In section 3, I return to the two formal models

*This paper has its beginnings in conversations on sloppy readings with Danny Fox temporally surrounding a presentation of (Schwarzschild 1998) by myself at the LF reading group at MIT, Without these I probably would have been unable to then find and interpret the data discussed here. For useful comments relating to content and/or presentation, I also thank Irene Heim, Norvin Richards, David Pesetsky, Carlo Ceccetto, Kazuko Yatsushiro, Roger Schwarzschild, Colin Philipps, Jason Eisner, Orin Percus, Roger Martin, Hisa Kitahara, Chris Tancredi, and the audiences at NELS 28 at the University of Delaware, at Keio University and at Yokohama National University. Remaining errors are, of course, my own fault.

¹Crossclausal dependencies differ from sentence-internal dependencies in many ways and there are generally assumed not to involve bound variable pronouns. Therefore, I put them aside here.

© 1999 by Uli Sauerland

available for semantic dependencies, and argue that an account of the facts of the first two sections is much easier under the assumptions of the variable-binding model.

1 Optionally Focussed Sloppy Pronouns

The main claim I argue for in this section is that two instances of a bound pronoun often differ in their interpretation. For example, I claim that the two occurrences of *his* in (2) differ in their interpretation.

- (2) Every boy likes his father and every teacher likes his father.

What kind of evidence would bear on this claim? In complete sentences, bound variable pronouns are always bound and the semantic relationship of binder and bindee obscures what the contribution of the bound pronoun to the meaning of the whole might be. And since a bound pronoun cannot enter a second binding relationship,² the first binder seems to, in some sense, absorb most of what the bound pronoun contributed to the interpretation. Hence it seems that by merely looking at truth conditions of sentences, the claim I'm making cannot even be addressed because of the nature of bound pronouns.³

Is there a test for the meanings of constituents smaller than complete sentences? Well, yes there is: It has been argued, for example by Rooth (1992), that intuitions on focussing and destressing are sensitive to the meanings of subsentential constituents. Consider the example in (3). On the natural intonation of (3), the adjective *Canadian* must be focussed, while the adjective *young* and the noun *athlete* must be destressed.⁴ Furthermore, the focussing pattern is reversed if, for example, the subject is *a young girl from Toronto* instead of *a young Mexican swimmer*. This example illustrates that the semantic relationship of the two noun phrases in (3) affects the stress patterns possible. Moreover, the relevant conditions seem to be sensitive only to the meaning of the two noun phrases, not to the specific lexical items used or the syntactic structure, since all the NPs considered differ in their lexical items (see also Tancredi 1992).

- (3) A young Mexican swimmer was talking with a young [CaNAAdian]_F athlete.
antecedent focus domain

²Not knowing much about the topic, I assume that examples with so-called split antecedents like (i) involve really conjunctions of more than one bound pronoun, which can be phonologically realized for example *their*.

(i) Every wife kissed every husband on their honeymoon.

³To verify the claim I'm making on the basis of truth conditions would require us to separate the contribution of the pronoun from that of the binder to the meaning of the whole sentence. This separation is of course possible—both formal models I discuss in section 3 achieve this—and, in fact, required to account for the compositionality of meaning. However, none of the possibilities of doing the separation seems to be intuitively preferable.

⁴Stress on *athlete*, for example entails that swimmers aren't athletes contrary to usual world knowledge, and is therefore unnatural.

More specifically, it's the relationship of the antecedent and focus domain indicated in (3) that determines the focus placement in the focus domain. Intuitively, it's the case that the parts of the focus domain are stressed that contain 'new' information,⁵ while the information of the whole focus domain except for the focussed parts is 'given' by the antecedent. In (3) for example, *young swimmer* renders *young athlete* given. To capture the concept of 'given', Schwarzschild (1998) introduces the *Existential Closure* of a function f that is a mapping onto truth values. He defines this concept as existential quantification over all argument positions of f . For example, if *young swimmer* and *young athlete* are formally represented as functions from individuals into truth functions, their existential closures can be paraphrased as '*There is a young swimmer*' and '*There is a young athlete*' respectively. Of these the former, assuming usual concepts of *swimmer* and *athlete*, entails the latter.

The requirement of entailment between the existential closures of antecedent and focus domain must, in addition, be sensitive to the foci in the focus domain. Otherwise, the requirement would not be fulfilled in (3) since '*There's a young Mexican swimmer*' doesn't entail '*There's a young Canadian athlete*'. The effect of focus is captured by introducing the *Presuppositional Skeleton* of a phrase (Jackendoff 1972, Rooth 1985, and others). The presuppositional skeleton of a phrase is usually assumed to be computed basically by the standard semantic composition procedure, except that focussed phrases contribute something other than their lexical content to the skeleton. I adopt here Jackendoff's (1972) idea that the focussed constituents of a phrase XP contribute special focus-variables of the semantic type of their lexical content to the value of the presuppositional skeleton of XP, which are then bound by existential quantification. For the example (3) from above the focus semantic value of the focus domain is *There's an athlete of some nationality*., which is entailed by the existential closure of the antecedent. In this way, focus semantics explains the intonation of sentences like (4).

Intuitions about intonation, I claim, can provide us new insight into the internal structure of clause-internal semantic dependencies. In the remainder of this section I present a new discovery—namely that bound variable pronouns can optionally be focussed under certain conditions—that I believe can lead to such new insights. Consider first the examples in (4), which both have the same words and only differ in their intonation. The interpretation that is relevant in the following is the one where *his* is in both conjuncts dependent on the subject, as indicated by the connection lines. Since this interpretation is called the *sloppy reading* if the second pronoun is elided (Ross 1968), I use the term *sloppy reading* also to refer to the indicated interpretation of (4). The sloppy interpretation is available in both examples; in (4a), where the pronoun *his* in the second conjunct is focussed, and in (4b), the pronoun *his* is not stressed.⁶

⁵Examples like (i), where one occurrence of *his* must be focussed, while the other cannot be, demonstrate that the relevant concept of novelty must make reference to the position in the focus domain.

(i) If Kai's mother bought anybody's picture, his mother bought HIS picture.

antecedent
focus domain

⁶Given that the phonetic realization of focus is sometimes hard to detect (see Rooth 1996), the possibility of ellipsis with a sloppy reading in (i) is further evidence that in (4b) focus is really absent since generally the

- (4) a. Every boy likes his father and every teacher likes [HIS]_F father
 b. Every boy likes his father and every teacher likes his father

Another example with optional focus on a sloppy pronoun is (5).⁷

- (5) Every professor thinks that she's a genius, and every girl thinks that SHE/she's a genius.

Note that the presence of focus is related to the intended interpretation. This is particularly apparent, when the antecedent of the pronoun is a proper name, as illustrated in (6).⁸ (6a) with focus on the pronoun does not allow one of the interpretations of (6b) without focus on the pronoun, namely one where the pronoun in the second conjunct refers to *Kai*, just like the pronoun in the first conjunct. This interpretation I call *strict* interpretation like the analogous reading in the case of VP-ellipsis. In contrast to the strict reading, the sloppy reading is available in both (6a) and (6b), just like we already saw in (4) and (5).

- (6) a. Kai visited his grandparents and Riku visited [HIS]_F grandparents. (sloppy '*Riku's grandparents*', *strict '*Kai's grandparents*')
 b. Kai visited his grandparents and Riku visited his grandparents. (sloppy '*Riku's grandparents*', strict '*Kai's grandparents*')

The contrast between strict and sloppy readings can also be found in cases with quantificational antecedents; namely, when the second VP is in a subordinate clause as in (7). Again, we find that focus on the pronoun in (7a) blocks the strict interpretation, but permits the sloppy interpretation, while (7b) without focus on the pronoun allows both interpretations.

- (7) Every boy saw his father before the teacher saw [HIS]_F/his father. (sloppy '*the teacher's father*', *strict '*the boy's father*')

possibility of destressing is a prerequisite for ellipsis (Tancredi 1992, Rooth 1992, but Schwarz 1999)

- (i) Every boy likes his father and every teacher does (like his father).

⁷Orin Percus (p.c.) pointed out that in his judgement only examples with possessive pronouns like (4) allow the focus, while examples like (5) don't. The few other informants I have consulted about (5) so far agree with my indicated judgements. Percus's intuition might be related to the question what intermediate steps of the semantic composition can be relevant domains of focus semantics, though this idea would not readily explain the apparent variability in judgments.

⁸The same point could be made with the interpretation of (4a) where the pronoun *his* is referring to one discourse salient person.

- (7) Every boy saw his father before the teacher saw his father. (sloppy ‘*the teacher’s father*’, strict ‘*the boy’s father*’)

Finally there are examples where even a sloppy interpretation doesn’t seem to allow focus on a pronoun, which were first pointed out to me by Irene Heim (p.c.). Namely, this seems to be the case when the binder of the second pronoun is a quantifier whose range is a subset of the range of the quantifier binding the first pronoun. Consider the paradigm in (8). In (8a), it is ungrammatical to focus the second pronoun. This seems to be related to the fact that the quantifier binding the pronoun, *every young student*, ranges over a subset of the range of quantifier *every student* in the first conjunct: In (8b), where the second quantifier ranges over teachers focus is perfectly acceptable, just as in the examples considered above.⁹

- (8) a. *I expected every student to call his father, but only every YOUNG student called HIS father.
 b. I expected every student to call his father, and every TEACHER to call HIS father.

In sum, the facts laid out in the above discussion, all concerned examples of a pronominal in a distressed VP, where the antecedent of the distressed VP contained a corresponding pronoun and, furthermore, both pronominals had a potential antecedent. The generalization that emerges is that focus on the pronoun in the distressed VP is ungrammatical if either the pronoun is identical in reference to its antecedent (the strict reading) or when the pronoun is bound by a quantifier with a range that is a subset of the quantifier binding the corresponding pronoun in the antecedent VP. In other cases of sloppy readings, the pronoun can optionally be focussed.

I begin the account of the generalization with the explanation of why focus on the pronoun is always incompatible with the strict interpretation. What needs to be considered in this case are the conditions on the presence of focus marking—when focus is licensed. For ease of exposition, I adopt first a simplified version of Schwarzschild’s (1998) Avoid F condition, and discuss the full version below. Consider the paradigm in (9): When (9a) is available as antecedent, it’s not possible to focus *berries* as in (9b₂).

- (9) a. Mary picked berries at somebody’s farm.

⁹The examples in (ia) and (ib), where range of the second quantifier is not a subset, but does overlap with the range of the first quantifier, are difficult to obtain a firm judgement on and, therefore, I leave them for future research.

- (i) a. ??I expected every student to call his father, but instead every BOY called HIS father.
 b. ??I expected every young student to call his father, but in the end, every STUdent called HIS father.

b₁. Namely, she picked berries at SANDy's farm.

b₂. *Namely, she picked BERries at SANDy's farm.

Schwarzschild's (1998) account of (9) relies minimally on the assumption that at least an entire sentence must be a focus domain, and as such have an antecedent.¹⁰ Therefore, (10a) must be the antecedent of (10b). Recall from above that this requires that the existential closure presuppositional skeleton of (10b) must be entailed by the existential closure (10a). More intuitively, this means that (10b) must mean almost the same as (9a) except for the focussed parts of (9b). Schwarzschild observes that this requirement on (10b) cannot be satisfied without focus on *Sandy*, but it can be satisfied without focus on *berries* because *berries* repeats information from (10a) while *Sandy* provides different information from (9a). Based on similar considerations, Schwarzschild proposes that only the required focus is licensed. This can be captured by the condition in (10), which I call the weak Avoid F condition, since it's weaker than Schwarzschild's actual proposal.

- (10) (*Weak*) *Avoid F*: A Focus on XP is only licensed if there is a Focus Domain YP such that YP would not have an antecedent without the focus on XP.

The condition in (10) predicts strict readings to be absent in examples like (6a), repeated in (11). On the strict interpretation, *his* in both conjuncts refers to Kai. Since, there's no difference in meaning, there's no possible placement of focus domains such that the focus on *his* is required. Therefore, the focus on *his* is incompatible with the strict reading.

- (11) Kai visited his grandparents and Riku visited [HIS]_F grandparents. (sloppy '*Riku's grandparents*', *strict '*Kai's grandparents*')

The compatibility of focus with the sloppy reading in cases like (12) indicates that there must be a focus domain containing the pronoun which doesn't have an antecedent, unless the pronoun is focussed. Which constituent could be this focus domain? I show first that the entire clause cannot be the focus domain that requires the focus on the sloppy pronoun. The point is more easily made by looking at example (12) (repeated from (4a)) since the semantic dependency of *his* on the quantificational antecedent is uncontroversial in this case.

- (12) $\underbrace{\text{Every boy likes his father}}_{\text{antecedent}}$ and $\underbrace{\text{every TEACHER likes [HIS]}_F \text{ father}}_{\text{focus domain}}$

Consider now the focus value of the focus domain indicated in (12). There are two foci, on *his* and on *teacher*. The focus on *teacher* is required for identity of focus domain and

¹⁰In fact, Schwarzschild assumes many more focus domains, as discussed below.

antecedent in (12) since, otherwise, the mismatch of *boy* and *teacher* would also lead to a difference in meaning of the domains considered. The question is then whether in addition to the focus on *teacher* focus on the dependent pronoun *his* is required. To answer this question, look at the focus value the focus domain in (12) has if *his* isn't focussed. This is paraphrased in (13), and the antecedent indicated in (12), in fact, entails the truth of (13), since it claims that for *X* being the property of boyhood, every *X* likes his father. Therefore, the focus domain indicated in (12) cannot be licensing the focus on (12).

(13) There is a property *X* such that every $\overbrace{X \text{ likes the}}^{\text{focus domain}}$ *his* father.

Rooth (1992) first observes that the focus domain placement in (12) predicts a sloppy reading to be possible without requiring focus on the pronoun, as I just demonstrated. He argues that this consequence explains the possibility of a sloppy reading in (12) without focussing the pronoun. I think there are good reasons to adopt Rooth's proposal to explain the possible absence of focus in (12) (Sauerland 1998, chapter 4), but then licensing the focus on *his* in (13) is unexplained.

I propose that (12) contains an additional focus domain when the sloppy pronoun is focussed. Namely, a focus domain that contains the bound pronoun, but not the binder—in the following, I call this an *Intervening Focus Domain*. In fact, since as we saw, a focus domain that contains binder and bound pronoun never requires focus on the bound pronoun, an intervening focus domain must be involved in the licensing of the focus in (12). Consider, for example, the intervening focus domain indicated in (14).

(14) Every boy likes $\underbrace{\text{his father}}_{\text{antecedent}}$ and every teacher likes $\overbrace{\text{HIS father}}^{\text{focus domain}}$.

The intervening focus domain in (14) except for the bound pronoun is identical in meaning to the antecedent. If the meaning of the two instances of bound pronouns was the same as well, the presence of a focus on *his* would not be required, and thereby, not licensed. Therefore, I conclude that the meaning of the two occurrences of *his* in (14) must be different, as I claimed at the beginning of this section. This conclusion relies on the two independently established assumptions I introduced above; namely, that focus must be required (Schwarzschild 1998) by a difference in meaning between focus domain and any available antecedent and that for a focus domain that includes the binder focus on the bound pronoun cannot be required (Rooth 1992).

The last part of the empirical generalization that needs to be accounted for is the observation in (15) (repeated from (8a)). It seems to be the case that a sloppy reading is incompatible with a bound pronoun when the range of the binder is a subset of the range of the binder of the corresponding pronoun in the antecedent. If the account so far is correct, there are two reasons the focus on the sloppy pronoun in (15) could not be licensed: either an intervening focus domain is impossible in (15) or the bound pronoun in (15) doesn't

differ in meaning from the corresponding pronoun in the antecedent. At present, I don't have any evidence bearing on the choice between the two possibilities, and choose the latter for lack of an idea how to make the former precise. I come back on how to capture the latter idea in section 3.¹¹

- (15) *I expected every student to call his father, but only every YOUNG student called HIS father.

For the account of the optional focus in (13), I assume that the intervening focus domain is optionally possible: When the intervening domain is present, it forces focus on the bound variable, when it's absent, the pronoun must be destressed. In the remainder of this section, I point out that this account has implications for the theory of focus. As pointed out above, Schwarzschild (1998) doesn't propose the weak Avoid F condition in (10), but a stronger version that is, in effect, equivalent to (16).¹² While the weak condition in (10) minimizes focus only for a given placement of focus domains, the condition in (16) also involves a comparison amongst different placements of focus domains.¹³

- (16) *Strong Avoid F*: A focus on XP is only licensed if, on any placement of focus domains, there's none that requires less focus marking. Less focus marking is defined as either a smaller number of foci or smaller foci.

The optional focus on the bound variable pronoun in example (4a) is incompatible with the strong statement of Avoid F in (16): Since all possible placements of focus domains are considered, optionality is predicted only when the number of foci is the same for each of the options. A case where a focus is optionally present, however, is ruled out by (16). Therefore, (4a) is an argument for a weaker statement of Avoid F like the one in (10) (see Sauerland 1998 for more discussion).

2 Obligatorily Focussed Sloppy Pronouns

In the previous section, I proposed that, in examples like (4a) a sloppy pronoun is optionally focussed because a focus domain that intervenes between the pronoun and its binder is

¹¹I haven't been able to consult many informants on examples like (i) as continuation of (15) yet. To me it seems that the focus on *his* is licensed, which is predicted by the proposal in the text.

(i) ... every OLD student didn't call HIS father.

¹²Schwarzschild actually frames his discussion based on the assumption that focus domains and focus marking must be in complementary distribution: a constituent must be either a focus domain or a focus. While it's of course desirable to be able to predict the presence of focus marking from the distribution of focus domains or vice versa, it seems to me to be an open issue what the precise relationship between the two concepts is. For reasons of clarity, I use both concepts in the text.

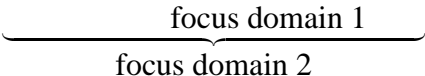
¹³Here, I assume the weak Avoid F condition in a form that is slightly different from (10) above. Namely, I assume that, for a fixed placement of focus domains, focus marking must be minimized in the sense of the definition in (16).

optionally possible. This account predicts that, if the intervening focus domain is obligatory, a sloppy pronoun must obligatorily be focussed. In this section, I argue that this prediction is indeed borne out.

To test the prediction, a case where a focus domain is obligatory must be considered. One case of an obligatory focus domain already noted in the previous section are complete sentences. However, in complete sentences bound pronouns must be bound, and therefore the prediction cannot be tested in this case.¹⁴ Schwarzschild (1998) argues, in effect, that also complex foci are obligatorily focus domains. Here, I use the term *Complex Focus* for focus marked constituents that consist of more than one word, where *word* could be understood as a potentially stress bearing unit with an independent semantic contribution. Schwarzschild’s argument for complex foci being focus domains relies on the observation that the placement of pitch accent within a complex focus is subject to the same principles as placement of pitch accent within a complete sentence is.

Example (17) illustrates Schwarzschild’s observation. (17) could be a dialog between two people. For our purposes, pitch placement in (17d) is important while the preceding sentences make various antecedents available. In addition, (17b) illustrates the pitch placement expected for (17d) if fewer antecedents were available.

- (17) a. A: Who cut the carrots?
- b. B: John didn’t. He SHREDDed green CABbage.
- c. A: Did Mary cut the carrots?
- d. B: No. Mary cut [[ChiNEse]_F cabbage]_F



As already observed in the previous section, complete sentences, and therefore (17d), must be focus domains. This domain is indicated as focus domain 2, that requires an antecedent. Since *Mary* and *cut* are destressed in (17d), the antecedent for focus domain 2 must be (17c).¹⁵ Since the object of *cut* differs between focus domain 2 and its antecedent, it must be focussed. Otherwise focus domain 2 wouldn’t match its antecedent. This shows that *Chinese cabbage* constitutes a complex focus. For similar reasons, *green cabbage* in (17b) also constitutes a complex focus. The remaining question is how pitch accent is placed within a complex focus. The difference between (17b) and (17d) shows that the pitch accent

¹⁴The argument here is reminiscent of the observation that *her* in the second conjunct in (i) must be focussed if the woman Bill likes is different from the one John likes. However, (i) doesn’t involve binding.

(i) John likes her and Bill likes HER.

¹⁵In fact, the antecedent of focus domain 2 could also be (17a), but the difference wouldn’t matter for the following discussion.

isn't uniformly placed on the head noun. In (18d), where *cabbage* isn't new information anymore, pitch accent falls on *Chinese*—just like in complete sentences, only the parts of a focus domain that contain new information can receive pitch accent. The assumption that a complex focus constitutes obligatorily a focus domain explains the difference between (17b) and (17d). For this focus domain (indicated as focus domain 1 in (17d)), no matching antecedent is available in (17b), hence both *green* and *cabbage* must be focussed and the main pitch accent is placed on the head noun *cabbage*. In (17d), focus domain 1 has the potential antecedent *green cabbage* from (17b). To match this antecedent, *cabbage* need not be focussed in (17d), and therefore must not be focussed because of Avoid F. *Chinese*, however, must be focussed, and therefore receives the pitch accent.

Now consider the example in (18), which is similar to (17), but the complex focus in (18d) contains a pronoun. The crucial judgement is whether the sloppy pronoun in (18d) requires focus.

- (18) a. A: Who cut the carrots?
 b. B: John didn't. He_i broke his_i right hand.
 c. A: Did Mary cut the carrots?
 d. B: No. *Mary_j cut [her_j LEFT hand]_F

 focus domain 1

 focus domain 2

All five informants I have consulted with about example (18) and some similar ones so far, have found a difference in status between (18d) and the alternatives (19d') and (19d'') in the direction indicated. In (19d') the pronoun is focussed, and the sloppy reading is available. (19d'') shows that a strict reading is available without focus on the pronoun.

- (19) d'. B: No. Mary_j cut [HER_j LEFT hand]_F
 d''. B: No. Mary_j cut [his_i/John_i's LEFT hand]_F.

How is the judgement in (18d) predicted by the account given so far? For reasons analogous to those applying in (17), the object of *cut* in (18d) must be focussed. Therefore, the object must also constitute a focus domain following Schwarzschild's reasoning here illustrated by (17) above—a focus domain that intervenes between the pronoun and its binder. This focus domain is indicated as focus domain 1 in (18d), and it requires an antecedent. If *hand* is destressed, the only matching antecedent to be considered is *his right hand* in (17b). The focus on *left* is certainly required for the antecedence relationship to hold between this potential antecedent and focus domain 1. But, as we see in (18d) focus on the sloppy pronoun is also required. This shows again that the sloppy pronoun

his in the antecedent and the sloppy pronoun *her* in the focus domain differ in meaning. The difference between (18d) and the examples of the previous section is that, in (18d), the intervening focus domain is obligatory. As predicted, focus on the sloppy pronoun is therefore required in (18d).

3 Variables or Combinators

The generalization the previous two sections established answers the question when one instance of a bound pronoun pro_2 has the same meaning as a preceding instance of a bound pronoun pro_1 . Namely, I showed that identity holds if and only if the range of the binder of pro_2 is a subset of the range of pro_1 . In effect, the meaning of two instances of a bound pronoun are different in most cases. This section develops the theoretical significance of this observation for the study of the semantic mechanism that creates dependencies. I claim that the result makes it possible to distinguish between two formal models of the dependency creating mechanism—variable binding and combinatorial logic—and argues in favor of variable binding. I first introduce combinatorial logic and show how the empirical generalization of the previous sections seems to my mind fundamentally at odds with the combinatorial logic mechanism of binding. Then I show that the variable binding mechanism can account for the same empirical generalization if certain restrictions on the use of indices are imposed.

Just like variable binding, combinatorial logic has originally been developed as a precise way to express mathematical ideas (Schönfinkel 1924, Curry 1930), where the main attraction of it has been the fact that dependencies can be expressed without the use of indexed variables. A number of people have proposed to utilize combinatorial logic as the formal model of semantic dependencies in linguistics (Szabolcsi 1987, Hepple 1990, 1992, Dowty 1992, Jacobson 1992, 1993, 1994, 1998a, 1998b). For the following discussion, I adopt the notational conventions of Curry and Feys (1958) and some ideas of Jacobson (1998b), but the argument against the combinatorial approach in linguistics applies to all its instantiations.

In combinatorial logic, bound pronouns are semantically vacuous. Following Jacobson (1998b), I assume that the interpretation of any bound pronoun is the identity function on the domain of individuals. Consider, for example, (20a), where *himself* is bound by *John*.

- (20) John likes himself.
 John W (likes $B_{\triangleright} id$)

I assume here that the meaning *likes* can be modelled as a unary function of type $\langle e, \langle e, t \rangle \rangle$ corresponding to a two place predicate from pairs of individuals into truth values. The meaning of the VP *likes himself* is formed out of the meaning of its part by composition of the two functions, indicated by the functor B_{\triangleright} . But, since composition of a function f with the identity function always yields f again, the meaning of the VP is again the two-place *like* function of type $\langle e, \langle e, t \rangle \rangle$. Therefore, the object argument position of *likes* is still

open, when the VP combines semantically with the subject. Binding of the object argument position is accomplished by, in a sense, unifying the subject and object argument positions and then applying the resulting function to the subject. For this unification of two argument positions, I adopt the *Duplicator* functor W defined as in (21).

(21) Wf is defined as $\lambda x.f(x)(x)$

In the example (21), W applied to the two-place VP-predicate *likes* yields a one-place predicate that could be paraphrased as *self-like*. This one-place predicate is then applied to the subject, and the resulting description of the meaning of (20) seems correct.

The main difference between the combinatorial treatment of dependencies, and the one using variables is that on the combinatorial treatment bound pronouns are semantically vacuous, and the argument positions they leave open are only filled when the antecedent is combined semantically with the constituent containing the bound pronoun. This applies in example (22) as well—the interpretation assigned to the VP *likes his mother* is a two-place predicate created by concatenating *like* and *father*. Then, the duplicator W applies creating a one-place function paraphrasable as *like self's mother*, and this is combined with the subject.

(22) Every boy likes his father and every teacher likes his father.
 every boy $W(\text{like } B_{\downarrow} \text{ father})$ and every teacher $W(\text{like } B_{\downarrow} \text{ father})$

How could the combinatorial approach capture the difference in meaning between two bound pronouns? The semantic representation in (22) shows that the VP-meaning in both conjuncts is exactly the same. In fact, if bound pronouns are taken only to mark unfilled argument positions, by necessity all bound pronouns are identical in meaning, since unfilled argument positions are not distinguished. Therefore, it seems that the main motivation of the combinatorial approach—that it doesn't use indexed variables—makes it impossible to have bound pronouns make different contributions to the meaning. The basic assumption of the combinatorial approach, that all pronouns mean the same, I believe cannot be maintained.

A possible amendment to the combinatorial approach one might pursue is to assume that different instances of bound pronouns carry different presuppositions with them. The idea would be that, for example, *his* in (23) contributes only an open argument position to the meaning, but adds the presupposition that this open position can only apply to boys and teachers respectively. Formally this could be represented by assuming that *his_{boy}* in (23) denotes the identity function restricted to the set of boys, while *his_{teacher}* denotes the identity function restricted to the set of teachers.

(23) Every boy likes his_{boy} father and every teacher likes his_{teacher} father.

I think this would be an interesting idea to pursue in more detail, and might ultimately be similar to the approach using indexed variables I develop below. The main problem that this idea would still have to face is to account for the optional absence of focus on the sloppy pronoun in an example like (23). Rooth’s (1992) approach, which was summarized following (12) above, cannot be applied, since without focus on the pronoun the focus value of the second conjunct in (23) would be that given in (24). But, the pronoun in (24) still carries the presupposition restricting it to the set of teachers, hence, (24) isn’t entailed by the first conjunct of (23).

(24) There’s a property X such that every X likes his_{teacher} father

Now consider the variables approach to dependencies. If pronouns correspond to indexed variables, two instances of bound pronouns can differ in the meaning, namely when their indices differ. Hence, the observation that bound pronouns differ in meaning can be represented on the variables approach. Look at the semantic representation of (25), which is repeated from (4a) above. For the antecedent and focus domain indicated in (25), I claim that the the antecedence relationship only holds if the pronoun *his* in the second conjunct is focussed.

(25) Every boy likes his father and every teacher likes HIS father
Every boy λx x likes x ’s father and every teacher λy y likes $[y]_F$ ’s father
 antecedent focus domain

The antecedent in (25) is different from the antecedents considered before in that it contains an unbound variable. It turns out that one way of applying the concept of entailment between antecedent and focus domain to this case that gets the desired result—namely, forces focus on the pronoun in the focus domain—is the following: Under any assignment of variables to individuals, the existential closure of the antecedent must entail the existential closure of the focus value of the focus domain under the same assignment (Heim 1997). If the pronoun in the focus domain is focussed, the antecedence relation is satisfied because for any x it’s true that, if someone likes x , someone likes somebody. However, if the pronoun in the focus domain isn’t focussed, the antecedence relation doesn’t hold in (25), since it’s not the case for all x and y that, if someone likes x , someone likes y . Hence, the focus on the bound variable in (25) is required.

In this way, indexed variables can be used to account for the presence of focus. However, the variables approach also doesn’t capture straightforwardly that focus on the bound pronoun isn’t possible in cases where the range of the binder is a subset of the range of the binder of the antecedent. In the generalization above, we observed that bound pronouns are only different in meaning when the ranges of the binders don’t overlap. Capturing this observation is possible on the variables approach, for example, by proposing correlations between the range of a binder and the index used in a dependency on the variables approach. At this point, I propose the condition in (26) to capture this effect, but obviously many

questions arise. Among them are: What if there are two potential antecedents of a QP? What explains the relationship between quantifier range and index?

- (26) The variable index introduced by a quantifier QP_1 must be the same as that introduced by an antecedent quantifier QP_2 in the preceding discourse if the range of QP_1 is a subset of the range of QP_2 . Otherwise the index introduced by QP_1 must be *new* (i.e. different from all indices already used in the discourse).

4 Conclusion

The main empirical discovery of this paper is optional focus in cases like (27), which I termed sloppy readings in analogy to the sloppy readings in examples with ellipsis. This is to my knowledge the first example of a truly optional focus, and has interesting implications for the theory of focus developed at the end of section 1, which received additional support from the findings in section 2.

- (27) Every boy likes his father and every teacher likes his/HIS father.

I argued that the possibility of focus in (27), also, sheds light onto the internal workings of clause-internal semantic dependencies and the semantic mechanism that creates them. Namely, it provides a fairly direct test whether the semantic content of two instances of bound pronouns means the same, because the contrastiveness requirement of focus requires a difference in meaning. The generalization I established in section 1 is that one instance of a bound pronoun has the same meaning as a preceding one if and only if the range of its binder is a subset of the range of the binder of the preceding one.

This result might in turn have an interesting theoretical consequence which I developed in section 3. Namely, it seems to distinguish between the two main formal models of the semantic mechanism creating dependencies: combinatorial logic and variable binding. I showed that the variable-free system of combinatorial logic, in principle, doesn't allow a semantic difference between two instances of a bound pronoun, and is therefore incompatible with the result. In a system that uses variables, however, examples like (27) can be analyzed as involving contrast between variables with different indices.

References

- Curry, Haskell B. 1930. Grundlagen der kombinatorischen Logik. *American Journal of Mathematics* 52.509–536.
- , and Robert Feys. 1958. *Combinatory Logic, Volume I*. Amsterdam: North-Holland.
- Dowty, David R. 1992. 'Variable-free' syntax, variable-binding syntax, the natural deduction Lambek calculus, and the crossover constraint. In *Proceedings of WCCFL 11*, 161–176. Stanford, California, Stanford University, Center for the Study of Language and Information.
- Heim, Irene. 1997. Predicates or formulas? Evidence from ellipsis. In *Proceedings of SALT VII*, ed. by Aaron Lawson and Eun Cho, 197–221. Ithaca, New York: CLC Publications.

- Hepple, Mark. 1990. *The Grammar and Processing of Order and Dependency: A Categorical Approach*. Ph.D. dissertation, University of Edinburgh, Scotland.
- . 1992. Command and domain constraints in categorial theory of binding. In *Proceedings of the Amsterdam Colloquium*, University of Amsterdam, The Netherlands.
- Jackendoff, Ray. 1972. *Semantic Interpretation in Generative Grammar*. Cambridge: MIT Press.
- Jacobson, Pauline. 1992. Antecedent contained deletion in a variable free semantics. In *Proceedings of SALT II*, 193–213. Columbus, Ohio State University, Working Papers in Linguistics.
- . 1993. Bach-Peters sentences in a variable-free semantics. In *Proceedings of the Eighth Amsterdam Colloquium*.
- . 1994. *i*-within-*i* effects in a variable free semantics and a categorial syntax. In *Proceedings of the Ninth Amsterdam Colloquium*. University of Amsterdam, The Netherlands.
- . 1998a. ACE and pied-piping: Evidence for a variable-free semantics. Presentation at SALT 8, MIT.
- . 1998b. Towards a variable-free semantics. *Linguistics and Philosophy*. (to appear).
- Partee, Barbara. 1973. Some structural analogies between tenses and pronouns. *Journal of Philosophy* 70.601–609.
- Percus, Orin. 1998. Some instructions for the worldly. In *Proceedings of WCCFL 17*, Stanford, California, CSLI. (to appear)
- Rooth, Mats. 1985. *Association with Focus*. Ph.D. dissertation, University of Massachusetts, Amherst.
- . 1992. Ellipsis redundancy and reduction redundancy. In *Proceedings of the Stuttgart Ellipsis Workshop*, ed. by Steve Berman and Arild Hestvik. Arbeitspapiere des Sonderforschungsbereichs 340, Bericht Nr. 29, IBM Germany, Heidelberg.
- . 1996. On the interface principles for intonational focus. In *Semantics and Linguistics Theory VI*, ed. by Teresa Galloway and Justin Spence, 202–226. Ithaca, CLC Publications.
- Ross, John R. 1968. *Constraints on Variables in Syntax*. Ph.D. dissertation, Massachusetts Institute of Technology, Cambridge.
- Sauerland, Uli. 1998. *The Meaning of Chains*. Ph.D. dissertation, Massachusetts Institute of Technology, Cambridge.
- Schönfinkel, M. 1924. Über die Bausteine der mathematischen Logik. *Mathematische Annalen* 92.305–316.
- Schwarz, Bernhard. 1999. Silent verb phrases as bound variables. Manuscript, University of Massachusetts, Amherst.
- Schwarzschild, Roger. 1998. Givenness and optimal focus. *Natural Language Semantics*. (to appear in revised form).
- Szabolcsi, Anna. 1987. Bound variables in syntax (are there any?). In *Proceedings of the Amsterdam Colloquium*, 331–351. University of Amsterdam, The Netherlands.
- Tancredi, Christopher. 1992. *Deletion, Deaccenting and Presupposition*. Ph.D. dissertation, Massachusetts Institute of Technology, Cambridge.