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Command and Domain Constraints in a Categorial Theory of Binding

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1 Introduction

This paper presents a categorial account of binding, which was first described in Hepple (1990).[1] The grammatical framework of the account is an extended version of the Lambek calculus. I will here address only cases where personal and reflexive pronouns are bound (i.e. excluding, for example, referential uses of personal pronouns).[2] The paper focusses particularly on two classes of constraint that are observed to limit the possibilities for binding, These constraints have received a considerable amount of attention in attempts to formulate accounts of binding, and have presented particular problems for categorial accounts. The two classes of constraint that concern us are: *command* constraints, which relate to asymmetries that are observed for which phrase positions may bind which others, and *domain* constraints, which involve requirements on the dominating phrases within which a pronoun's antecedent must either be present or absent.

In what follows, I first present a formulation of the Lambek calculus, before outlining the basis of the account of binding. Then, I show how the Lambek account may be adapted to appropriately characterise constraints on binding, addressing domain and command constraints in turn. The treatment of domain constraints involves extending the calculus with modal operators which may be used to specify 'linguistic boundaries'. The treatment of command constraints is based on adapting the insight of Montague Grammar work, which links grammatical hierarchy to argument order. Finally, the resulting approach is illustrated by applying it to the problem of long-distance reflexivisation in Icelandic, a phenomenon of particular interest because of its unusual locality behaviour.

2 Lambek calculus

In this section, I will introduce the Lambek calculus (Lambek 1958, 1961). I use a natural deduction formulation of the calculus (see Morrill et al. 1990; Barry et al. 1991). Natural deduction proofs proceed from a number of initial assumptions, some of which may be "discharged" or "withdrawn" during the course of the proof. For the product-free Lambek calculus, we require the inference rules shown in (1). The notation of a type with dots above it is used to designate a proof of that type. Assumptions are simply individual types, as licensed by the hypothesis rule. Undischarged assumptions are termed *hypotheses*. Note that in this formulation, each type in a proof is associated with a lambda expression, its *proof term* (shown to the right of a colon). The elimination rule /E states that a proof of A/B and a proof of B may be combined as shown to construct a proof of A. The introduction rule /I states that given a proof of A, we may discharge some hypothesis B within the body of the proof to construct a proof of A/B. Square brackets are used to indicate a discharged assumption. Note that there is a side condition on this rule, which is required to maintain the constituent order significance of the directional slash.

(1) Hypothesis rule: $\mathrm{A}{:}x$

Elimination rules:

$$\frac{\begin{matrix}\vdots & \vdots \\ \mathrm{A/B}{:}f & \mathrm{B}{:}x\end{matrix}}{\mathrm{A}{:}fx}/\mathrm{E} \qquad \frac{\begin{matrix}\vdots & \vdots \\ \mathrm{B}{:}x & \mathrm{A\backslash B}{:}f\end{matrix}}{\mathrm{A}{:}fx}\backslash\mathrm{E}$$

Introduction rules:

$$\frac{\begin{matrix}[\mathrm{B}{:}x]^{\mathrm{i}} \\ \vdots \\ \mathrm{A}{:}f\end{matrix}}{\mathrm{A/B}{:}\lambda x.f}/\mathrm{I}^{\mathrm{i}}$$

where B is the rightmost undischarged assumption in the proof of A

$$\frac{\begin{matrix}[\mathrm{B}{:}x]^{\mathrm{i}} \\ \vdots \\ \mathrm{A}{:}f\end{matrix}}{\mathrm{A\backslash B}{:}\lambda x.f}\backslash\mathrm{I}^{\mathrm{i}}$$

where B is the leftmost undischarged assumption in the proof of A

To demonstrate that some type combination $\mathrm{X_1,..,X_n} \Rightarrow \mathrm{X_0}$ is possible, a proof of $\mathrm{X_0}$ is given having hypotheses $\mathrm{X_1,..,X_n}$ (in that order) with zero or more discharged assumptions interspersed amongst them. The proof term for the conclusion of a proof expresses its meaning as a combination of the meanings of the proof's hypotheses, and the inference rules specify how this lambda expression is constructed. Each assumption has a unique variable for its proof term. The elimination and introduction rules correspond to semantic operations of functional application and abstraction, respectively. In general, proof terms are omitted to simplify presentation. The proof of the combination $\mathrm{a/b, b/c} \Rightarrow \mathrm{a/c}$ ("simple forward composition") in (2) illustrates this approach.

(2)

$$\frac{\dfrac{\mathrm{a/b}{:}x \quad \dfrac{\mathrm{b/c}{:}y \quad [\mathrm{c}{:}z]^{\mathrm{i}}}{\mathrm{b}{:}(y\,z)}/\mathrm{E}}{\mathrm{a}{:}(x\,(y\,z))}/\mathrm{E}}{\mathrm{a/c}{:}\lambda z.(x\,(y\,z))}/\mathrm{I}^{\mathrm{i}}$$

The availability of rules allowing introduction of slash connnectives in the Lambek calculus has the consequence that it allows great flexibility in the assignment of types to strings, which in turn allows considerable flexibility in the assignment of syntactic structure to sentences. Such flexibility (in this and certain other categorial approaches) has provided the basis for categorial accounts of a range of phenomena, including extraction and non-constituent coordination. Note that various categorial operations which are treated as primitive in other approaches are theorems of the Lambek calculus, for example, the composition and type-raising operations of Combinatory Categorial Grammar (Steedman, 1987; Szabolcsi, 1987),

Despite its appealing elegance and simplicity, the standard Lambek calculus is clearly inadequate as a linguistic framework, being unable to handle a broad range of phenomena. Various proposals have been made for dealing with these shortcomings by augmenting the basic calculus with a range of further operators whose logical behaviour is such as to allow description of some aspect of the linguistic data. We shall consider two extensions of the basic calculus before going on to address the treatment of binding. Some further extensions will be introduced in context later on.

The first extension is required in the treatment of extraction. I assume a treatment of extraction (deriving ultimately from proposals by Ades and Steedman, 1982) in which extracted items are given higher order types. For example, a relative pronoun might be (rel/(s/np)), a type which seeks a 'sentence lacking a noun phrase', in effect 'abstracting' over the missing NP in the extraction domain. Natural deduction proofs of such examples involve an additional assumption which appears in the place of the missing element, and which is later discharged in a slash introduction inference. However, given the side conditions on these introduction rules (see above), the basic calculus can only handle cases of extraction where the site of the missing element would be peripheral in the overall constituent from which it is missing. This problem can be solved using an idea borrowed from linear logic, where *structural modalities* are employed to allow controlled involvement of structural rules.[3] I shall employ an operator $\triangle$, which has the inference rules (3). (The $\triangle$I and $\triangle$E rules give behaviour for $\triangle$ somewhat like that of necessity in the modal logic S4. In practice, the rule $\triangle$I will not be required in this paper.) The $\triangle$P permutation rule has the effect of undermining the ordering of $\triangle$-marked types relative to other types in a proof.[4] It is convenient to use a 'derived' inference rule $(/\triangle)$I shown in (4), which is similar to /I, except that it lacks a side condition (since a $\triangle$-marked assumption could always move to right peripheral position within a subproof under some sequence of permutation steps, so as to meet the side condition on /I). A relative pronoun (rel/(s/$\triangle$np)) allows for extraction from non-peripheral positions, as illustrated in (5).

(3) Rules for $\triangle$:

$$\frac{\begin{array}{c}\vdots\\ \triangle\mathrm{A}{:}x\end{array}}{\mathrm{A}{:}x}\triangle\mathrm{E} \qquad \frac{\begin{array}{c}\vdots\\ \mathrm{A}{:}x\end{array}}{\triangle\mathrm{A}{:}x}\triangle\mathrm{I}\ \text{where each hypothesis in the proof of A is a }\triangle\text{-type} \qquad \frac{\begin{array}{cc}\vdots & \vdots\\ \mathrm{A}{:}x & \mathrm{B}{:}y\end{array}}{\mathrm{B}{:}y \quad \mathrm{A}{:}x}\triangle\mathrm{P}\ \text{where A or B is a }\triangle\text{-type}$$

(4) Derived inference rule $(/\triangle)$I:

$$\frac{\begin{array}{c}[\triangle\mathrm{B}{:}x]^{\mathrm{i}}\\ \vdots\\ \mathrm{A}{:}f\end{array}}{\mathrm{A}/\triangle\mathrm{B}{:}\lambda x.f}(/\triangle)\mathrm{I}^{\mathrm{i}}$$

(5)

$$\dfrac{\dfrac{\text{which}}{rel/(s/\triangle np)} \quad \dfrac{\dfrac{\dfrac{\text{Mary}}{np} \quad \dfrac{\dfrac{\dfrac{\text{gave}}{s\backslash np/pp/np} \quad \dfrac{[\triangle np]^{i}}{np}\triangle E}{s\backslash np/pp}/E \quad \dfrac{\dfrac{\text{to}}{pp/np} \quad \dfrac{\text{Bill}}{np}}{pp}/E}{s\backslash np}/E}{s}\backslash E}{s/\triangle np}(/\triangle)I^{i}}{rel}/E$$

The second extension is involved in the treatment of *locality* phenomena, such as island constraints on extraction and domain constraints on binding. Morrill (1989;1990) suggests that the basic Lambek calculus be augmented with an operator $\Box$ for handling locality constraints, which corresponds in its behaviour to a (S4-like) necessity operator. Hepple (1990) argues that Morrill's proposal is inadequate to deal with the observed complexities of locality phenomena, in that the single $\Box$ operator provides what is in effect a single notion of 'linguistic boundary'. Hepple (1990) develops Morrill's proposal by moving to a *polymodal* system, in which an indefinite number of interrelated modalities (notated by 'labelled boxes' $\boxed{a}$, $\boxed{b}$, ..., etc) can be defined. A full understanding of this system would require a discussion of the interpretation of types for the Lambek calculus, which is beyond the scope of the present paper (see Hepple (1990) for a more complete exposition). Suffice it to say here that the interpretation of types is handled in terms of sets of strings, which are all subsets of some overall 'language' of strings $\mathcal{L}$. The label within each box names a particular string set (or 'sublanguage') which is used in its definition. Interderivability between distinct boxes arises given the statement of the modal inference rules, shown in (6), and particularly the introduction rule $\Box$I, which refers to relations between defining string sets.[5]

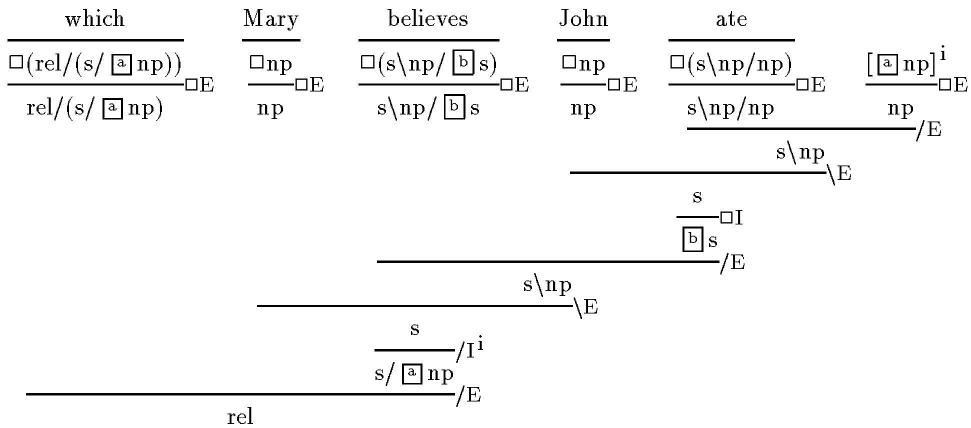
(6) Rules for $\boxed{\alpha}$:

$$\dfrac{\begin{matrix}\vdots\\ \boxed{\alpha}A\end{matrix}}{A}\Box E \qquad \dfrac{\begin{matrix}\vdots\\ A\end{matrix}}{\boxed{\beta}A}\Box I$$

where each path to a hypothesis leads to an independent subproof of some modal type $\boxed{\alpha}X$ such that $\mathcal{L}_\alpha \subseteq \mathcal{L}_\beta$

The polymodal boxes are used to specify linguistic boundaries. In particular, a functor of the form $X/\boxed{\alpha}Y$ (i.e. which seeks a modal argument) specifies that its argument constituent is potentially an enclosed domain. For example, a sentence complement verb such as *believes* might have a type: $s\backslash np/\boxed{a}s$ (for some modality $\boxed{a}$). This approach requires that lexical items must be to some extent modal, to allow modal constituents (such as $\boxed{a}s$) to be derived from them. For this purpose, I assume a sublanguage $\mathcal{L}_*$, whose modality is notated by the empty box $\Box$, and which is required to be the outermost type-forming operator of all lexical types (i.e. all lexical types are of the form $\Box$X). Since we want lexical types to be able to appear embedded under any modal domain, the sublanguage $\mathcal{L}_*$ is assumed to be a subset of all the other modality defining sublanguages used. Some possible lexical types within this system are: $\Box$np (noun phrase), $\Box$(s\np/np) (transitive verb), and $\Box$(s\np/$\boxed{\text{a}}$s) (sentence embedding verb). The basic idea for handling island constraints with this system is based around the interrelation of the modalities used in specifying modal boundaries and the types of extracted items. This is illustrated by the following example involving relativisation from an embedded clause (which omits the $\triangle$ operator to simplify):

(7)



Although this proof has been drawn as running through to completion, it is only in fact correct if the $\Box$I rule has been correctly applied. In line with the remarks above, we know that $\mathcal{L}_* \subseteq \mathcal{L}_{\text{a}}$ and $\mathcal{L}_* \subseteq \mathcal{L}_{\text{b}}$, and hence the proof is correct just in case $\mathcal{L}_{\text{a}} \subseteq \mathcal{L}_{\text{b}}$. In this way, the grammar writer can specify the sensitivity of processes like movement to particular linguistic boundaries, by the choice of modalities in constructing lexical types. Hepple (1990) discusses this account in more detail in relation to the treatment of island constraints.

3 Binding: the basic method

I will next present the basic method of the account of binding. I treat reflexives and bound pronouns as being semantically identity functions over individuals (i.e. having lambda semantics $\lambda x.x$).[6] The syntactic type of such pronouns is (in the most basic instance) np/$\ominus$np. This type contains an unfamiliar operator $\ominus$, but if we ignore its presence for the moment, we can see that the syntactic type is also essentially an identity function. This type for bound pronouns serves to introduce an argument position which can be co-bound with some other argument position, and, given the identity semantics, binding the pronoun's argument is equivalent to binding the argument position that the pronoun itself occupies. The operator $\ominus$ serves to identify the pronoun's argument as one that is available for binding, and also prevents the pronoun incorrectly taking a lexical NP as argument (e.g. giving **himself John* as a NP). I shall not give any inference rules for $\ominus$ here, making it effectively a "dead" operator.[7] Hence, $\ominus$ cannot be introduced or eliminated in syntax, and so $\ominus$ occurrences must originate lexically, with the types of anaphors and bindable pronouns.

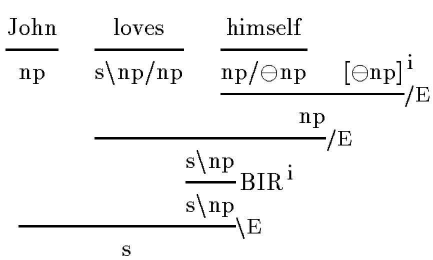
Binding is effected by the Binding Interpretation Rule (BIR), shown in (8). The BIR discharges a hypothesis $\ominus$B within the proof(which must correspond to a bindable pronoun's argument since only such pronouns introduce $\ominus$ operators), but does not change the proof's conclusion type. In the semantics of the result constituent, the lambda operator binds two instances of the variable v (since v already appears as a subterm of f) and so co-binds the pronoun's argument with the first argument sought by the main functor of the proof. Note that the link between the types of the discharged assumption and the argument sought by the proof's conclusion type (i.e. types B and $\ominus$B) allows a pronoun to determine the type of its binding argument (e.g a pronoun np/$\ominus$np requires a NP binder).

(8) Binding Interpretation Rule (BIR):

$$\begin{array}{c} [\ominus\mathrm{B}{:}x]^{\mathrm{i}} \\ \vdots \\ \dfrac{\mathrm{C}{:}f}{\mathrm{C}{:}\lambda x.fx}\,\mathrm{BIR}^{\mathrm{i}} \end{array} \qquad \text{where C is A\\B or A/B}$$

The BIR's use is illustrated in (9). This proof assigns the meaning (10a), which reduces to (10b) (since himself$'$ = $\lambda x.x$).

(9)



(10) a. (λv.loves$'$ (himself$'$ v) v) john$'$

b. (loves$'$ john$'$ john$'$)

4 Domain constraints on binding

We shall next consider this account in relation to locality constraints on binding. In the case of reflexives, locality constraints typically take the form that the binder of the reflexive must occur inside of some specified domain. Such limitations can be readily addressed within an account that employs the polymodal system for specifying linguistic boundaries described earlier. For example, consider the following attempt to derive the example **Mary$_i$ thinks John loves herself$_i$*, using anaphor type $\Box$(np/$\ominus$np):

(11)

$$\dfrac{\dfrac{\text{Mary}}{\Box np}}{np}\Box E \qquad \dfrac{\dfrac{\text{thinks}}{\Box(s\backslash np/\boxed{b}s)}}{s\backslash np/\boxed{b}s}\Box E$$

$$\dfrac{\dfrac{\dfrac{\dfrac{\text{John}}{\Box np}}{np}\Box E \quad \dfrac{\dfrac{\dfrac{\text{loves}}{\Box(s\backslash np/np)}}{s\backslash np/np}\Box E \quad \dfrac{\dfrac{\dfrac{\text{herself}}{\Box(np/\ominus np)}}{np/\ominus np}\Box E \quad \ominus np}{np}/E}{s\backslash np}/E}{s}\backslash E}{\boxed{b}s}\Box I\ ***$$

To complete this proof, the string *John loves herself* must be derived as a modal clause. However, the subproof includes an undischarged assumption $\ominus$np, corresponding to the argument of the reflexive. (Note that to get the intended reading, the BIR would need to apply at a later stage in the proof.) Since this assumption is not $\Box$-modal, the side condition on the box introduction rule $\Box$I is not met, and so the proof cannot be continued. Thus, with this reflexive type, a reflexive occurring within a modal domain must also be bound within this domain.

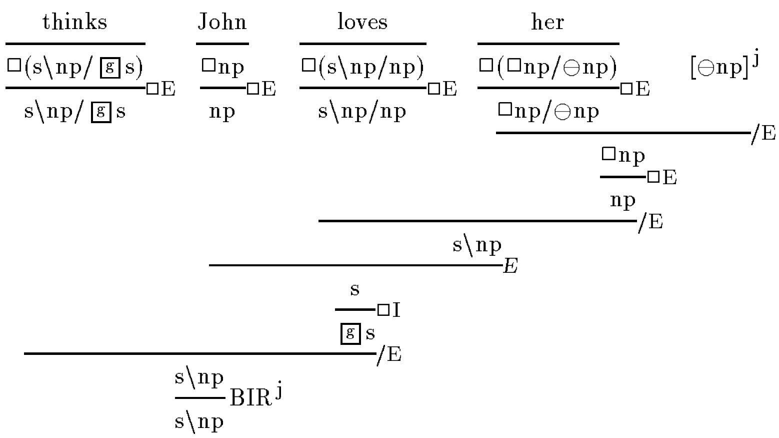
However, the possibility arises for assigning types to bindable pronouns that allow binding outside the minimal modal domain. Consider the possible pronoun type $\Box(\boxed{\alpha}np/\ominus np)$, and the subproof (12) based on it:

(12)

$$\dfrac{\dfrac{\dfrac{\Box(\boxed{\alpha}np/\ominus np)}{\boxed{\alpha}np/\ominus np}\Box E \quad \ominus np}{\boxed{\alpha}np}/E}{np}\Box E$$

Here, the pronoun has combined with the additional hypothesis corresponding to its argument, giving an (independent) subproof of the modal type $\boxed{\alpha}$np. Such a subproof *could* appear embedded under a modal domain (say, $\boxed{\beta}$), just in case the modality $\boxed{\alpha}$ licenses box introduction for the relevant domain modality (i.e. if $\mathcal{L}_\alpha \subseteq \mathcal{L}_\beta$). The $\ominus$ assumption could then be discharged at a later stage so that the pronoun was bound from outside of its immediate modal domain.

Consider the case of personal pronouns in syntactically bound uses, as for example in *Every girl$_i$ thinks John loves her$_i$*. Personal pronouns are not required to be bound *within* any particular domain. In the present account, such behaviour can be allowed by assigning them a type such as $\Box(\Box np/\ominus np)$, where the value subtype np is marked with the modality $\Box$ (whose defining language $\mathcal{L}_\emptyset$ is assumed to be a subset of all the other defining languages used). The presence of this $\Box$ allows pronouns bearing this type to be syntactically bound from outside of *any* modal domain. A proof for the VP of *Every girl$_i$ thinks John loves her$_i$* is shown in (13). This proof assigns a reading which simplifies to the expression in (14).

(13) 

(14) λv.thinks′ (loves′ v john′) v

However, the locality behaviour of personal pronouns is generally deemed to have a second aspect, involving requirements on *disjoint reference*, exemplified by the unacceptable *$John_i$ loves him_i*. I follow Dowty (1980) and Reinhart (1983) in assuming that such disjoint reference behaviour should receive a pragmatic explanation. By this view, the coreferential reading of *he likes him* is syntactically possible but disfavoured pragmatically because the sentence is ambiguous and the same meaning can be unambiguously expressed by *he likes himself*.[8]

Later in the paper, I will return to the issue of locality constraints on binding, addressing the phenomenon of long distance reflexivisation in Icelandic, and showing how it can be handled within this framework.

5 Command constraints on binding

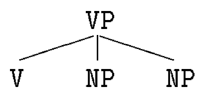
Certain asymmetries in the possibilities for binding, for example that subjects may bind objects but not vice versa, have been widely explained in terms of *c-command*, particularly in Goverment and Binding work. c-command is a condition on phrase-structure configurations, essentially requiring that a binder must occur in a hierarchically superior position to the bound element. An alternative approach is possible in approaches such as Montague Grammar, where order of subcategorisation is taken to encode relative obliqueness, and has been used in place of phrase-structure as a basis for defining grammatical relations (Dowty, 1982). For example, a notion *F-command* has been used (Bach & Partee, 1980; Chierchia, 1988), which is stated in terms of function-argument structure, and which is such that an argument of a functor F-commands the 'earlier' (and therefore more oblique) arguments of the same functor and their subconstituents. For example, in the type (((X/A)/B)/C), argument A F-commands B and C, whilst B F-commands only C. A related approach is taken in Head-driven Phrase Structure Grammar (Pollard & Sag, 1987; 1990), where heads, though not strictly functional, display explicit ordered subcategorisation which encodes obliqueness. Here, an *o-command* relation is employed, which is similar to F-command but stated purely in terms of order of subcategorisation and obliqueness, rather than function-argument structure.

Chierchia (1988) notes one advantage of F-command is that it correctly predicts the possibilities (15) for binding between the objects of double object constructions (since the first object is taken to be less oblique than the second), whereas c-command fails to predict the ungrammaticality of (15b) under the widely assumed structure shown in (16a). Barss and Lasnik (1986) also note this problem, and consider in addition the alternative structure in (15b), which fares even worse in predicting precisely the converse of the observed grammaticality/ungrammaticality for the examples in (15).

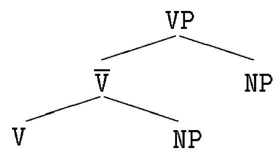
(15) a. Mary showed John_i himself_i

b. *Mary showed himself_i John_i

(16) a.



b.



As a basis for handling command constraints within our Lambek framework, we might also allow argument order to encode relative obliqueness. This move, however, presents some difficulties. Firstly, a problem arises because the Lambek calculus is a highly flexible categorial system, and allows type transformations which may radically alter the structure of types, for example x/y\z ⇒ x\z/y where two counterdirectional arguments of a function are reordered. Clearly, such flexibility threatens the use of argument order to encode relative obliqueness. This problem can be avoided by adopting two additional connectives, ø and ⦸, which have elimination rules just like those for / and \, but have *no introduction rules.* This lack of introduction rules means that occurrences of these connectives cannot be created in syntax, and gives an asymmetric relation between these new connectives and their corresponding standard connectives, e.g. it is possible to 'convert' a ø into a /, as in xøy ⇒ x/y, but the converse *(x/y ⇒ xøy) is not possible. Hence, occurrences of these connectives must originate in the lexicon and functions constructed with them must exhibit lexically given argument order. These connectives are used to specify *primitive subcategorisation*, i.e. lexically given functional structure, where argument order encodes obliqueness.

Secondly, problems arise with respect to the treatment of word order, The Lambek calculus, like various other categorial systems, allows only the use of concatenation for combining the strings associated with types that are combined. When combined with an assumption that argument order should encode relative obliqueness, this characteristic gives rise to some incorrect predictions about word order. For example, consider the sentence *John gave a book to Mary*, where *to Mary* is the verb's most oblique complement, and hence should be the *first* argument of the verb's functional type. But then, given the use of just concatenation for combining strings, *to Mary* should appear next to *gave* in the observed word order. These problems are avoided in Montague Grammar by the use of non-concatenative operations for combining strings, most importantly *wrapping*.

Various 'wrap simulation' methods have been proposed within 'concatenative' categorial frameworks as a means for allowing the Montagovian treatment of grammatical relations to be adopted (e.g. Szabolcsi 1987; Jacobson 1987; Kang 1988). Jacobson (1987) suggests a method which incorporates a view that standard English word order involves verb movement. I will here outline a Lambek 'wrap simulation' approach, proposed in Hepple (1990), which also incorporates this idea. A role for verb movement in English word order has also been suggested in some non-categorial approaches (e.g. Larson, 1988; Koster, 1988), in part to avoid problems arising in the cases for which Montague Grammar uses wrapping.

The account of word order to be described factors apart the specification of a head's position from the specification of the order of its complements. Certain phenomena suggest the appropriateness of this separation, for example the Verb Second behaviour of Germanic languages (where a verb may appear in radically different positions in different clauses without there being any concomitant change in the order of its complements). In the new approach, word order results from the interaction of three factors: (i) the argument order of a head's functional type (corresponding to obliqueness), (ii) the directionality of each argument, (iii) a lexical process of *Head Location*, which determines the position of the head relative to its complements. Factors (i) and (ii) together determine the linear order of a head's complements, and would also determine the position of the head were it not for the involvement of factor (iii).

This approach requires that we adopt a non-standard view of the categorial lexicon, in which lexical type assignments are built up over several stages, with only the 'end product' of this process being available to syntax. This notion of 'stages in construction' is handled by allowing the lexicon to consist of a number of distinct 'compartments', where the types assigned to any word may differ in different compartments. A designated 'final' compartment specifies the type assignments that are made available to syntax, all other compartments being invisible to syntax. Type assignments in different compartments are related by lexical rules. Certain compartments specify *initial* type assignments (i.e. ones not resulting from the operation of a lexical rule).

The process of Head Location is effected by a lexical rule (whose input and output types I shall refer to as *prelocation* and *located* head types, respectively), and employs the general approach to extraction outlined above. A head having prelocation type H can be allowed to occur left peripherally in phrases of type X by giving it a lexical type $X/(X/\triangle H)$. This type-change is essentially an instance of type-raising, although not a theorem of the syntactic calculus. The Head Location rule for English verbs is shown in (17), where vp abbreviates possible VP types of English (i.e. types $s\backslash A$, where A is any subject type), and vpϕ stands for any type vp or function into vp. The located types produced by the rule only allow the verb to appear to the left of its own VP projection, not those of any dominating verbs, because, firstly, the 'movement' effected by the rule is bounded, and secondly, the verb must appear left peripherally to some VP projection bearing the same features for tense etc as the verb's prelocation type (since the three occurrences of vp in the output type are identical tothe vp subtype of the input). These conditions can only be satisfied when the verb appears beside its own VP projection.

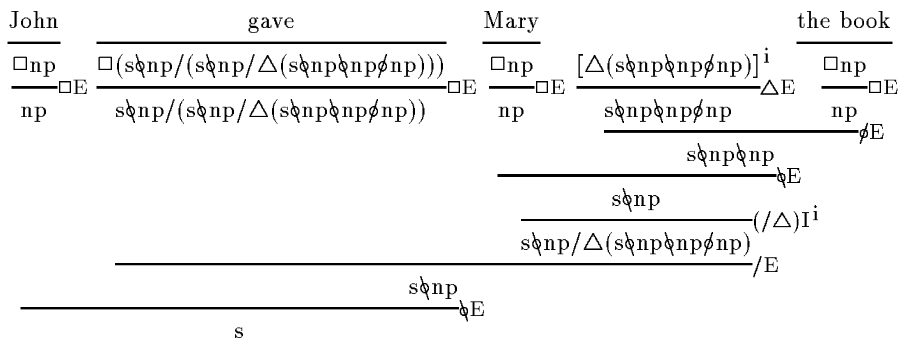
(17) English Verb Location:

$$\mathrm{vp}\phi{:}f \Rightarrow \mathrm{vp}/(\mathrm{vp}/\triangle(\mathrm{vp}\phi)){:}\lambda g.gf$$

Some verbs are shown in (18) with a prelocation type and the final lexical type assignment that it gives rise to following Head Movement and a final step adding an outermost □. In the prelocation types, first objects have been assigned leftward directionality, and second objects rightward directionality. See Hepple (1990) for discussion of how directionality determines complement order in this approach, and how these directionalities for first and second arguments are arrived at. The derivation (19) illustrates this view of word order.

(18)	eat	s⍀np⍀np	□(s⍀np/(s⍀np/△(s⍀np⍀np)))
	gave	s⍀np⍀np⌿np	□(s⍀np/(s⍀np/△(s⍀np⍀np⌿np)))
	put	s⍀np⍀np⌿pp	□(s⍀np/(s⍀np/△(s⍀np⍀np⌿pp)))

(19)



The approach to handling word order and subcategorisation just outlined has the characteristic that there is a stage in the lexicon at which the type assigned to a verb (or other head) is one whose argument order encodes relative obliqueness. Hepple (1990) shows how this characteristic allows relation changing phenomena to be handled by lexical rules, modifying proposals from Montague Grammar (e.g. Bach, 1980; Dowty, 1982). The final lexical type assignments of this approach, however, do not have an argument order that corresponds to relative obliqueness, being instead simply raised types produced via Head Location. Note though that the prelocated type of a head appears as a subtype of the final lexical type assignment that derives from it, and so the information of relative obliqueness encoded by the prelocation type is at least present. As we shall see next, in relation to the treatment of binding, this obliqueness information is still available from the final lexical type assignment to be exploited in the syntactic domain. To ensure that binding possibilities accord with an obliqueness constraint, we need only modify the BIR as follows:

(20) Binding Interpretation Rule (BIR):

$$\begin{array}{c} [\ominus B{:}x]^{i} \\ \vdots \\ \dfrac{C{:}f}{C{:}\lambda x.fx}\,\text{BIR}^{i} \end{array} \qquad \text{where C is } A\not\backslash B \text{ or } A\not/ B$$

Observe that the only difference between this version of the rule and that given earlier is that now the rule applies to proofs of functional types whose principal connective is one of the primitive subcategorisation slashes $\not/$ or $\not\backslash$. It follows that the next argument sought by functional type of the proof must be less oblique than any argument with which the functor has already combined. Since the anaphor must already have combined with the functor at the stage when the BIR applies, the anaphor must appear as, or as a subpart of, a more oblique argument of the functor than the argument that serves as binder. Hence, binding obeys an obliqueness requirement as with F-command and o-command. Note that unlike Pollard and Sag's account, where o-command is stated as a *constraint* on well-formed binding relations, the command characteristic of binding relations in the present approach emerges directly from the fact that verb types encode obliqueness information and from the statement of the BIR.

The approach is illustrated in (21), which shows a derivation for the VP *showed Mary$_i$ herself$_i$*, with binding between first and second objects. No proof is possible for the converse binding **showed herself$_i$ Mary$_i$*.

(21)

$$\dfrac{\text{showed}}{\Box(s\not\backslash np/(s\not\backslash np/\triangle(s\not\backslash np\not\backslash np\not/ np)))}\qquad \dfrac{\text{Mary}}{\Box np}\qquad \dfrac{\text{herself}}{\Box(np/\ominus np)}$$

$$\dfrac{\Box(s\not\backslash np/(s\not\backslash np/\triangle(s\not\backslash np\not\backslash np\not/ np)))}{s\not\backslash np/(s\not\backslash np/\triangle(s\not\backslash np\not\backslash np\not/ np))}\,\Box E \qquad \dfrac{\Box np}{np}\,\Box E \qquad \dfrac{[\triangle(s\not\backslash np\not\backslash np\not/ np)]^{j}}{s\not\backslash np\not\backslash np\not/ np}\,\triangle E \qquad \dfrac{\Box(np/\ominus np)}{np/\ominus np}\,\Box E \quad [\ominus np]^{i}$$

$$\dfrac{np/\ominus np \qquad [\ominus np]^{i}}{np}\,/E$$

$$\dfrac{s\not\backslash np\not\backslash np\not/ np \qquad np}{s\not\backslash np\not\backslash np}\,\not/ E$$

$$\dfrac{s\not\backslash np\not\backslash np}{s\not\backslash np\not\backslash np}\,\text{BIR}^{i}$$

$$\dfrac{np \qquad s\not\backslash np\not\backslash np}{s\not\backslash np}\,\not\backslash E$$

$$\dfrac{s\not\backslash np}{s\not\backslash np/\triangle(s\not\backslash np\not\backslash np\not/ np)}\,(/\triangle)I^{j}$$

$$\dfrac{s\not\backslash np/(s\not\backslash np/\triangle(s\not\backslash np\not\backslash np\not/ np)) \qquad s\not\backslash np/\triangle(s\not\backslash np\not\backslash np\not/ np)}{s\not\backslash np}\,/E$$

Examining this proof, it is possible to see why the obliqueness information of the prelocation type can still be exploited after Head Location. Observe that the prelocation type of the verb *does* participate within the proof, appearing as an additional hypothesis that is later dicharged.

6 Long distance reflexivisation in Icelandic

In this section, we consider the phenomenon of long distance reflexivisation in Icelandic, which is of interest because of its unusual locality behaviour. I will show that this unusual behaviour can be straightforwardly handled within the framework described above, most importantly by exploiting the polymodal treatment of domain constraints.

The core data concerning Icelandic long distance reflexivisation (LDR) is described by Thrainsson (1976). Icelandic reflexivisation is in general clause bounded, but under certain conditions unbounded or long distance reflexivisation is possible. Firstly, Icelandic LDR is subject oriented, i.e. only subject phrases are possible binders. Secondly, the possibility of LDR is dependent upon the presence of subjunctive mood. LDR arises only when the reflexive appears in a complement possessing subjunctive mood, as shown by the following pair of sentences:

(22) a. *Jón$_i$ veit aδ María elskar sig$_i$
Jon$_i$ knows that Maria loves(I) REFL$_i$

b. Jón$_i$ segir aδ María elski sig$_i$
Jon$_i$ says that Maria loves(S) REFL$_i$

(*I* and *S* in the glosses of these examples indicate a verb in indicative or subjunctive mood, respectively.) In (22a), where the embedded clause has indicative mood, the reflexive cannot be bound by the matrix subject. In (22b), the embedded clause is in subjunctive mood, and long binding by the matrix subject is allowed. In example (23), any of the the several subjects may act as antecedent, showing that binding may be made across any number of clause boundaries provided that the intervening clauses are all in subjunctive mood. Interestingly, the clause whose subject acts as binder does not itself need to be in subjunctive mood, only those embedded beneath it.

(23) Jón$_i$ segir aδ María$_j$ telji aδ Haraldur$_k$ vilji aδ Billi$_l$ heimsæki sig$_{i/j/k/l}$
Jon says that Maria believes(S) that Harold wants(S) that Billy visits(S) REFL

Subjunctive mood in Icelandic is introduced by particular items, such as subordinating conjunctions (e.g. *nema* 'unless' and *ef* 'if') and nonfactive verbs. For example, a nonfactive verb such as *segir* ('say') may introduce subjunctive mood, whereas a factive verb like *víta* ('know') may not, the latter generally taking an indicative complement. However, what has been called a *domino effect* is observed (Thrainsson, 1976) in which subjunctive mood introduced onto some complement may be propagated down through embedded complements, where subjunctive mood might not otherwise appear. In (23), the verb *segir* introduces the subjunctive mood of its complement, from whence subjunctive 'trickles down' to the clauses embedded beneath. I shall assume a simple lexical treatment of this 'domino effect', which is based on a generalisation about the distribution of the [+subjunctive] feature on lexical types, which can be stated as the following 'licensing condition', governing type assignment in the lexicon.

(24) Domino Effect Condition:

Any functor that is itself marked as [+subjunctive] may specify [+subjunctive] on any of its complements.

This condition means that there is no limitation on the 'downward transmission' of the [+subjunctive] feature, with the consequence that the [subjunctive] feature may be specified on many constituents where it has no morphological realisation.

Let us next consider how the core facts about Icelandic LDR may be handled in the approach outlined above. The subject orientation characteristic may be handled by adopting a modified version of the BIR which is further restricted as to the functional type of proofs to which it may apply, e.g. if the BIR could apply only to proofs of VP types, then only clausal subjects would be possible binders. In fact, the relevant notion of 'subject' for Icelandic LDR is broader than this, including possessive NPs. The following version of the BIR allows for both of these kinds of antecedent subject (recall that the type of the binding argument is determined by the type assigned to the reflexive, and so does not need to be limited by the binding rule).

(25) Binding Interpretation Rule (BIR):

$$\dfrac{\begin{array}{c}[\ominus \mathrm{B}{:}x]^{\mathrm{i}}\\ \vdots\\ \mathrm{C}{:}f\end{array}}{\mathrm{C}{:}\lambda x.fx}\,\mathrm{BIR}^{\mathrm{i}} \qquad \text{where C is } \mathrm{A}\not\backslash\mathrm{B} \text{ or } \mathrm{A}\not/\mathrm{B},\ \mathrm{A} \in \{\mathrm{s},\mathrm{np}\}$$

I assume a type $\Box(\boxed{\scriptstyle\mathrm{u}}\,\mathrm{np}/\ominus\mathrm{np})$ for long distance reflexives. Note that the value subtype of this type is marked with a modality $\boxed{\scriptstyle\mathrm{u}}$, whose presence, as we saw earlier, will make syntactic binding insensitive to the presence of any modal boundaries with a modality $\boxed{\scriptstyle\alpha}$ such that $\mathcal{L}_{\mathrm{u}} \subseteq \mathcal{L}_{\alpha}$. The core data of can consequently be handled simply by including the condition (26) to constrain the possibilities for lexical type assignment.

(26) Subjunctive Boundaries Condition:

where a lexical functor seeks a complement of type $\boxed{\scriptstyle\alpha}\,\mathrm{X}$, then:
$\mathcal{L}_{\mathrm{u}} \subseteq \mathcal{L}_{\alpha}$ holds *if and only if* the type X is marked [+subjunctive]

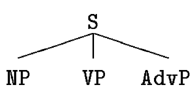
This condition has the consequence that modal boundaries marked on [+subjunctive] complements do not present barriers to binding of LD reflexives, and, since the requirement is biconditional, binding of LD reflexives is blocked by modal boundaries marked on any complement that is not [+subjunctive]. The condition is insensitive to the origin of the [+subjunctive] marking, and so its operation interacts appropriately with that of the Domino Effect condition to allow long binding even where subjunctive mood is present only due to the domino effect. Note that because the Subjunctive Boundaries Condition refers only to the featural status of the argument of the functor, rather than the functor itself, the approach accounts quite straightforwardly for the perhaps otherwise puzzling characteristic of Icelandic LDR, that the mood of the clause in which the *antecedent* appears is irrelevant to the possibility of LDR.

We shall next briefly discuss a possible counterargument to this account. The above treatment of Icelandic LDR does not differ in its essential view of what is important in determining binding possibilities from the account as it was developed in relation to English, i.e. an antecedent must o-command the anaphor, and no 'blocking' boundaries may intervene between the two. Maling (1984) argues that c-command is irrelevant for Icelandic LDR, but these arguments apply also against o-command, and so warrant our attention. Maling's principal counterexamples (first noted by Thrainsson, 1976) involve the fact that a matrix subject may not bind a reflexive occurring in certain adverbial clauses, e.g. (27a,b), where subjunctive is present and where c-command holds under the structure that Maling assumes, shown in (28).

(27) a. *Jón$_i$ yrδi glaδur ef Sigga byδi sér$_i$
John$_i$ would-be(S) glad if Sigga invited(S) REFL$_i$

b. *Jón$_i$ kemu ekki nema Sigga bjóδi sér$_i$
John$_i$ comes(I) not unless Sigga invites(S) REFL$_i$

(28)



Clearly, the status of such cases as counterexamples rests on the correctness of the structure that Maling assumes. Approaching these examples from a categorial perspective, where a central assumption is that syntactic structure is essentially just a refinement of semantic 'structure', we would by default expect a type such as s\s for an adverbial clause like *nema Sigga bjóδi sér*$_i$ (*unless Sigga invites(S) REFL*) since it semantically relates *propositions* rather than *predicates*. With this type for the adverbial, o-command does not hold and the impossibility of binding is expected. Note that binding is possible in cases involving "phrasal" rather than "sentential" adverbials, e.g. (29). Again on a semantic basis, we would expect a 'predicate modifying' type such as (s⧹np)\(s⧹np) for the adverbial, and given this type the subject argument *does* o-command the anaphor inside the adverbial, correctly predicting the grammaticality of binding.

(29) Jón$_i$ kemur ekki án konu sinnar$_i$/*hans$_i$
Joh comes not without wife(G) REFL$_i$/*his[−refl]$_i$
'John won't come without his wife'

Let me close with a few remarks about the significance of this account of Icelandic LDR. Because of its unusual locality behaviour, and because c-command has been argued irrelevant to it, Iceland LDR has been seen as belonging to a separate subclass of cases in which certain reflexives may show discourse-governed coreferential behaviour. The present account not only demonstrates that it is possible to assimilate the treatment of these LD reflexives to the treatment of ordinary bound reflexives and pronouns, but also, by its combination of categorial structures with a command condition, serves to explain some otherwise mysterious aspects of the data, e.g. the asymmetry between phrasal and sentential adverbs. In so far as it successfully demonstrates that we must acknowledge the existence of non-local syntactic binding of reflexives, the account suggests that the demarcation between the possibilities for bound and coreferential uses of reflexives cannot be handled solely in terms of a notion of 'codependent' or 'coargument', as has been suggested in various recent proposals.

Notes

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2. Cases in which a pronoun is not bound are familiar for personal pronouns, but perhaps less familiar for reflexives. Some recent accounts (e.g. Pollard and Sag, 1990 have emphasised the need to recognise a limited subclass of cases in which reflexives are not bound, but rather show coreferential behaviour which is subject to various discourse/semantic restrictions. These cases will not be discussed here, but see Hepple (1990) for discussion, and some proposals for handling these cases within the framework described by this paper.

3. See Morrill *et al* (1990) and Barry *et al*, (1991) for discussion of structural modalities, and proposals for their use in handling phenomena involving word order variation, optionality and iteration.

4. Note that the permutation rule $\triangle$P is unusual in being *multiply conclusioned.* It is standard in Lambek work to assume that in all permissible derivations, a *single* conclusion type is derived from one or more premises. To maintain this restriction, we may stipulate that any *complete* proof must be single-conclusioned. It follows that a permutation inference may not be the final inference in any complete proof.

5. The $\Box$I rule might seem to have an unnecessarily complicated side condition, in refering to 'independent subproofs'. To justify this condition, first consider a system with only a single necessity operator $\Box$. An intuitively sensible side condition for $\Box$I would require that "every hypothesis of the proof is a mod-type", i.e. intuitively, if a conclusion is drawn purely on the basis of necessary assumptions, then we may infer that the conclusion is necessary. Such a rule turns out to be equivalent to one with a side condition that "each path to a hypothesis of the input proof leads to an independent subproof of a $\Box$-type". Note firstly that a single type constitutes an independent subproof, and so the complex version of the rule can be applied to any proof that the simpler version of the rule can be applied to. Conversely, consider a case where a proof has a single non-modal hypothesis, which does occur within an independent subproof of a $\Box$-type. If that subproof is excised from the overall proof, leaving its modal end-type as simply a hypothesis, this will yield a well-formed modified proof, one to which the simpler version of the $\Box$I rule could apply. Finally, the excised subproof may be reinserted, yielding the same result as the more complex version of the rule had applied to the original proof. This process generalises to cases where a proof

has more than one independent subproof. By analogy, it should be clear that the □I in (6) is equivalent to one with the simpler side condition that "each hypothesis is some modal type $\boxed{\alpha}X$ such that $\mathcal{L}_\alpha \subseteq \mathcal{L}_\beta$".

6. The characteristic of treating pronouns as identity functions gives a link between the present account of binding and that of Jacobson (this volume). In fact, the two accounts have a considerable amount in common, although this is to some extent obscured by differences of formalism. Indeed, I believe that many of the insights of Jacobson's proposals can be readily incorporated into the present approach.

7. In Hepple (1990), $\ominus$ is a permutor structural modality, though having different modal behaviour from □. See Hepple (1990) for discussion of the advantages for the account that follow from the additional flexibility that the presence of these inference rules allows.

8. More specifically, Dowty (1980) suggests that disjoint reference arises from a "neo-Gricean conversational principle" which we might paraphrase thus: "Where two equally simple expressions A and B are available to express a meaning X, but where A unambiguously means X whilst B is ambiguous between meanings X and Y, then B should be reserved for expressing Y."

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