Towards a Lean Constraint Based Implementation of Binding Theory*

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1 Introduction

Due to its pervasiveness in natural languages and its intriguing properties, reference and anaphor processing has been a central topic for NLP research. Given the intensive attention devoted to this subject, it can however be said that sentential anaphor processing has been quite overlooked, when compared to the amount of research effort put in tackling non sentential anaphoric dependencies. This tends to be so because there seems to be a more or less implicit assumption that no substantial difference exists between the two processes.

While this may be arguably true for the heuristics involved in picking out a given antecedent from a list of suitable candidates, a more subtle point asks itself to be made when we focus on the conditions which limit sentential anaphoric relations, but from which non sentential ones are exempt.

In theoretical linguistics these grammatical conditions are grouped under the heading of Binding Theory. In computational linguistics however, though there have been a few papers directly concerned with the implementation of this theory, mainstream research tends to disregard its conceptual, grammatical or practical modularity. When it comes to define the algorithm for setting up the list of suitable candidates from which the antecedent should be chosen, binding conditions, holding just at the sentential level, are most often put on a par with any other kind of conditions, morphological, semantic, pragmatic, etc., which hold for anaphoric relations at both sentential and non sentential level.

The interesting point to be made in this connection is that, if the modularity of grammatical knowledge is to be ensured in a sound reference resolution system, more attention should be paid to previous attempts of implementing Binding Theory. It would then become evident that this theory, in its current formulation, appears as a piece of formalised grammatical knowledge which however escapes a full and lean declarative implementation.

In fact, implementation efforts concerning Binding Theory[1] bring to light what tend to be eclipsed by mainstream clean theoretical formulations of it. Behind the apparent declarative aspect of its definition under the form of a set of principles (plus definitions of associated concepts, e.g. o-command, o-bound, local domain, etc.), there is a set of procedures which turn out to be an essential part of the theory. These procedures form an algorithm with the following outline. After parsing have been completed, (i) *indexation*: assign indices to NPs; (ii) *filtering*: store the indexed tree if the indexation respects binding principles, reject otherwise; (iii) *recursion*: repeat (i) with a new assignment until all possible assignments are exhausted.

This sort of resistance to full declarative encompassing is also apparent when one considers how Binding Theory is handled in grammatical theories developed on top of constraint based formalisms and particularly concerned with computational implementability, like LFG or HPSG.

As to HPSG, it has passed quite unnoticed that its Binding Theory is the only piece of grammar not encoded in HPSG formalism. In the Appendix of the foundational book (Pollard and Sag (94)),

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[1] Vd. Chomsky (81), Correa (88), Ingria *et al*. (89), Fong (90), Giorgi *et al.* (90), and Pianesi (91).

where the fragment of grammar developed along its 400 pp. is encoded in the adopted formalism, Binding Theory escapes such encoding. Bredenkamp (96) and Backofen *et al.* (96) subsequent elaboration on this issue implied that some kind of essential limitation of the formalism might have been reached and that HPSG Binding Theory is still waiting to be accommodated into HPSG grammars.

As to the LFG formulation of Binding Theory, it requires the integration of inside-out equations, a special purpose extension to the general declarative formalism. And even though initial scepticism about their tractability was partially dissipated by Kaplan and Maxwell (88), the recent survey of Backofen *et al.* (96) reports that no implemented formalism, and no implemented grammar, is known to handle LFG Binding Theory.

In this connection the central aim of the research to be presented here is to render possible a lean declarative implementation of Binding Theory in constraint based formalisms without resorting to special purpose complex mechanisms. This involves two steps. First, as a sort of enhancing step back, a new account of Binding Theory is set up. Second, by means of the discussion of an example, the new shape of the theory is suggested to support full declarative implementation in the basic HPSG formalism. Due to space constraints, this paper is mostly concerned with the first, while the latter receives just a basic sketch in last section, being developed in future papers.

2 Preliminaries

2.1 The binding square of opposition

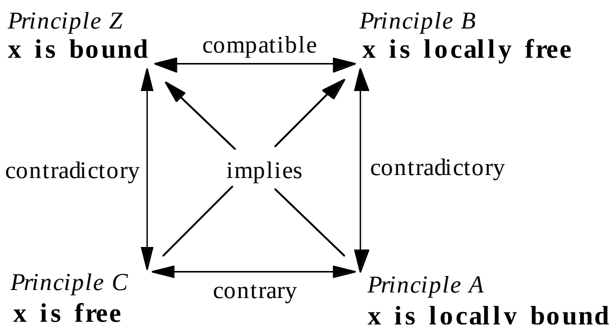
Recent cross linguistic research, e.g. Xue, Pollard and Sag (94) and Branco and Marrafa (97), has shown that the binding ability of long-distance reflexives is not reducible to recursive concatenation of short distance relations, as it has been assumed in GB accounts, but that it is ruled by a fourth binding principle:

(1) Principle Z

An o-commanded anaphoric pronoun must be o-bound.

This new perspective on long-distance reflexives had an important impact in the whole shape of Binding Theory. Branco and Marrafa noted that the four principles can be arranged in a classical Aristotelian square of oppositions, as in (2)[2].

(2)



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[2] The exemption restrictions in Principle A (cf. Pollard and Sag (94):Chap.6) and Principle Z (cf. Branco and Marrafa (98)), requiring o-command of the relevant noun phrase for the principles to hold, were removed from the formulation of these principles in the square of (2). In the account of Binding Theory to be developed in the present paper, those restrictions are shown to be simple side effects of the new formulation to be given to Principles A and Z. The patient reader is kindly asked to wait until Section 4.1 for a justification for this claim.

This suggests that the Binding Theory might have an unsuspected underlying quantificational structure. In Section 3 we aim at showing that there is actually such structure and at determining its basic lines. In the remainder of the present section the central concepts and tools used in next section will be presented.

2.2 Phase quantification

Barwise and Cooper (81) seminal work gave rise to a fruitful research tradition where Generalised Quantifier Theory has been applied to the analysis of natural language quantification. These authors suggested that a universal characterisation of NL nominal quantification could be formally given by means of formal properties defined in that theory. The property "to live on" was postulated as being the most prominent one, admittedly constituting the common specific nature of all nominal quantifiers.

Later, Loebner (87) suggested a criterion to ascertain the quantificational nature of natural language expressions in general. That is the property that, for a one place second order operator Q expressed by a given expression, there be a corresponding dual operator ~Q~.

This duality based perspective on the essence of natural language quantification permitted to extend quantification well beyond the classic cases of nominal quantification supported by the determiners *all*, *some*, *most*, *many*, etc., namely by covering also the realms of temporality and possibility. Moreover, items like *still*/*already*, and others (*enough*/*too*, scaling adjectives, *many*/*few*, etc.) though they do not lend themselves to be straightforwardly analysed in terms of set quantification, they can also be arranged in a square of duality. The formalization of the semantics of these aspectual items by Loebner led to the enlarging of the notion of quantification through the introduction of the new concept of phase quantification.

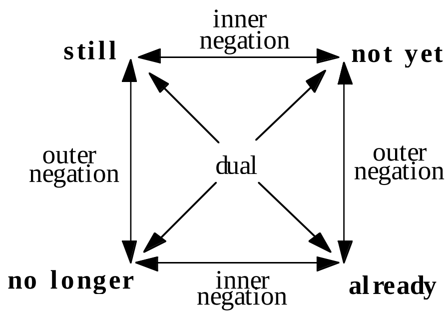
He noted that *still* and *already* express duals and that they are corners of a square of duality. Let P be "she is asleep" and ~P "she is awake", durative propositions which are the arguments of the semantic operators corresponding to *already* and *still*. Then:

(3) She is already asleep iff it is not the case that she is still awake.

ALREADY P iff ~ STILL ~P

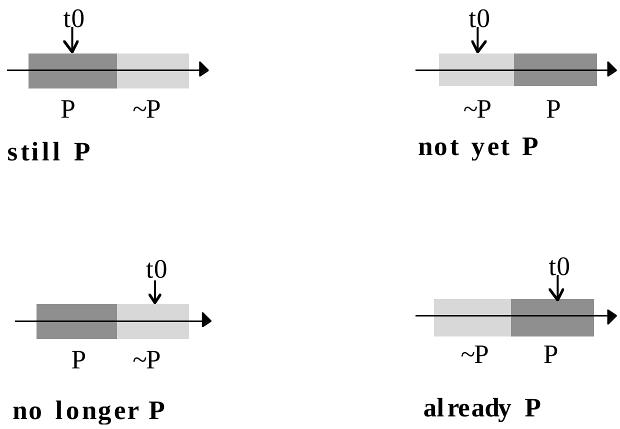
Further similar tests can be made in order to show that these aspectual items enter the following square of duality:

(4)



In order to get a formalization of (4), Loebner noted that *already* should be taken as conveying the information that there is a phase of not-P which has started before a given reference time *t0* and might be followed by at most one phase P which reaches till *t0*. This can be displayed in a time axis by means of the diagram in (5).

(5)



Similar diagrams for the meaning of the other aspectual phase quantifiers of this square of duality are easily interpretable. Inner negation results in exchanging the positive and the negative semiphases, while outer negation concerns the decision whether the parameter *t0* falls into the first or the second semiphase.

Phase quantifiers in general (*already*, scaling adjectives, etc.) were thus characterised as requiring two ingredients: (i) a property P, which defines a positive phase in a sequence of two opposite phases; (ii) a parameter point. The four types of quantifiers just differ in presupposing that either the positive or the negative semiphase comes first and in stating that the parameter point falls into the first or into the second semiphase.

Next Loebner showed that the semantics of phase quantifiers sketched in the diagrams above can be formalised in such a way that a square of duality formed by the generalised quantifiers λX.some'(D,X)/ λX.every'(D,X) turns out to be subjacent to the square of duality of *already*/*still*. In order to do it, he just needed the auxiliary notion of starting point of the relevant semiphase. This is rendered as the infimum of the set of the closest predecessors of the parameter point *pt* which form an uninterrupted linear sequence with property P, or ~P (termed GSI(R,pt) by Loebner):

(6) $\text{GSI}(R,pt) =_{df} \inf\{x \mid x<pt \ \& \ R(x) \ \& \ \forall y(x<y\leq pt \ \& \ R(y) \rightarrow \forall z(x<z<y \rightarrow R(z)))\}$

The semantics of the four phase quantifiers above can then be rendered in the following way, making *pt*=*t0* for the parameter point and R=P or R=~P:

(7)

still	$\lambda P.\text{every}'[\lambda x.(\text{GSI}(P,a) < x \leq t0), P]$
already	$\lambda P.\text{some}'[\lambda x.(\text{GSI}(\sim P,a) < x \leq t0), P]$
not yet	$\lambda P.\text{no}'[\lambda x.(\text{GSI}(\sim P, a) < x \leq t0), P]$
no longer	$\lambda P.\text{not\_every}'[\lambda x.(\text{GSI}(P,a) < x \leq t0), P]$

3 Binding Conditions and Phase Quantification

Taking Loebner's view on natural language quantification, our goal in this section is to make apparent the quantificational structure of binding. We show that on a par with the square of opposition of (2), binding principles also form a square of duality. We argue that binding principles are but the reflex of the phase quantificational nature of corresponding nominal expressions.

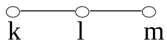
Reflexives, pronouns, long-distance reflexives and R-expressions will be shown to express phase quantifiers acting on the grammatical obliqueness axis.

3.1 Phase quantification ingredients

In order to show that the above referred nominals express phase quantifiers the relevant components involved in phase quantification should be identified.

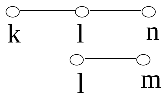
The relevant **scale** here is not the continuous linear order of moments of time, as for *still*/*already*, but a discrete partial order made of discourse referents a la Discourse Representation Theory (DRT) arranged according to the relative obliqueness of grammatical functions. Note that in multiclausal constructions there is the corresponding subordination of different clausal obliqueness hierarchies (for the sake of comparability with diagrams (5) involving time arrow, Hasse diagrams for obliqueness are displayed with a turn of 90˚ right):

(8) Kim said Lee saw Max.



Note also that the relation "less oblique than" may not be linear:

(9) Kim said Lee, who saw Max, hit Norma.



The sequence of two **opposite semiphases** is defined by a property P. Contrarily to what happens with *already*, where operator (quantifier) and operand (durative proposition) are rendered by different expressions, in binding phase quantification the operand P is also contributed by the nominal expressing the operator, i.e. expressing the binding phase quantifier.

For a given nominal N, P is determined by the relative position of N in the "scale". For a discourse referent *r* corresponding to N, semiphase P is a linear stretch containing only elements that are less than or equal to *r* in the obliqueness order, that is discourse referents corresponding to nominals o-commanding N. Moreover, if semiphase P is presupposed to precede semiphase ~P, P is such that the last successor in it is local wrt to *r*; and if semiphase ~P is presupposed to precedes semiphase P, P is such that the first predecessor in it is local wrt to *r*. In both cases the closest P neighbour of semiphase ~P has to be local wrt *r*, where the notion of locality has the usual sense given in the definition of binding principles:

(10) $P_r(x)$ iff_{def} $(x \leq r \text{ or } r \leq x)$ & $\forall y[(\sim P_r(y)$ & $(x \mathrel{-\!\!<} y \text{ or } y \mathrel{-\!\!<} x)) \longrightarrow x$ is local wrt r]

As to the **parameter point**, in binding phase quantification, it is the discourse referent *a* which is the antecedent of *r*.

3.2 Obliqueness quantifiers

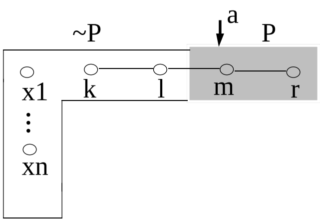
We can now formalise phase quantification subjacent to nominals. Let us start with an **anaphoric** expression N like *himself*.

(11) a. Kim said Lee thinks Max_i hit $himself_i$.

a'. *Kim said Lee_i thinks Max hit $himself_i$.

b. $\mathbf{Q_A} =_{def} \lambda P.some'(\lambda x.(GSI(\sim P,a)<x\leq a),P)$

c.



N can thus be interpreted as presupposing that a semiphase ~P precedes a semiphase P and requiring that the parameter point occurs in the latter, that is, the antecedent *a* is to be found in semiphase P among the discourse referents corresponding to the local o-commanders of *r*, the discourse referent corresponding to N[3].

This is captured by the definition of the phase quantifier Q_A. Satisfaction of $Q_A(P)$ obtains iff between the bottom of the uninterrupted linear sequence ~P most close to the parameter point/antecedent *a* and *a* inclusive there is at least one discourse referent in P. Given that ~P.P, this amounts to requiring that *a* be in P, and that *a* be a local o-commander of *r*.

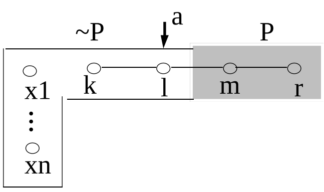
Next, it is then easy to see how the phase quantificational force of a **pronominal** expression N should be formalised:

(12) a. *Kim said Lee thinks Max_i hit him_i.

a'. Kim said Lee_i thinks Max hit him_i.

b. $\mathbf{Q_B} =_{def} \lambda P.no'(\lambda x.(GSI(\sim P, a) < x \leq a),P)$

c.



Here the parameter point *a* occurs in semiphase ~P, which amounts to the antecedent being picked outside the set of local o-commanders. $Q_B(P)$ is satisfied iff no discourse referent between the bottom of the uninterrupted linear sequence ~P more close to the parameter point/antecedent *a* and *a* inclusive is in P. Given that ~P.P, this amounts to requiring that *a* is in semiphase ~P and *a* is not a local o-commander of *r*.

Like in diagram of (11), ~P is taken here as the complement set of P. All discourse referents which are not local o-commanders of *r* are in it, either o-commanding *r* or not. Notice that set ~P includes also discourse referents $x_1 ... x_n$ introduced by previous sentences or the extra-linguistic context, which in constructions similar to (12)b. accounts for possible deictic readings of the pronoun. Below, when studying R-expressions, we will see why the possible non linearity of the obliqueness order will led us to consider that ~P is slightly more complex than just the complement set of P.

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3 For the sake of simplicity, agreement requirements between N and its antecedent are overlooked here.

Coming now to **long-distance reflexives**, ruled by the fourth binding principle in (1), we get the following formalisation (example (13) is from Portuguese):

(13) a. [O amigo de Kim]$_i$ disse que ele próprio$_i$ acha que Lee viu Max.

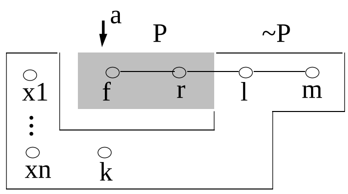
[Kim's friend]$_i$ said LDR$_i$ thinks Lee saw Max.

a'. *[O amigo de Kim$_i$] disse que ele próprio$_i$ acha que Lee viu Max.

[Kim's$_i$ friend] said LDR$_i$ thinks Lee saw Max.

b. $\mathbf{Q_Z} =_{def} \lambda P.every'(\lambda x.(GSI(P, a)<x \leq a),P)$

c.



Here, like for short-distance reflexives in (11), *a* is required to occur in P though the presupposition now is that semiphase P is followed by semiphase ~P. Taking into account the definition of P in (10), the antecedent of N is thus required to be an o-commander (local or not) of N. The semantics of phase quantifier Q_Z is such that, for Q_Z(P) to be satisfied, between the bottom of the uninterrupted linear sequence P more close to the parameter point/antecedent *a* and *a* inclusive every discourse referent is in P. This amounts to requiring that *a* be in semiphase P, and that *a* be an o-commander of *r*.

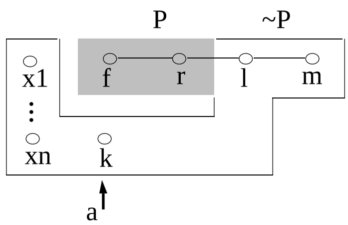
Finally **R-expressions** call to be formalised as the fourth phase quantifier of (7):

(14) a. [Kim's$_i$ friend] said Kim$_i$ thinks Lee saw Max.

a'. *[Kim's friend]$_i$ said Kim$_i$ thinks Lee saw Max.

b. $\mathbf{Q_C} =_{def} \lambda P.not\_every'(\lambda x.(GSI(P,a)<x \leq a),P)$

c.



The parameter point *a* is required to occur in ~P, which means that *a* cannot be an o-commander (local or not) of *r*. This renders the same condition as expressed by Principle C, that R-expressions be free, though it also encodes an uncommon assumption about the referential autonomy of R-expressions. Here, like for other more obvious dependent reference nominals, the interpretation of R-expressions is taken as being dependent on the interpretation of other expressions or on the salience of discourse referents made available by the communicative context. Taking an extreme example in order to support the plausibility of this view and awkwardly abbreviate a deep philosophical discussion, one should notice that even a proper name is not a unique label of a given individual, once knowing who is the person called John (out of those we know that are named John) depends on the context.

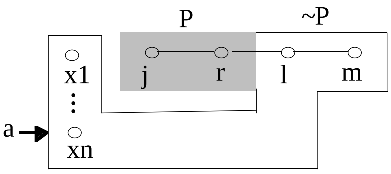
Note that like in previous diagrams, in (14) ~P is taken just as the complement set of P. However, Q_C asks finally for a serious ponderation of this and a more accurate definition of ~P for phase quantification in non linear orders, where it is possible that not all elements are comparable.

For $Q_C(P)$ to be satisfied, between the bottom of P and the parameter point/antecedent *a* inclusive not every discourse referent is in P. Since we have here the presupposition that P.~P, and given P is an uninterrupted linear sequence, this would amount to requiring that *a* be in ~P.

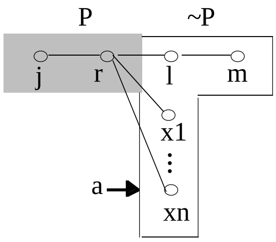
It is worth noting then that if we keep ~P simply as the complement set of P, the interpretation of R-expressions is however not adequately predicted by $Q_C(P)$.

(15) a. John said Kim_j thinks Lee saw Max.

b.



c.



Let D be {x: GSI(P,a)<x≤ a}, the domain of Q_C. Taking (15)b., it is easy to check that in constructions like (15)a., D is always empty. In fact, it is not the case that GSI(P,a)≤a as a=x1 is not comparable to any other element of P, and *a fortiori* it is not comparable to the bottom of P. Consequently, every'(D,P) is trivially true whatever discourse referent x*n* we take as antecedent for *r*, and not every'(D,P) is trivially false. The interpretation of (15)a. sketched in (15)b. would thus be incorrectly ruled out.

What these considerations seem then to suggest is that, when phase quantification operates on non linear orders, negation of the operand P is slightly more complex than simple Boolean negation rendering the complement set. We are thus taught that negation of P involves also the lifting of the complement set of P, $\overline{P}_{\perp}$, with ⊥ equal to *r*, the top of P, when P.~P[4]. It is easy to check with diagram (15)c. that this specification of ~P makes it possible to satisfy $Q_C(P)$ in exactly the correct constructions.

3.3 The binding square of duality

Following Loebner's claim that logical duality is the cardinal property to recognise the quantificational character of natural language expressions, we are thus led to the view that the interpretation of referentially dependent nominals is ruled by their phase quantificational force over the obliqueness order. Since the defining formulas of binding quantifiers result from (7) just by assigning P the definition in (10) and taking the parameter point *pt* to be the antecedent *a*, it is with no surprise that we get the following square of duality for binding phase quantifiers:

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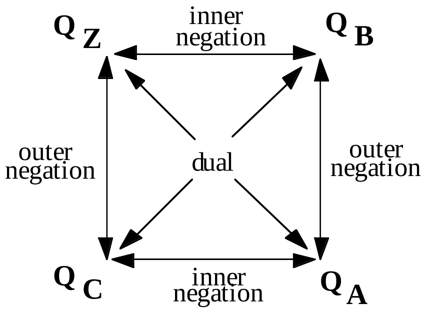
[4] Though it is empirically not necessary, for the sake of uniformity, when ~P.P, the order-theoretic dual of this specification of ~P can be assumed.

(16)



4 Towards a Lean Implementation

This new conception of binding has important consequences for our understanding of the dependent reference mechanisms captured by Binding Theory. It may also have an important impact in our conception of both generalised quantification in natural language and the twofold semantic capacity of nominal expressions (referential and quantificational).

Here we cannot do but to limit ourselves to hint how a few central issues usually associated to binding are handled under this new viewpoint. Then we proceed to consider the importance of this new perspective for the integration of Binding Theory into the grammar of natural languages, and for the implementation of the theory in constraint based grammars.

4.1 Further insights into binding

Parameterization It is well known that though binding principles are assumed to hold universally in all languages, final "grammatical geometry" between nominals of a given type (anaphoric, pronominal, etc.) and their antecedents may be different from language to language.

Dalrymple (93) suggested that this is due to language specific conditions impinging: (i) on the eligibility of the antecedent (whether it is a Subject or not); and (ii) the range of the local domain (whether it is finite, tensed, etc.).

As to the variation in (i), Branco (96) showed that it is a consequence of a lexical property of the predicates, whose obliqueness hierarchy may be either linear or non linear. As to (ii), this variation may be accommodated in the definition of property P in (10), in particular in the definition of "local wrt to r", to be provide for each particular language. Both solutions are perfectly confluent with the UG standpoint that variation across languages in the “grammatical geometry” between referentially dependents items and their antecedents results from language specific parameterization.

Lexical gaps It is also well known that although the four binding principles are claimed to be universal, there are languages which have not all the corresponding four type of nominals. For instance, English is not known to have long-distance reflexives.

The answer for this is now quite simple. Like what happens in other squares of duality, it is possible that for a given language not every corner of the binding square in (16) is lexicalized. Loebner (87) discusses at length this issue of non lexicalized corners. In English, for instance, it is noted that the square of duality concerning deontic possibility involving *right* happens to have only two lexicalized corners, *right* and *duty*.

Exemption and logophoricity Also worth considering here is the borderline case where the maximum shrink of semiphase P occurs. In that case, P is the singleton whose sole element is *r*, the discourse referent whose interpretation is to be anchored by finding an antecedent for it.

Given the definition of binding quantifiers, the maximum shrink of P into a singleton affects in a significant way only the quantifiers where the parameter point/antecedent *a* is to be found in P, namely Q_A and Q_Z. In these cases, for *a* to be in P and the quantification to be satisfied, *a* can only be *r* itself, which makes of *r* its own antecedent. Consequently, although the phase quantification is satisfied, a "meaningful" anchoring of the discourse referent *r* remains to be accomplished as by the sole effect of quantification satisfaction *r* is just anchored to itself.

Admittedly, a general overarching interpretability requirement of natural languages imposes that the significant anchoring of nominals be consummated. In the cases under consideration, this induces an exceptional logophoric effect. For the anaphor (short or long-distance) to be interpreted, and given that satisfaction of its binding constraint (Q_A or Q_Z) is somehow vacuously ensured, it should thus find a really anchoring antecedent outside any other specific restriction.

This delivers us an explanation for the exemption restrictions in the definitions of Principles A and Z (cf. Pollard and Sag (94) and Branco and Marrafa (98)) and for the so called logophoric effects associated to exempt anaphors. Therefore, restrictions which appeared until now to be mere stipulations receive in this approach a principled justification.

4.2 Representing intra-grammatical quantification

Coming now to its formal integration into grammar, Binding Theory can hardly be said to clearly belong either to the realm of Syntax or to the realm of Semantics. It is a fact that important syntactic notions, e.g. grammatical function or obliqueness hierarchy, are crucially involved in the make up of binding conditions. However, the singular mechanisms involved in the formulation of binding quantification have no parallel with any other devices at work in syntactic explanation.

On the other hand, it is also a fact that core semantic devices, e.g. phase quantification, are involved in the formulation of binding conditions. However, also on the semantic side, the formal mechanisms involved exhibits a considerable degree of idiosyncrasy. In formal semantics, representations of natural language expressions are interpreted against a model whose entities are *extra-grammatical* elements, like objects, events, instants of time, relations, etc.. The formal interpretation of phase quantification encapsulated in binding conditions, however, requires models whose entities are *intra-grammatical* elements, like obliqueness relations, discourse referents, etc..

In spite of these idiosyncrasies, it appears that semantic frameworks turn out to be better suited to shelter Binding Theory. This is so because those frameworks provide most of the tools needed to integrate binding conditions into the grammars of natural languages, thus reducing the need of special purpose devices for handling Binding Theory.

In what follows we try to give support to this point of view by sketching an analysis of example (17)a. in DRT. With this case study, we try to suggest how binding conditions may be neatly integrated into the grammar of natural languages.

(17) a. A man entered. He was whistling.

b.

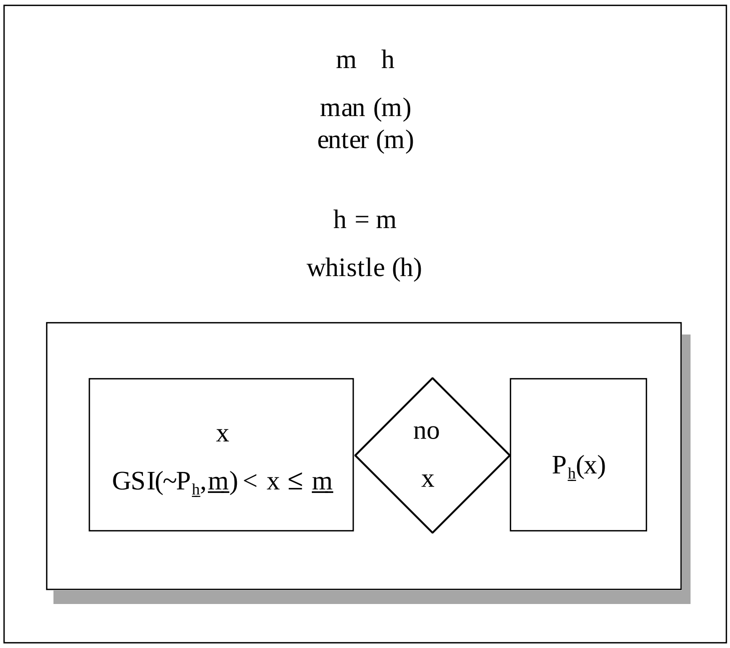
m h
man (m) enter (m)
h = m
whistle (h)

Following Kamp and Reyle (93), and letting aside semantic aspects irrelevant to the present discussion, (17)b. can be taken as the semantic representation of (17)a.. As usual in DRT, the anaphoric link between *he* and *a man* is captured by the condition **h=m**.

In order to represent the phase quantificational power of the pronoun, we need a slight improvement of the expressive power of DRSs. Given that binding quantification is intra-grammatical, it requires a specific model to be interpreted. We use shaded DRSs to indicate that the conditions in the shaded DRSs are to be interpreted against such specific model with intra-grammatical entities. Additionally, given that in shaded DRSs we want to talk about a given discourse referent **r** possibly present in non shaded DRSs, we use the notation $\underline{\mathbf{r}}$ to ensure that the referent of $\underline{\mathbf{r}}$ is **r**, not the referent of **r**.

With this in place, we can improve (17)b., and obtain (18) as the semantic representation of (17)a., where the binding condition associated to the pronoun is now included.

(18)



It can be objected that this extension of the DRS in (17)b. is in a certain sense innocuous or irrelevant. This may be so because the new shaded DRS corresponding to the binding quantifier does not add any real constraint to the meaning represented in (17)b. The constraints in (17)b are in a certain sense stricter than the constraint expressed in the shaded DRS. The shaded DRS states that no discourse referent less oblique than or as oblique as the antecedent **m** is local wrt **h**, i.e. **m** is not a local o-commander of **h**. The DRS of (17)b. in turn states the more strict condition that **m**, a discourse referent introduced in the parsing of a previous sentence, not locally o-commanding **h**, is the antecedent of **h**.

This objection however makes sense just if one neglects the fact that, unlike other DRS conditions, the inclusion of anaphoricity conditions, like **h=m**, does not result from strict semantic analysis. As it is well known from anaphora resolution studies, the inclusion of **h=m** results from “all sorts of considerations, non-linguistic as well as linguistic, that makes a particular choice of the antecedent *suitable*” (Kamp and Reyle (95):p.70). Therefore, in DRT anaphoricity conditions like the one at stake, though they are well formed and contribute to the semantic representation, they are *ad hoc* from the strict point of view of semantic analysis. Unlike other DRS conditions, their inclusion in DRSs is somehow stipulative as they do not result from the direct mapping from syntactic representations into semantic representations.

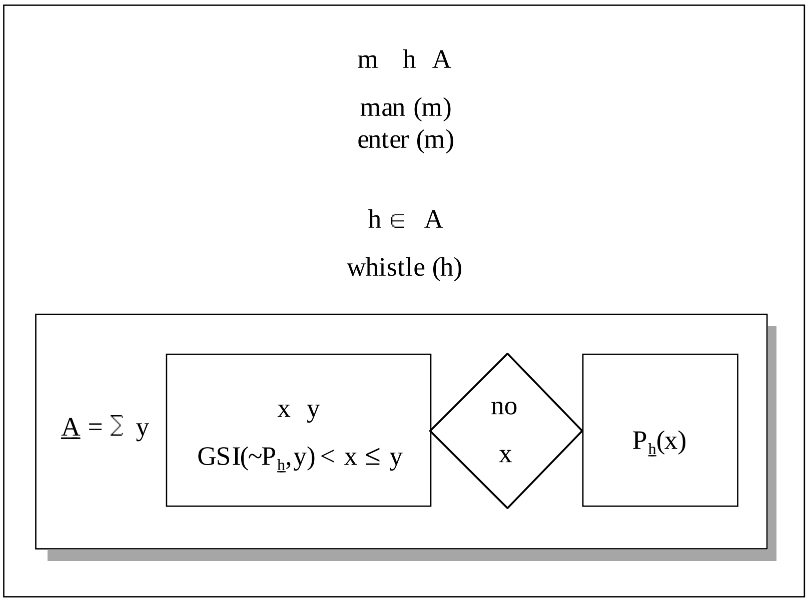
These considerations, while answering to the possible objection on the irrelevance of the shaded DRS in (18), also suggest how we should move towards a more thorough representation of (17)a., where the potential of the binding condition is completely exploited.

First, we use the Abstraction operator Σ of DRT to obtain the set $\underline{\mathbf{A}}$ of all discourse referents that satisfy the duplex condition of the shaded DRS as $\mathbf{y}$. Consequently, $\underline{\mathbf{A}}$ includes all discourse referents that, when used as antecedents of **h**, comply with Principle B, i.e. referents which are not local o-commanders of **h**.

Second, we adopt an attitude of strict semantic parsimony in the construction of semantic representations. In the process of constructing DRSs from corresponding syntactic representations, we include only semantic conditions that can be obtained just from the grammatical representations available for the construction rules of DRSs. Concomitantly, we opt for an underspecified semantics of the anaphoric potential of the pronoun. This is obtained by replacing the stipulation **h=m** with the condition $\mathbf{h \in A}$.

The resulting semantic representation can be found in (19).

(19)



The DRS of (19) is then the semantic representation of (17)a. where the anaphoric potential of the pronoun is both explicitly stated and correctly limited according to the conditions imposed by Principle B of Binding Theory.

As it naturally follows from this discussion about the case study of (17)a., we think that every referentially dependent NP, be it ruled by Principle A, B, C or Z of Binding Theory, should receive a similar semantic representation with an adequate duplex condition expressing the corresponding phase quantifier. The fact that, unlike so called quantificational NPs, the quantificational force of those nominals is intra-grammatical should not hamper us to render a complete characterisation of their semantic properties.

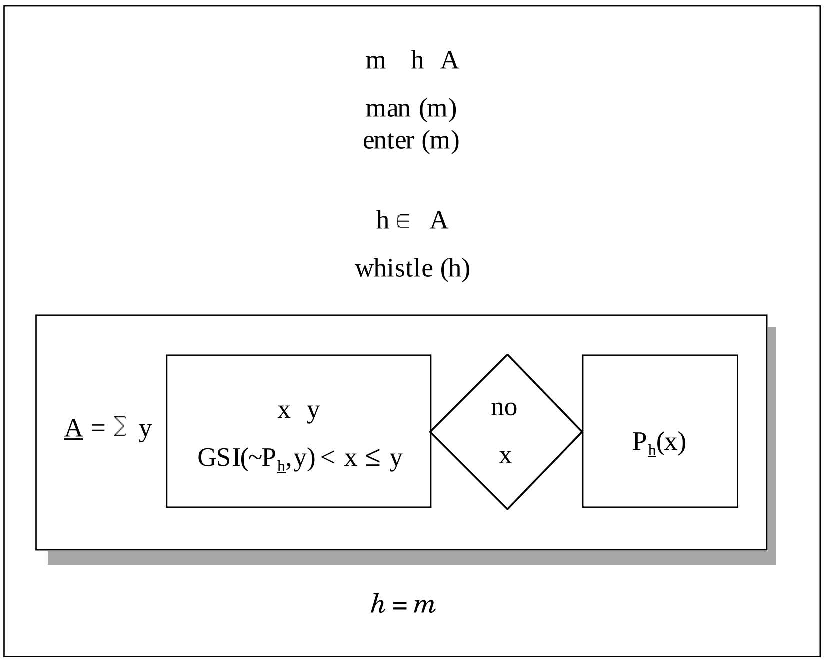
It is also worth noticing that the analysis of binding conditions here argued for ensures a neat accommodation of Binding Theory into the grammar of natural languages.

First, what is commonly recognised as a modular piece of grammatical knowledge is effectively represented as such. The present solution assigns Binding Theory full citizenship in grammar, and avoids that binding constraints be conceptually mixed with heuristics and preferences, with a totally different epistemic status, as it is often the case in systems for anaphor resolution.

Second, the present solution avoids important problems of efficiency and decidability of previous accounts. There is no need to resort to special purpose post-processing mechanisms of indexation and filtering (GB), which induce an explosion of the number of parse trees to be handled. It also permits to dispense with specific and complex equational devices (LFG).

Third, grammatical representations that include semantic representations as the one depicted in (19) constitute a highly suitable input for anaphor resolution systems. Underspecified representations as (19) are an adequate basis for monotonic improvements concerning the specification of relationships between referentially dependent expressions and their antecedents. It is quite easy to conceive that a post-grammatical module for anaphora resolution should generate (20) from (19), where the condition **h∈A** is specified by the addition of **h=m**.

(20)



4.3 Binding Theory in HPSG

The new conception of Binding Theory presented in this paper is currently being integrated in an HPSG grammar implemented in ProFIT 1.54 (Erbach (95)). Space limits restrict us here to a very brief rationale of that ongoing research, which will be fully presented in future papers.

As noted above, the interesting point to make in this connection is that the new insight into binding phenomena elicited by the discovery of their quantificational nature constitute a breakthrough for the desideratum of giving Binding Theory a lean declarative implementation. In theoretical terms, the first step will be to integrate semantic representations like (19) into the HPSG feature system by adopting a principle based semantics in line with Frank and Reyle (95). In practical terms the implementation of Binding Theory will certainly involve collecting discourse referents into set values of specific features. Given the possible non local nature of the elements of a given set, in order to avoid termination problems some mechanism of delaying constraint satisfaction has also to be ensured.

5 Conclusions

In this paper we presented a cogent argument for the quantificational nature of binding conditions. We argued that these conditions can be taken as the effect of phase quantification on the universe of discourse referents, expressed by referentially dependent nominals.

A new conception of binding phenomena emerged from this radical shift on our understanding of the sentential limits on anaphoric relationships. This new conception was also shown to constitute a decisive step towards a lean constraint based encompassing of Binding Theory. First, what has been considered to be binding principles can now integrated in the semantic representation of natural languages as intra-grammatical phase quantification. Second, an underspecified semantics of the anaphoric potential of nominals can be built on the representation of such quantificational mechanisms, for whose formalisation DRT was shown to offer a suitable framework.

It was also suggested that, in the multilevel sign based approach of HPSG, the integration of this new piece of semantic representation in the grammar of natural languages is most likely to be accomplished quite straightforwardly.

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