Towards a Logical Account of Binding Theory

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Abstract. Binding theory (**BT**) is a kind of syntactic module which contains three principles (*A*, *B*, *C*) governing reflexive pronouns (e.g., himself), non reflexive pronouns (e.g., him) and referential expressions (e.g., the boy). Each one of these principles states some structural configurations in which such elements admit, require or exclude a term of the same reference. Previous logical accounts of **BT** use extended directional systems such as Lambek calculus and its extensions. They all propose to enhance the core logic with new connectives (e.g., control operators, discontinuity connectives) in order to deal with some phenomena inherent to binding such as locality constraints and discontinuity.
Our research work aims at formalizing **BT** principles in a compact and elegant fashion using an undirected logical grammar called: Logical Grammars with Labels (**LGL**). The relevance of this formalism stems from its ability to constrain the use of hypothetical reasoning and its ease to handle resource sharing.

1 Preliminaries

Like Abstract Categorial Grammars [3], **LGL** are based upon an undirected logical system which distinguishes between two fundamental levels namely the *abstract* level (tectogrammatics) and the *concrete* level (dealing with phonetics, semantics ...) [1]. The abstract level is managed by a reduced fragment of Intuitionnistic Implicative and Exponential Linear Logic (**IIELL**) which constrains the use of hypothetical reasoning. In fact, the system excludes both the freely accessible logical axiom and the introduction rule of the linear implication $\multimap$. Available axioms are explicitly given by the lexicon: they take the form of *controlled hypotheses*[3] which are linked to certain lexical entries in order to occupy their intermediary sites. **LGL** is equipped with a refined elimination rule which combines a merge step (application) with a hypothetical reasoning phase (abstraction). This hybrid rule is used by linked entries to simultaneously discharge their associated controlled axioms. The two most important rules of **LGL** are given in Figure 1.

2 Treatment of reflexive binding in LGL

Locality constraints on reflexivization can be straightforwardly handled in **LGL** because the application of hypothetical reasoning is fully driven by the lexicon. On the

[3] A Controlled hypothesis is a consumable lexical axiom which can be either logical, e.g., $x : A \vdash x : A$ or proper, e.g., $\vdash w : A$.

$\multimap E$	$\multimap IE$
$\dfrac{u: A \multimap B \quad v: A}{(u\ v): B}$	$\dfrac{w: (A \multimap B) \multimap C\ [e_i] \qquad \dfrac{\begin{matrix}[x_1]^i \dots [x_k]^i \\ \vdots \\ v: B\end{matrix}}{A \multimap B}}{(w\ (\lambda x.\ v[x_1 := x, \dots, x_k := x])): C}$

Fig. 1. Some logical rules inherent to **LGL**

one hand, anaphors which obey Principle *A* and take their antecedent in their local domain (e.g., *himself*, cf. 1a&1b) are encoded using free lexical entries. Such entries are not linked to any controlled axiom, thus blocking recourse to hypothetical reasoning. On the other hand, long-distance anaphors (e.g., *ziji* in Chinese, cf. 1c) are formalized by means of linked entries which require the introduction of a controlled assumption to temporarily fill the pronoun position.

(1) a. John_i likes himself_i.

b. Bob_j thinks John_i likes $\text{himself}_{i/*j}$.

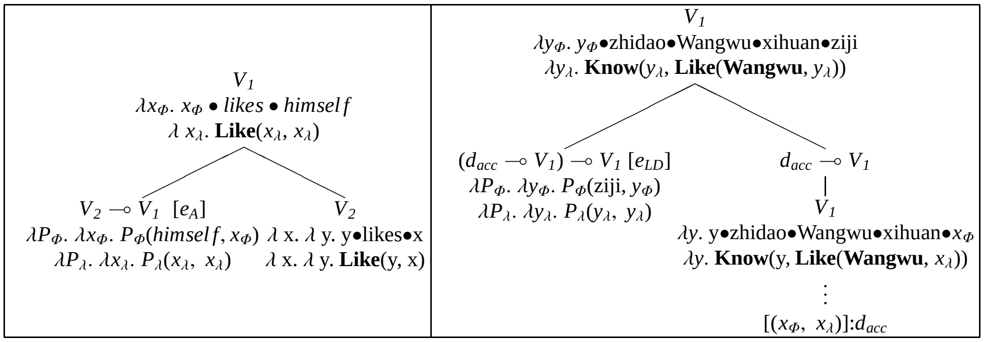
c. Zhangsan_k renwei Lisi_j zhidao Wangwu_i xihuan $\text{ziji}_{i/j/k}$
Zhangsan renwei Lisi knows Wangwu likes self
'Zhangsen thinks Lisi knows that Wangwu likes himself'

For example, to deal with object/subject reflexivization as in examples (1), we consider the following entries (where $V_1 = d_{nom} \multimap c$, $V_2 = d_{acc} \multimap V_1$ and X=$(x_\Phi,\ x_\lambda)$; x_Φ (resp. x_λ) is a phonetic (resp. semantic) variable):

$$e_A \quad \vdash \begin{pmatrix} \lambda P_\Phi.\ \lambda x_\Phi.\ P_\Phi(\text{himself}, x_\Phi) \\ \lambda P_\lambda.\ \lambda x_\lambda.\ P_\lambda(x_\lambda,\ x_\lambda) \end{pmatrix} : V_2 \multimap V_1$$

$$e_{LD} \quad \vdash \begin{pmatrix} \lambda P_\Phi.\ \lambda y_\Phi.\ P_\Phi(ziji, y_\Phi) \\ \lambda P_\lambda.\ \lambda y_\lambda.\ P_\lambda(y_\lambda,\ y_\lambda) \end{pmatrix} : V_2 \multimap V_1 \mathrel{-\!\!\ni} [X : d_{acc} \vdash X : d_{acc}]$$

Entry e_A forces the reflexive '*himself*' to merge with arguments of type V_2 which are either lexical or stemming from the combination of lexical items. Hence, unlike the transitive verb '*likes*' which is lexical, the compound expression '*thinks John likes*' cannot be considered as a potential argument for entry e_A because we are unable to assign it type V_2 without applying hypothetical reasoning. On the other hand, entry e_{LD} is designed to combine with expressions of type V_1 built using a controlled assumption of type d_{acc}. This combination encapsulates an abstraction step and makes it possible to bind the reflexive '*ziji*' with a subject outside the embedded clause, as illustrated by the derivation scheme below :



We can also deal with more complicated cases which prove to be problematic for directional systems (e.g., Lambek calculus [6] and its extensions, such as [4, 7]), in particular, examples involving object-oriented reflexives (cf. 2a) or *pied-piping* (the reflexive is not an immediate complement of the verb) (cf. 2b).

(2) a. John shows Bob$_i$ himself$_i$ in the mirror.
b. John$_i$ shows Mary a picture of himself$_i$.

We account for the first phenomenon by forcing ditransitive verbs to combine with their indirect object before merging with their direct object (e.g., λx. λy. λz. z•shows•y•x). Such subcategorisation order ensures accessibility to the antecedent semantics which should be duplicated. Moreover, pied-piping examples are handled by licensing the introduction of a controlled hypothesis which has to be discharged at the level of the NP where the reflexive is embedded.

3 Treatment of non-reflexive pronouns in LGL

Our treatment of non-reflexive anaphora binding follows the same ideas of Kayne in [5] where he argues that the antecedent-pronoun relation (e.g., between *Bob* and *him* in example 3a) comes from the fact that both enter the derivation together as a doubling constituent [*Bob*, *him*] and are subsequently separated after movement.

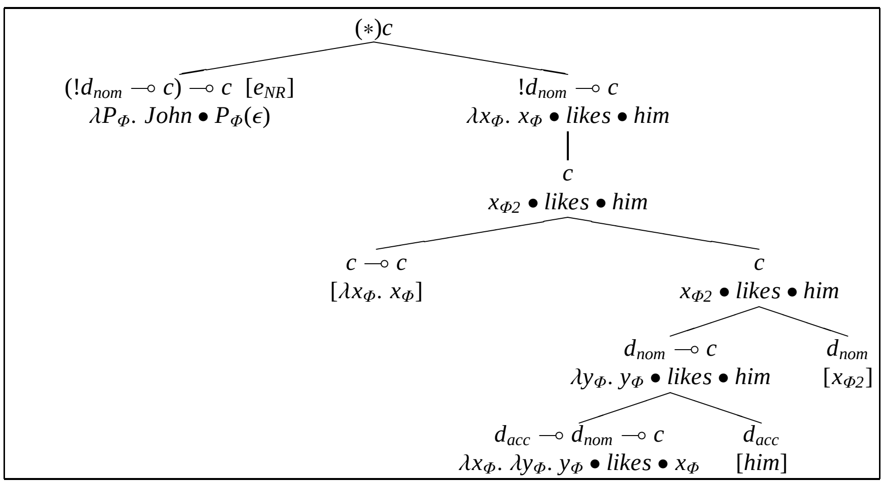
(3) a. Bob$_j$ thinks John$_i$ likes him$_{j/{*}i}$.
b. *John$_i$ likes him$_i$.

Moreover, in order to capture condition *B*, Kayne suggests that the doubling constituent should move to an intermediate landing site (outside the clause where the pronoun is embedded) before reaching its final position [5]. The impossibility of binding the pronoun '*him*' to '*John*' in statements (3) could thus be explained by the prohibition of downward movement, since the transient site is located above the subject '*John*'.
Taking as a start point Kayne's proposal, we encode doubling constituents such as [*John*, *him*] by means of an enhanced entry e_{NR} which is linked to three controlled axioms: the first one represents the pronoun '*him*', the second one specifies the intermediate position while the last one is used to occupy the antecedent site. The exponential (!)

is introduced to allow the contraction of controlled assumptions, thus guaranteeing their simultaneous abstraction. This is useful for sharing the semantics between the pronoun and its antecedent.

$$e_{NR} \;\vdash \begin{pmatrix} \lambda P_{\Phi}.\ John \bullet P_{\Phi}(\epsilon) \\ \lambda P_{\lambda}.\ P_{\lambda}(\mathbf{John}) \end{pmatrix} : (!d_{nom} \multimap c) \multimap c \;\text{-}\!\!\!\ni\; \begin{array}{l} ([(x_{\Phi 1}, x_{\lambda 1}) : d_{nom} \vdash (him, x_{\lambda 1}) : d_{acc}] \\ [\ \vdash (\lambda y_{\Phi}.\ y_{\Phi}, \lambda y_{\lambda}.\ y_{\lambda}) : c \multimap c] \\ [(x_{\Phi 2}, x_{\lambda 2}) : d_{nom} \vdash (x_{\Phi 2}, x_{\lambda 2}) : d_{nom}]) \end{array}$$

The transient position is formalized as a proper axiom with abstract type $c \multimap c$, its essential role is to constitute a border delimiting the local domain of the pronoun '*him*'. Let us specify that in the presence of entries related to several hypotheses, the derivation cannot converge unless these assumptions are introduced according to an appropriate order (by skimming the list of axioms, appearing to the right of the symbol $\text{-}\!\!\!\ni$). Hence, in the case of using entry e_{NR}, the last controlled hypothesis (i.e., $(x_{\Phi 2}, x_{\lambda 2})$) has to be introduced at the end. Thus, it cannot fill the subject position of the clause which is c-commanded by the intermediate site. This makes it possible to block the binding between the pronoun '*him*' and the subject '*John*' in examples 3 as illustrated hereafter (where we focus on the phonetic/syntactic interface):



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