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Crossover: a unified view*

RUTH KEMPSON

School of Oriental and African Studies

DOV GABBAY

Imperial College of Science, Technology & Medicine

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This paper informally outlines a Labelled Deductive System for on-line language processing. Interpretation of a string is modelled as a composite lexically driven process of type deduction over labelled premises forming locally discrete databases, with rules of database inference then dictating their mode of combination. The particular LDS methodology is illustrated by a unified account of the interaction of *wh*-dependency and anaphora resolution, the so-called 'cross-over' phenomenon, currently acknowledged to resist a unified explanation. The shift of perspective this analysis requires is that interpretation is defined as a proof structure for labelled deduction, and assignment of such structure to a string is a dynamic left-right process in which linearity considerations are ineliminable.

1. Crossover – the problem

In recent years, and especially since Lasnik & Stowell (1991) and Postal (1993), the phenomenon of crossover has been acknowledged to be problematic. Originally brought to light by Postal (1972), its subdivision into two discrete phenomena, strong and weak crossover, is taken to be entirely uncontroversial. Strong crossover is the restriction universally displayed across all languages which prohibits a pronoun from being interpreted as dependent on a c-commanding operator if it both precedes and c-commands the trace bound by that operator:

(1) *Who$_i$ did he$_i$ think that Bill liked e$_i$?

This phenomenon is said to be due to a principle C effect, the trace being required to be free (not co-indexed) with respect to any c-commanding

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expression in an A-position (Chomsky 1981). Weak crossover on the other hand is a restriction that has to be separately stated to preclude a pronoun from being bound by some c-commanding operator in the presence of a following trace, because the pronoun does not c-command that trace and so could not give rise to any principle C effects arising from co-indexation with it:[1]

(2) *Who$_i$ did his$_i$ mother ignore e$_i$?

As is wellknown (cf. e.g. Higginbotham 1980), and discussed at length by Lasnik & Stowell, weak crossover appears to need a solution which is subject to semantic constraint, as there are environments – in particular non-restrictive relative clause constructions, parasitic gap constructions, and *easy to please* constructions, where this weak crossover effect disappears altogether; and, as Lasnik & Stowell argue, these seem to be associated with some concept of referentiality attributed to the *wh*-operator:

(3) John, who$_i$ his$_i$ mother had regularly ignored e$_i$, fell ill during the exam period.
(4) Which$_i$ of the team did the judge put away e$_i$ without his$_i$ mother being able to see e$_i$?
(5) Sam$_i$ is all too easy for his$_i$ mother to ignore e$_i$.

According to Lasnik & Stowell weak crossover effects only arise in a weak crossover configuration if the operator which is the putative binding of both pronoun and trace is a true quantifier phrase; and data such as (3)–(5) are said to constitute a discrete phenomenon of 'weakest crossover' in which the empty category is a pronominal epithet and not a 'true variable'. This correlation of nonreferentiality with weak crossover effects appears to make correct predictions for restrictive and nonrestrictive relative clauses, for though (3) displays no weak crossover effects, (6) is unacceptable on the indicated reading:

(6) *Every student who$_i$ his$_i$ mother had regularly ignored e$_i$ fell ill during the exam period.

[1] In the first GB account of weak crossover (Chomsky 1981), a parallel is drawn between such *wh*-examples as these and:
(i) His$_i$ mother ignores every child$_i$.
But, as observed by Postal, this parallelism seems less striking in the light of the problems he adduces (cf. Postal 1993 and also Williams 1994). For the most part, we shall focus exclusively on examples involving *wh*-constructions (though cf. section 3.1). We shall also focus principally on accounts of crossover in the Principles and Parameters framework, since it is in this framework that these phenomena have received most attention (though cf. Dowty 1992).

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As demonstrated by Postal, however, not only does the semantic solution have to be hedged around with additional syntactic restrictions (for example that if the quantifier phrase is in a PP, the PP as a whole must inherit quantificational properties from its subparts), but there are cases such as the so-called 'connectivity' data (Higgins 1972) where despite a relation of reference, weak crossover effects none the less remain in force:

(7) *It was Carl_i that_i a picture of him_i fell on e_i.

There are also cases involving genuine quantification that do not give rise to weak crossover effects, as witness the possible distributed interpretation of *their* in (8), *their doctor* ranging over as many doctors as patients:[2]

(8) Most of the patients, in particular all those who_i their_i doctor had said e_i were harmless were allowed home.

The true-quantifier condition on weak crossover effects is therefore neither necessary nor sufficient.

Moreover, there is a parallelism between weak crossover phenomena and what Postal calls 'secondary strong crossover' data which remains entirely unexplained under the Lasnik & Stowell account. Despite the fact that (9)–(10) constitute 'strong crossover' examples, the pronoun being in an argument position c-commanding the *wh*-trace and being c-commanded by the *wh*-phrase as a whole, these too display the context-dependence characteristic of the weak crossover restriction in that, unlike other strong crossover examples, the restriction displayed in (9)–(10) is suspended under exactly the same circumstances as the weak crossover effect, as (11)–(12) demonstrate:[3]

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[2] A referee suggests that (8) is nothing more than a case of a definite, here demonstrative, NP in which weak crossover effects are lifted in virtue of the referential status of the head, an effect we address later. However *those*, though unarguably demonstrative and hence definite, is not acting as a referential expression as witness its omission in the rather more stilted (i):

(i) Most of the patients, in particular all who their doctor had said were harmless, were allowed home.

In particular it cannot be dismissed as an E-type use picking out the witness set that can be constructed from its antecedent *most of the patients*.

[3] Some examples of this category are unacceptable as observed in Higginbotham 1980:

(i) John_i, whose_i face he_i shaved, was bleeding profusely.

Given the acceptability of the indicated interpretation of (ii), we take this to be a nearness effect without structural significance:

(ii) John_i, whose_i face Sue said he_i was painfully aware was very ugly, didn't turn up for the photo session.

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(9) *Whose$_i$ mother$_j$ did you tell him$_i$ e$_j$ had refused the operation?
(10) *Whose$_i$ exam results$_j$ was he$_i$ certain e$_j$ would be better than anyone else's?
(11) John, whose$_i$ mother$_j$ I told him$_i$ e$_j$ had refused the operation, was very upset.
(12) John, whose$_i$ exam results$_j$ he$_i$ had been certain e$_j$ would be better than anyone else's, failed dismally.

Postal, wishing to preserve the semantic intuition of Lasnik & Stowell, refines it with a notion of scope domain saying that while extracted true quantifier phrases invariably give rise to weak crossover effects, extracted non-true quantifier phrases yield weak crossover effects only when the pronoun is in a 'scope island' not containing the extraction site, a scope island being a phrase that a quantifier phrase inside cannot take scope over. For example in (13)

(13) Every man's$_i$ mother adores him$_i$.

the subject noun phrase is not a scope island because (13) is wellformed under the indicated interpretation, but the subject noun phrase in (14) is a scope island because from a complement PP a quantifier phrase cannot take scope over a pronoun within the VP:

(14) *The mother of every man$_i$ adores him$_i$.

The ungrammaticality of (15) is thus predicted, *him* being contained in such a scope island:

(15) *John$_i$, who$_i$ a picture of him$_i$ has annoyed e$_i$, is complaining to the press.

However, as he himself points out, this is barely more successful than the Lasnik & Stowell suggestion in the light of the well-formedness of (16):

(16) John$_i$, who$_i$ a picture of his$_i$ mother has annoyed e$_i$, is complaining to the press.

whose acceptability is not affected by the fact that *his mother* is contained within the larger scope-island phrase *a picture of*. He suggests the further modification that the relevant restriction must refer to the pronoun's being in a minimal phrase that is a scope island. But this notably lacks the semantic basis observable in the Lasnik & Stowell account. And in any case, there remain the cases that despite being genuinely quantificational nevertheless do not give rise to weak crossover effects such as (8).

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Postal further brings to general attention data from French and the observation made by others that even a language in all relevant configurational respects identical to English nevertheless may display no weak crossover effects in relative clauses at all

(17) le médicin$_i$ que sa$_i$ femme a presenté e$_i$ a cette infirmière charmante
'the doctor who his wife introduced to that delightful nurse'

while nevertheless apparently retaining them in some focus constructions, such as (18):

(18) *C'est quelqu'un$_i$ d'autre que sa$_i$ mère a appelé e$_i$.
'It's someone else that his mother called.'

The conclusion Postal arrives at is that the weak crossover phenomenon remains deeply mysterious.[4]

This paper proposes an analysis within an interpretation-as-deduction framework that enables us to explain the crossover data without bifurcation into strong and weak (or indeed weakest) crossover. The account emerges as a consequence of general properties of the reasoning system and the assumption that interpretation is built up on a left-right basis. Far from assiduously removing all trace of linearity from the account, to the contrary it makes this a central pivot of the explanation. According to this deductive framework (which is introduced in section 2), interpretation of a sentence is projected as a goal-directed natural deduction task of reasoning. The general pattern builds on the well-established model of parsing-as-deduction over logical type specifications (Moortgat 1988; König 1989; Hepple 1990; Pereira 1990, 1991; Morrill 1994), but uses the added richness provided by introducing labels into the logical language to define concepts of natural language structure. Within this general perspective, analyses of *wh*-expressions, pronominals and relative clauses are presented in terms of the dynamics of the particular labelled deductive system, each of these analyses being set up as a direct reflection of the process involved in interpreting these structures in context. Section 3 shows that the analyses of the individual phenomena when taken together are sufficient to predict the array of crossover effects both weak and strong, without any extra ancillary construction-specific principle. The shift of perspective that this account requires is that the assignment of structure to a string is a dynamic process, sensitive to left-to-right incrementation of structure. Seen in orthodox terms,

[4] More recently, Hornstein (1995) has offered an explanation of weak crossover phenomena that purports to absorb the weakest crossover data as a subcase. His principal focus is on quantifier-pronominal dependencies. He does not take up the distinction between restrictive and nonrestrictive relative clauses, nor the problem of focus constructions. Furthermore, the account provides no basis for distinguishing the French and English data and does not extend to secondary strong crossover data. Given the data to be considered here, it would therefore at best be incomplete.

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this is a principle B account, defined in terms of the relation between the *wh*-expression and the pronominal, resting on the ancillary assumption that a reconstruction process transmits information about the *wh*-expression down through the tree clause by clause. But the perspective is new and should not be simply recast in old terms.

2. A Labelled Deductive System for natural language interpretation – LDS_{NL}

The background theoretical framework is a model of utterance interpretation being developed by Gabbay and Kempson (Gabbay & Kempson 1992; Kempson 1995a, b; Kempson, Meyer-Viol & Gabbay forthcoming, Kempson, Meyer-Viol & Gabbay in preparation). We are seeking to define a framework within which utterance interpretation can be modelled as an inferential yet structure-building process which allows integration of encoded constraints on interpretation and pragmatic processes such as anaphora resolution (cf. Marlsen-Wilson & Tyler 1981, Fodor 1983, Sperber & Wilson 1986, Kempson 1988, Partee 1989).[5] According to this model, utterance interpretation is a task of reasoning in a Labelled Deductive System which leads to progressive assignment of structure to a string on a left-right basis.

LDS is a very general logic methodology within which information about the proof instead of being informally recorded alongside the proof, as in a Fitch style of natural deduction, is incorporated into it as part of the logical system (Gabbay 1994, 1996). The basic declarative units have the form 'α:A', where α is a label and A a formula. A database Δ is a set of declarative units. Using inference rules, a database can prove declarative units, written:

$\Delta \vdash \alpha$:A

All rules, e.g. Modus Ponens, are defined over pairs of label-plus-formula, the set of premises $\{\alpha$:P, β: P$\rightarrow$Q$\}$ leading to conclusion $\mu(\beta,\alpha)$: Q with μ some operation on the labels relative to some extra restriction $\psi(\alpha, \beta)$ holding between α and β:

(19) $\rightarrow_{\psi,\mu}$ Elim: (Modus Ponens)

$$\frac{\alpha\text{:P} \qquad \psi(\alpha,\beta) \qquad \beta\text{:P}\rightarrow\text{Q}}{\mu(\beta,\alpha)\text{: Q}}$$

[5] Concepts such as cognitive effort and inferential effect needed to model the way in which actual choices of interpretation are made (Sperber & Wilson 1986), could in principle be defined within this framework, but this is not addressed here. There is also no attempt to model the larger process of deriving contextual implicatures. To extend the coverage of the present framework to include this process would involve nesting the present framework within a larger system (given the LDS methodology of defining how one logical system can be nested within another, this is not in principle problematic).

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The labels provide a local record of any information relevant to individual steps of the proof – assumptions used, pertinent semantic information, extra control devices further restricting the applicability of the rules, etc. The general methodology is to blur syntactic and semantic characterizations of inference by absorbing semantic (or other meta-level) information into the syntax of the system. The particular interpretation of the labels depends on the particular LDS.

In the LDS for natural language interpretation being developed by Gabbay and Kempson (Gabbay & Kempson 1992; Kempson 1995a, b), semantic constructs are given a proof-theoretic format; and steps of type deduction (Modus Ponens) are used to project interpretation of clause-sized units.[6] The formulae are the logical types $\mathbf{e}$, $\mathbf{t}$, $\mathbf{e \rightarrow t}$, $\mathbf{e \rightarrow (e \rightarrow t)}, \ldots$, corresponding to the syntactic categories DP, IP, intransitive verb, transitive verb, and so on. The labels to such formulae are the concepts expressed by words, expressions of a predicate logic. This logic of the labels contains predicate constants 'sing', 'see', 'smile', etc., names 'John', 'Mary', etc., and restricted variables of the form 'x, ψ(x)', each variable having an associated restriction on its range. These restricted variables are of two types, free and dependent (cf. section 2.3). There are also specialised place-holding metavariables (see below). The initial premises are projected from the lexicon. The operation μ on the labels for every step of Modus Ponens is functional application. These steps project databases of premises of the form (20):

(20) $\{\text{John}:\mathbf{e},\ \text{smile}:\ \mathbf{e \rightarrow t},\ \text{smile(John)}:\mathbf{t}\}$

The operations of the semantics (functional application) are thereby represented in the proof system alongside structural information while nevertheless retaining their separate identity as expressions of the labelling algebra. The effect is that for every step of Modus Ponens which eliminates type-structure in the formulae, conversely structure is increasingly built up in the labels.

The novelty of the general LDS framework is not merely in this co-presentation of different types of information, here syntactic and semantic, but in the freedom it provides to incorporate into the system extra restrictiveness in the inferences allowed without defining extra connectives.[7] For example, in developing an LDS for natural language interpretation, we may define the concept of subject proof-theoretically, with a restriction $\mathfrak{G}$ which when added to a label for a premise guarantees that that premise is to

[6] The pattern is an extension of the type-deduction familiar in categorial grammar formalisms, with semantic and syntactic information explicitly twinned as label and formula (cf. independent developments using such label-formula pairs by Moortgat 1995, 1997; Morrill 1994; Oehrle 1995).

[7] Gabbay & de Queiroz (1993) define a family of sub-structural logics through a fixed language of the formulae associated with labelling algebrae which impose a range of

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be used last in a minimal sequence of steps of Modus Ponens leading to a conclusion of type **t**. This definition of subject is the proof-theoretic analogue to Dowty's (1991) semantic characterisation ($\mathfrak{G}$ is a particular instance of ψ in μ-Modus Ponens as defined above). A simple example is (21):

(21) $\{(\text{John},\mathfrak{G}):\mathbf{e},\quad \text{saw}:\ \mathbf{e}\rightarrow(\mathbf{e}\rightarrow\mathbf{t}),\quad \text{Mary}:\mathbf{e}\}$

a set of premises from which two steps of Modus Ponens may establish the proposition expressed, with 'saw(Mary)(John)' as label to the formula **t**:

saw(Mary):$\mathbf{e}\rightarrow$t
saw(Mary)(John):**t**

Each clause is seen as a database conforming to the format of (21) – a set of premises containing one 'major' premise '$\beta:\mathbf{e^n}\rightarrow\mathbf{t}$', where $\mathbf{e^n}\rightarrow\mathbf{t}$ is $\mathbf{e}\rightarrow(\mathbf{e}\rightarrow\ldots(\mathbf{e}\rightarrow\mathbf{t})\ldots)$, plus a requisite number of 'minor' premises of the form '$\gamma:\mathbf{e}$', from which the outcome must be '$\alpha:\mathbf{t}$' for some α which is only established through the words as they are presented.[8] The words provide the assumptions, a pair of label and formula making up a single 'declarative unit', but they may also project additional information about how the database and its structure are to be projected – e.g., inflection determines which premise is to bear the annotation $\mathfrak{G}$ identifying it as subject (to be used last in the local database).[9] Clausal structure is then projected, as interpretation, from information given in the lexicon and steps of Modus

increasingly severe restrictions on the licensed inference steps. For example, the Linear Logic, restriction that each premise can be used once and once only can be expressed as the restriction that in a system in which each formula bears a label corresponding to its assumptions, the intersection of the labels in the pair of premises for which Modus Ponens is defined must be empty. This labelling methodology stands in contrast to the nonmodular approach of e.g. Linear Logic, in which the set of inferences licensed by such a more restricted sub-structural logic is captured through additional connectives, without labels.

[8] All noun phrases are presumed to project type **e** rather than the higher type $\mathbf{e}\rightarrow(\mathbf{e}\rightarrow\mathbf{t})$ standard since Montague (1974). This is on the assumption that determiners project variables of different kinds (cf. below and sections 2.2.1–2.3). We also assume that steps of deduction lead invariably to conclusions of type **t**. This presumes that the process of combination internally to noun phrase constituents is a process of unification internal to a given declarative unit, and is not one of type deduction. This assumption is replaced in a more recent formulation (Kempson, Meyer-Viol & Gabbay forthcoming) by the assumption that databases may be of arbitrary type and steps of deduction yield conclusions of type **e** as well as of type **t**.

[9] As is wellknown, the factors that identify subject, here the annotation of some premise as $\mathfrak{G}$ (= 'use last in local database'), vary from language to language. In some the information is encoded direct as a morphological case marker on the noun/determiner/suffix itself, in some it is identified solely from the word order, in others it is dependent purely on contingent information associated with the predicate selected. The definition of subject as a restriction on a process, incidentally, allows a simpler characterization of so-called free word order languages since no VP node needs to be posited a priori as a means

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Ponens in a conditional logic with labels. Each database also bears a label. So databases also take the form 's:A', where 'A' is a set of declarative units and this label 's' provides extra information about the inferential properties of the collection of premises as a unit. Following Finger & Gabbay (1993), who developed a natural deduction system for temporal logic with 't_1:A' taken to stand for 'A is true at time t_1', the database label is construed as specifying the time at which the conclusion derived from the set of premises is projected as holding. This label is projected from inflection on the verb. There is parallelism here with the use of Davidsonian event variables, but unlike either Davidsonian or DRT accounts, the structure is not flat – the label has a status as label to the database not shared by other variables internal to that database.[10] All information projected by the words that gives rise to this database configuration must be used once and once only, a restriction that means the logic has the restrictiveness of linear logic.

For a system to provide a base for modelling how utterances are assigned an interpretation, there is one essential ingredient over and above the projection of structure for a string: it needs a reconstruction of the phenomenon of context-dependence of natural-language input. Natural languages all display what Barwise & Perry (1982) called 'the efficiency of language' – licensing the use of a single expression to project many different interpretations, the intrinsic content of the expression being systematically weaker than the interpretation assigned to it in context. This phenomenon is a defining characteristic of natural-language systems, as has been emphasised within the paradigms of Situation Semantics (Barwise & Perry 1982), Discourse Representation Theory (Kamp 1981, Kamp & Reyle 1993) and Relevance Theory (Sperber & Wilson 1986) since the early '80's. Pronominals are a central and wellknown example. They are units of information whose intrinsic content radically underdetermines their interpretation: there is nothing in a pronoun that dictates its construal as a bound variable – (22), as an instance of discourse coreference – (23), as an E-type pronominal – (24), or as a result of a step of implicature – (25):

(22) Every male contestant$_i$ hopes that he$_i$ will not be tested for drugs.
(23) John$_i$ came in. He$_i$ said that Mary was sick.
(24) Most people$_i$ came to the party. They$_i$ had a good time.
(25) A (to B, who is paranoid about his newly separated wife):
I'm having a party. Don't worry. She won't be there.

If the context-dependency in the interpretation of pronominals is to be more

of projecting/licensing the subject/object constituent. The characterisation of VP as a constituent emerges solely from the steps of Modus Ponens deriving 'β:$\mathbf{e} \rightarrow \mathbf{t}$'.

[10] In the main the representation of tense is ignored, as not central to this paper.

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than merely described, then the preferred analysis should posit a single linguistic specification for each morphological pronoun,[11] the varying forms of interpretation being explained in terms of the way choices become available within a given context of use.[12] The labels provide a natural basis for representing this concept of under-determined information, for we can say that an expression projects a fully specified type but that its label may be incompletely specified. The completion of any such label involves a choice by the hearer of some other label antecedently made available (either by direct presentation in the discourse (22)–(23), or by inference (24)–(25)). To express this underspecification, the labelling algebra will be defined to contain a range of specialised metavariables distinguished according to the range of labels they may be instantiated by. In the case of pronouns we shall say that pronouns project information about their logical type but otherwise only a distinguished metavariable (here listed as '$\mathbf{u}_{\mathrm{pro}}$') with a constraint on identifying the label to be paired with this type.[13] This constraint on the instantiation function that identifies this label is a locality constraint which stipulates that if the pronoun is projected as label to a minor premise (i.e. is of the form '$\mathbf{u}_{\mathrm{pro}}$:$\mathbf{e}$'), then the value of the metavariable $\mathbf{u}_{\mathrm{pro}}$ may not be selected from a label to another minor premise in the same constellation of minor premises within a single database (in more orthodox terms, a pronoun as argument to a verb (or adjective) may not be identified with any co-argument in the same complete functional complex). This constraint apart, the choice of antecedent for a pronoun is a pragmatic choice governed solely by pragmatic restrictions induced by presumption of the principle of relevance (cf. Sperber & Wilson 1986). In other words, the effect of principle B is modelled as a constraint on the pragmatic process of choosing what representation to select as constituting the interpretation of the pronoun in that particular context of use. The choice of label is part of the process of establishing α:$\mathbf{t}$ but has to be chosen from other labels of appropriate type that are accessible from within the overall discourse structure as it is incrementally built up.

[11] This assumption is not uncontroversial. Cf. Fiengo & May (1994, 1996), who argue that sentences containing pronominal elements are systematically formally ambiguous according as they receive different assignments of indices. Since this assumption precludes the possibility of characterizing the under-determinacy intrinsic to natural-language expressions, choosing rather to characterise anaphoric expressions as displaying very considerable linguistic ambiguity, we do not adopt it here.

[12] The consequence of assuming a unitary linguistic specification for a given morphological pronoun, with the choice of antecedent for all pronouns being invariably pragmatic and made on-line, is that locality restrictions on bound-variable construals of a pronoun will have to be a consequence of determiner-specific restrictions on the availability of the variable the determiner projects. Cf. section 2.3. and fn.23.

[13] Metavariables, which are place-holders standing proxy for the label to be assigned, will be invariably represented in bold face.

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2.1 Wh-*expressions and Goal-directed deduction*

If we add an explicit element of goal-directedness to this very simple system, we find a pattern remarkably similar to that displayed by *wh*-structures. Initial *wh*-expressions act as though they were specifications of a goal to be achieved in the deductive process. To see this consider the proof (26).

(26) $P\rightarrow(Q\rightarrow R) \vdash Q\rightarrow(P\rightarrow R)$

1	α: $P\rightarrow(Q\rightarrow R)$		GOAL $Q\rightarrow(P\rightarrow R)$
2	β: Q	Assumption	GOAL $P\rightarrow R$
3	γ: P	Assumption	GOAL R
4	$\alpha(\gamma)$: $Q\rightarrow R$	Modus Ponens	
5	$\alpha(\gamma)(\beta)$: R	Modus Ponens	
6	$\lambda x\ \alpha(x)(\beta)$:$P\rightarrow R$	$\rightarrow$ Intro. Discharge (3)	
7	$\lambda y \lambda x\ \alpha(x)(y)$: $Q\rightarrow(P\rightarrow R)$	$\rightarrow$ Intro. Discharge (2)	

(The labels in this proof are arbitrary – they provide a name for the premise which can be used to display how the premises applied. $\rightarrow$Introduction involves retraction of an assumption, a step which is recorded in the accompanying label as λ-abstraction.[14] It is not otherwise used in this paper.)

Two properties of goal-directed reasoning stand out:

(A) To specify some goal and elements to be contained in that goal does not constitute achieving it or having those elements. P and Q are not elements of the proof in (26) in virtue of being elements of the goal: no more are R, and indeed $Q\rightarrow(P\rightarrow R)$. Such elements only become parts of the proof as they are assumed or derived.

(B) The properties of the goal, together with the rules of the system, determine the form of subordinate routines to be set up in achieving that goal. Hence the goal is reflected in the subordinate routines within the tree structure that direct the path to be followed in getting to that goal. In other words, to show a goal G with label α, i.e. show 'α:G', we enter a subcomputation, the rules and nature of which depend on α and on G. Here

[14] This correspondence between a step of λ abstraction and of Conditional Introduction is a reflection of the so-called Curry-Howard isomorphism between the lambda calculus and intuitionistic logic (cf. Morrill (1994) for a recent account of this correspondence).

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in a conditional logic system, the effect is that each subformula explicitly represented in the goal is carried down within the representation of subordinate goals until the subroutine of assuming or deriving the subformula succeeds in achieving the step involving that subformula necessary for the eventual success in achieving the overall goal.

These two properties display a striking parallelism with *wh*-expressions in *wh*-initial languages such as English. The initial *wh*-element is exceptional as a constituent in not being visible, for example, for purposes of anaphoric dependency from the point of its occurrence in the string. Simplifying somewhat, it only becomes visible once the gap is established. This is the basic crossover pattern, parallelling property A above:

(27) *Who$_i$ does Joan think that he$_i$ worries e$_i$ is sick?
(28) Who$_i$ does Joan think e$_i$ worries he$_i$ is sick?
(29) *Who$_i$ does Joan think that his$_i$ mother worries e$_i$ is sick?
(30) Who$_i$ does Joan think e$_i$ worries his$_i$ mother is sick?

Other putative argument expressions intervening between the *wh*-expression and the pronominal may provide an antecedent, such as the correspondents to PRO or parasitic gaps, but crucially the occurrence of the *wh*-expression itself in initial position does not.

Secondly, the information about that initial *wh*-element gets carried down clause by clause until the point at which the gap is constructed (and no further). This is the basic reconstruction pattern, parallelling the property B above:

(31) Which pictures$_j$ of herself$_i$ did Bill say Sue$_i$ was planning to sell e$_j$.
(32) *Which pictures$_j$ of herself$_i$ did Bill say John was planning to sell e$_j$ to prevent Sue$_i$ giving them$_j$ away?

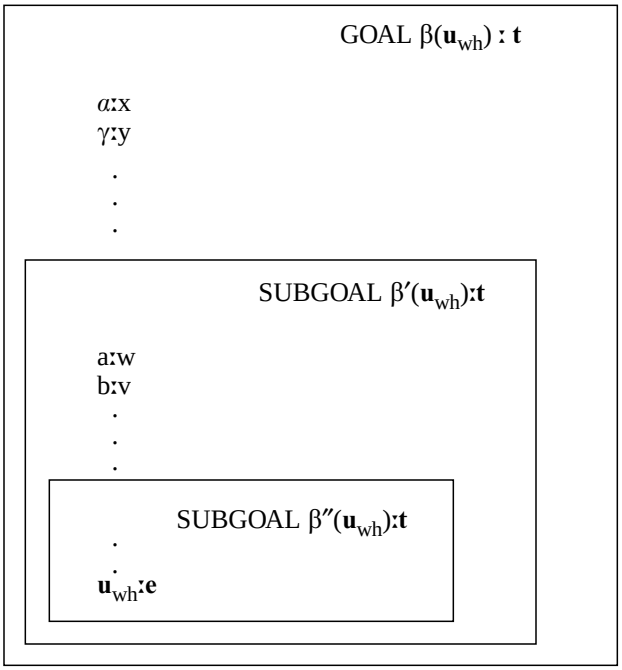
As (31) shows, the information of an antecedent-seeking anaphor may be carried down past some expression, here *Sue*, and be able to identify this expression as its antecedent. However, as (32) shows, such information cannot be presumed to carry on past the gap and be identified from some following NP expression, even when a pronoun occurs yet lower in the tree construed as dependent on the gap, and so in some sense also projects information pertaining to the anaphor.

If following this pattern of goal-directed proofs, we analyse *wh* as an initiator of a specifically goal-directed task – the task of constructing a 'gap' as assumption – we will predict this distribution in a principled way, for the information about the nature of the goal as expressed by the *wh*-expression will be automatically transferred through the configuration database by database (= clause by clause) until the point at which the requirement can be

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realised. We might present this schematically in the metabox format as in (33):

(33)



β, β' and β'' are variables standing in for some function composed from the words to be presented. The $\mathbf{u}_{wh}$ (to be read as 'gap') is a place-holding meta-variable as label to a formula of type **e** that must be constructed at some point during the interpretation process in order for the goal specification to be met, and the string licensed as wellformed. (This metavariable $\mathbf{u}_{wh}$ is instantiated either by the hearer in answer to the question, or, in relative clauses, by a unification device linking labels, of which more later – section 2.2). The rules of the system requiring all premises to be used will require that '$\beta(\mathbf{u}_{wh})$' is not itself carried down to subgoals '$\beta'(\mathbf{u}_{wh})$' or to '$\beta''(\mathbf{u}_{wh})$' for the words in each database must be used once and once only. Nevertheless the overall goal and subgoals have an essential shared element – namely the need at some point to construct the assumption corresponding to the gap.

To adopt this pattern in analysing *wh*-structures we shall require clause-sized units not merely to contain premises combining together by Modus Ponens but also to contain a goal specification that is not part of the database but a look-ahead device dictating what has to be done. In the simple case, the goal will simply be to deduce 'α:**t**', with α unspecified, but *Who does John*

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like?, for example, will get projected as in (34), with the initial *wh*-expression projecting the requirement of the enriched goal specification that some premise with the label $\mathbf{u}_{wh}$ be constructed and through steps of Modus Ponens yield a conclusion containing an occurrence of $\mathbf{u}_{wh}$ in its accompanying label:

(34) s_i:

		GOAL $\beta(\mathbf{u}_{wh})$:**t**
John, 𝔊	:	**e**
like	:	**e**→(**e**→**t**)
$\mathbf{u}_{wh}$	:	**e**
like ($\mathbf{u}_{wh}$):		**e**→**t**
like($\mathbf{u}_{wh}$)(John):		**t**

𝔊, recall, is the annotation marking the premise 'John:**e**' as to be used last in reaching this target. $\mathbf{u}_{wh}$ is a place-holding metavariable which has to be instantiated by some discrete expression of the labelling algebra, either in questions as projected from the answer (hence provided by the hearer) or, in relative clauses, through unification with the label projected by the determiner heading the whole noun phrase constituent (cf. section 2.2).[15]

As we can see from (34), *wh*-expressions in *wh*-initial languages have a distinguished status according to this analysis. They do not themselves project an assumption in the database, but merely a license to construct an assumption with a special label '$\mathbf{u}_{wh}$:**e**' (to be read as 'gap labelling type **e**') within the given proof domain that they initiate. Where that assumption is to be constructed is dictated by the sequence of words themselves. If both the goal specification and the requirement that information projected by all words be used once and once only are to be met, there must be just one point at which the requirements imposed by a word are not met by its neighbouring elements. This point is identifiable as the point at which a given type requirement imposed by a lexical item currently being interpreted cannot be satisfied by the following input sequence. In (34), this is exemplified by the null sequence following *like*. *Like* requires some assumption '*:**e**', for arbitrary *, a restriction which is met by constructing the needed assumption.

If in interpreting some initial string of words, the sequential projection of declarative units from the words does not create the possibility of constructing the assumption corresponding to the gap, and the words

[15] The database label s_i carries information projected by tense, here left on one side. This format can equivalently be set out in a tree configuration, in which nodes are distinguished according to the role entries in the database play in the proof process. This enables restrictions on interpretation (such as the analogue of the Binding Principle B) to be straightforwardly defined in terms of the database configuration licensing such dependencies (cf. p. 7). In this paper we omit all details of lexical specifications (cf. Kempson, Meyer-Viol & Gabbay forthcoming for the development of a formal definition of this meta-level process of incremental interpretation).

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present, rather, the need for a nested database labelling **t** as with the propositional attitude predicates *say*, *think*, etc., for which databases are required of the form in (35):

(35) s_i : ..... think: **t**→(**e**→**t**) s_j : [ ] : **t**

the principal goal as yet unrealised in s_i will have to be analogously carried down to s_j if it is to be met. Hence we get the pattern analogous to (26) in the interpretation of (36), which can be set out as a series of steps building up a database, as in (37):[16]

(36) Who do you think Bill likes?

(37)

STEP			
1	s_1:	GOAL $\beta(\mathbf{u}_{wh})$:**t**	
2		you, **G**:**e**	
3		think:**t**→(**e**→**t**)	
4	s_2:	SUBGOAL $\beta'(\mathbf{u}_{wh})$:**t**	
5		Bill, **G**:**e**	
6		like:**e**→(**e**→**t**)	
7		$\mathbf{u}_{wh}$:**e**	
8		like ($\mathbf{u}_{wh}$):**e**→**t**	MP 6,7
9		like($\mathbf{u}_{wh}$)(Bill):**t**	MP 5, 8
10		think (s_2,like($\mathbf{u}_{wh}$)(Bill)):**e**→**t**	MP 3,9
11		think (s_2,like($\mathbf{u}_{wh}$)(Bill))(you):**t**	MP 2, 10

In (37), steps of Modus Ponens (steps 8–9, 10–11) first derive the conclusion to the innermost database with the label projecting the propositional structure, and then successively the final conclusion 'think(like($\mathbf{u}_{wh}$)(Bill))(you):**t**'. This result simultaneously assigns an interpretation to *Who do you think Bill likes*? and fulfils the goal '$\beta(\mathbf{u}_{wh})$:**t**' imposed as a target by the

[16] For a given single database array of premises, there is one and only one position at which the required assumption can be constructed. The task of identifying the trace site in interpreting a given string becomes that of identifying the appropriate database configuration, in the case of ambiguity there being more than one such array. The concern in this paper is to outline the framework within which interpretation is projected, and accordingly, all problems of disambiguation are ignored. We simply assume that the very considerable problems posed by potential nondeterminism in the interpretation task can be solved by least effort constraints integral to the language processing task, given relevance considerations (cf. Sperber & Wilson 1986 and elsewhere).

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initial word in the string. Technically, the derivation is not quite this simple. An extension of Modus Ponens is necessary to allow its application at step 10 in (37), for we have a whole database deriving the type **t** at step 9. What is needed is to ensure that it is only the conclusion derived from this database that gets carried up by Modus Ponens and not the database-structure itself. This is achieved by defining a so-called 'metadeclarative unit' where a metadeclarative unit is defined as any database of premises Δ that uniquely prove some conclusion '$\alpha:A$', a concept that applies equally to 'Mary:**e**', which trivially proves itself, and some database of premises that nontrivially proves some conclusion. Modus Ponens is then defined in the neutral terms of metadeclarative units. We say $\Delta \vdash \alpha:A$ uniquely if Δ proves it using exactly all its assumptions exactly once:[17]

(38) *Modus Ponens* (*for metadeclarative units*)

$$\frac{\Delta:A \quad \Delta':A \rightarrow B}{\beta(\alpha):B} \quad \text{where} \quad \begin{array}{l} \Delta \vdash \alpha:A \\ \Delta' \vdash \beta:A \rightarrow B \end{array}$$

The change in the revised Modus-Ponens format is that the input to the rule is in terms of meta-declarative units, the output as before in terms of a declarative unit whose label solely reflects the semantic mode of combination.

The overall perspective thus adopted is that interpretation is the target-driven incremental projection of database configurations from the input provided by lexical specifications through to a conclusion satisfying the imposed target as goal.[18] This analysis of *wh*-initial expressions as a goal specification, rather than a straightforward premise contributing its

[17] Uniqueness of the derivation for a given database presenting an interpretation of the string is guaranteed by annotations such as '$\mathfrak{G}$' = 'use last', and the fact that unlike categorial grammars, no processes of type-lifting or composition of functions are allowed in this system.

[18] Gabbay, Kempson & Meyer-Viol (in preparation) and Kempson, Meyer-Viol & Gabbay (forthcoming) interpret utterance interpretation as a goal directed task of deduction in a stronger way, assuming that an imposed task to establish type X in the face of some discrete type Y imposes an introduction rule inducing two subgoals, to establish type Y and type $Y \rightarrow X$ (cf. fn. 8). This system of twinned introduction and elimination rules incrementally projects a tree describable by a modal tree-logic (Blackburn & Meyer-Viol 1994, Blackburn et al. 1995). This richer and more explicit structural projection of premises in a database enables us to characterise such initial positions in a string as underspecifying the structural relation holding between them and their neighbouring constituents. This completes the picture of potential underspecification of natural language sequences vis a vis their interpretation, for on this view natural language expressions may underdetermine both the content projected from them and the structural role which they contribute to the whole. On the simpler and more informal view put forward in this paper, the underspecification of the structural role which an expression may contribute to the whole in virtue of being part of some goal specification remains implicit only.

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interpretation from its position in the string, will be the heart of the analysis that follows.

2.2 *Linked databases and relative clause adjunction*

The system so far outlined has assumed only that databases of premises may be nested one within the other. Within this limitation, we have outlined an account of how clausal interpretations are projected, how the phenomenon of anaphora resolution can be modelled, and how *wh*-questions are interpreted. To be able to address the problem of crossover however, we shall need to add an account of relative clause modification – as clause adjunct structures. All standard analyses of relative clauses take the restrictive relative construal interpretation as basic, providing special stipulation for nonrestrictive construals. However, if we look at relative clauses from a processing perspective, it is the nonrestrictive construal of a relative clause which provides the most transparent case.

Seen as a means of incrementally compiling information, relative clauses are optional clausal units of information that can be added in to some host clause:

(39) John who adores Mary left Sue.
(40) The idiot who adores Mary left Sue.

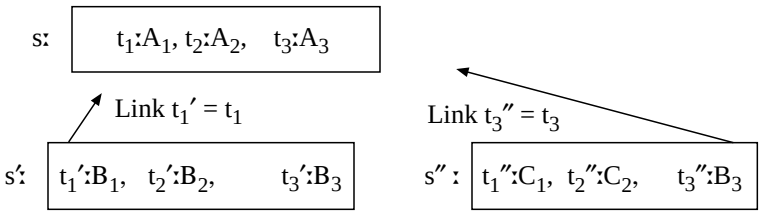
The relative clause in (39) for example simply provides a means of adding extra information about John into the database projected from the string *John left Sue*; and (40) differs from it only in that in (40) the predicate projected by the word *idiot* and the predicate projected from *who adores Mary* have somehow to be combined together.

The LDS notation provides a means of modelling this compiling of information from two independent databases according to a pattern taken directly from the LDS for modal logic (Finger & Gabbay 1993), in which relations between locally distinct databases of premises are defined through labels assigned to databases.[19] One such relation licensed in the present system is that of LINK. A LINKed pair of databases is a pair of databases that are independent of each other apart from the fact that a label in the one database is fixed as identical with another label appearing in the other. (Usually a variable **u** in one database is chosen to be equal to a label in another.) Diagrammatically in (41), t_1' is linked to t_1, t_3'' to t_3:

[19] Finger & Gabbay (1993) define a labelled deduction system for modal logic with labels for worlds and accessibility relations between worlds expressed as relations holding between labels expressed in the labelling algebra.

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(41)



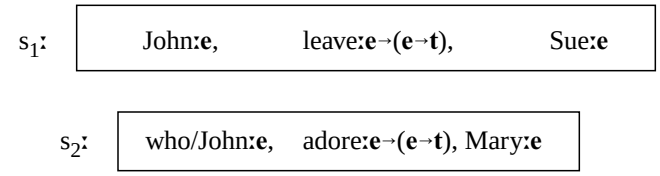
The relation LINK is defined for a pair of databases, one containing a distinguished meta-variable '$\mathbf{u}_{wh}$':

(42) LINK($\Delta(t_i:A)$, $\Delta'(\mathbf{u}_{wh}:A')$, $\mathbf{u}_{wh}/t_i$) – $\mathbf{u}_{wh}$ in Δ' is linked to t_i in Δ:
For a database Δ containing at least 1 occurrence of '$t_i:A$', Δ' a discrete database containing at least 1 occurrence of '$\mathbf{u}_{wh}:A$' in which '$\mathbf{u}_{wh}$' is a place-holding meta-variable, 't_i' unifies with '$\mathbf{u}_{wh}$', 't_i' as the most general unifier replacing all occurrences of '$\mathbf{u}_{wh}$'.

For any database Δ, $\Delta \subset \Delta''$, if LINK(Δ, Δ'), then LINK(Δ'', Δ'). If Δ and Δ' are labelled, we use the labels as names. So we can talk of LINK holding between databases '$\{\alpha:\mathbf{e}\}$', '$\{\mathbf{u}_{wh}:\mathbf{e}, \ldots\}$', or between '$s_1(\alpha:\mathbf{e})$', '$s_2(\mathbf{u}_{wh}:\mathbf{e})$', where s_1 labels a database containing '$\alpha:\mathbf{e}$', and s_2 labels a database containing '$\mathbf{u}_{wh}/\alpha:\mathbf{e}$'.

It is this pattern of linked databases that we adopt for relative clause modification. Following the pattern of (41) we can schematically represent (39) (ignoring tense) as two independent databases, linked through the construal of *who* as identical to the label projected by *John*:

(43)



The critical property of such linked databases is that they are independent save only for forced agreement with respect to two labels.

This informal sketch of relatives can be modelled directly by analysing who_{rel} as having a lexical specification that initiates the building of a new database with a goal specification that an assumption of the form '$\mathbf{u}_{wh}:\mathbf{e}$' be constructed, with the extra restriction that $\mathbf{u}_{wh}$ be identified with the label in the host database from which the construction of the new database is initiated to create a LINK relation between the two databases. In effect the content of the head nominal is copied over to the new database in which it must be used as a constructed assumption. Such a lexical specification will

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induce the sequence of steps in (44) in processing *John who adores Mary* as the first part of (39), steps 3–5 fulfilling the target specification imposed at step 2.

(44) STEP 1 s_1 | John:**e** | GOAL α:**t**

2 s_2 | GOAL $\beta'(\mathbf{u}_{wh})$:**t**
LINK (s_1(John:**e**), $s_2(\mathbf{u}_{wh}$:**e**), $\mathbf{u}_{wh}$/John)

3 $\mathbf{u}_{wh}$/John, $\mathfrak{G}$:**e**
4 adores:**e**→(**e**→**t**)
5 Mary :**e**

At step 2 in (44), the new database is initiated with an output condition imposed that not only must there be some minor premise '$\mathbf{u}_{wh}$:**e**' in this new database, but the value of the variable $\mathbf{u}_{wh}$ is to be fixed as identified by the label projected by *John*. Then, at step 3, as in (34), this condition combines with information projected by the verb that before it in the database should be a premise marked as 'use last', to determine that the assumption '$\mathbf{u}_{wh}$:**e**', with $\mathbf{u}_{wh}$ unified with 'John', must be constructed as the first entry in the database. A database deriving 'adore(Mary)($\mathbf{u}_{wh}$/John)' thus results, meeting the imposed target specification. The projection of interpretation for (39), as partially given in (44), is then completed in three steps: (i) the addition of the two further premises 'leave:**e**→(**e**→**t**)', 'Sue:**e**', (ii) the identification of 'John:**e**' as to be annotated as $\mathfrak{G}$ (= 'use last') in virtue of agreement on *leave*, and (iii) the resulting derivation of an interpretation of (39) as 'leave(Sue)(John) & adore(Mary)(John)'. In sum, this is a 'copy' analysis of relative clauses, the *wh*-complementiser being defined to be a copy of the head. The surprise, as we shall now see, is that this copy analysis of nonrestrictive relative clauses can be extended to restrictive relatives, given independent requirements on the account of determiners that is needed. The result will be a process-oriented analysis of relative clauses in which the interpretation of the two types of relatives emerges from the order in which available choices are made in the interpretation process.

2.2.1 *Determiners and relative clause modification*

The problem posed by determiners is that some determiners display context-dependent properties parallelling pronouns.The determiner *the*, for example, has properties parallel to pronouns, with uses that range over indexical, anaphoric, bound-variable, and E-type (amongst others):

(45) The door creaked.
(46) I couldn't get out of the car. The door was jammed.

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(47) Every house I put on the market I have checked to make sure that the house is problem-free.

(48) Every time I put a house on the market, I check that the house is problem-free.

This suggests that the definite article, like a pronoun, should be analysed in terms of some input metavariable with choice of a value for that variable to be made in context. Indeed the primary difference between definite NPs and pronouns lies in the predicate that is projected by the nominal content associated with the determiner as the restriction on the instantiation of that variable. Thus for example *the door* is said to project a metavariable $\mathbf{u}_{\text{the}}$ whose value has to be chosen in context given the restriction that the value to be selected must denote an individual bearing the property 'door' – represented as '$\mathbf{u}_{\text{the}}$, door($\mathbf{u}_{\text{the}}$)'.[20]

Such a predicate may however be recursively complex, as in (49), requiring a database structure which is projected through relative clause modification:

(49) The door which was open creaked.

The process of constructing complex restrictive predicates from relative clauses is modelled as the building of an ancillary database LINKed to the database containing the expression lexically projected from the nominal sequence so far interpreted without the metavariable $\mathbf{u}_{\text{the}}$ having yet been identified. If the new linked database configuration is to contribute to the restriction on the determiner in (49), it is the metavariable with its partially defined restriction, '$\mathbf{u}_{\text{the}}$, door($\mathbf{u}_{\text{the}}$)', which must get copied over to the ancillary database, and a linked database configuration then duly built to yield 'open ($\mathbf{u}_{\text{the}}$, door($\mathbf{u}_{\text{the}}$))'. In order to yield an output in which these two predicates combine to create the composite form '$\mathbf{u}_{\text{the}}$, door($\mathbf{u}_{\text{the}}$) & open ($\mathbf{u}_{\text{the}}$)', this newly built database must then be collapsed into a complex restriction on the metavariable within the initial database. The rule required

[20] This representation '$\mathbf{u}_{\text{the}}$, man($\mathbf{u}_{\text{the}}$)' is an abbreviation for a condition on the instantiation of the unrestricted variable $\mathbf{u}_{\text{the}}$ that its value must be some α such that 'man(α)' holds. With this definition in mind, we allow systematic representation of metavariables both with and without restrictions. Additional constraints may be imposed. However in the case of the determiner *the* and its associated metavariable $\mathbf{u}_{\text{the}}$, arguably no such additional constraint is required. Unlike pronouns, the potential richness of this predicate encourages the identification of the required value through inference, since a pronoun would suffice to ensure identification of some antecedent which is explicitly immediately accessible (cf. Ariel 1990 for the different accessibility conditions on antecedents of pronouns and definite NPs, and Matsui 1994 for a relevance-theoretic account of bridging cross-reference). A definite NP may also allow the construction of a new name m_{j} if the predicate is rich enough to serve as a basis for creating a new concept so named, an option also not available for pronouns. Pronouns and definite determiners may be argued to have different locality conditions on the process of instantiating their respective metavariables reflecting this difference, but this we ignore.

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applies to a pair of a database comprising a single declarative unit and a database linked to it, and is defined over metadeclarative units:

(50) *The Link Inference Rule*
$\Delta \vdash (\mathbf{c}_i, \quad (\mathbf{c}_i)) : \mathbf{e}$, $\Delta' \vdash \psi(\mathbf{v}_{wh}) : \mathbf{t}$

$(\mathbf{c}_i, \quad (\mathbf{c}_i) \ \& \ R_{\Delta'}\ (\mathbf{c}_i)) : \mathbf{e}$ provided that:
LINK $(\Delta((\mathbf{c}_i, \quad (\mathbf{c}_i)) : \mathbf{e}), \Delta'(\mathbf{v}_{wh} : \mathbf{e}), \mathbf{v}_{wh}/(\mathbf{c}_i, \quad (\mathbf{c}_i)))$ for $\mathbf{c}_i$, $\mathbf{v}_{wh}$ metavariables ranging over expressions of type $\mathbf{e}$, $R_{\Delta'}\ (\mathbf{c}_i)$ is intended to be $\psi(\mathbf{c}_i)$

The rule (50) follows the same format as the earlier extension of Modus Ponens. The input to the rule is in terms of metadeclarative units – the declarative unit trivially proving '$(\mathbf{c}_i, \quad (\mathbf{c}_i)) : \mathbf{e}$', and the database Δ' proving '$\psi(\mathbf{v}_{wh}) : \mathbf{t}$'. The output is a labelled formula, the label '$(\mathbf{c}_i, \quad (\mathbf{c}_i)\ \Delta\ R_{\Delta'}\ (\mathbf{c}_i))$' incorporating the predicate established from the conclusion '$\psi(\mathbf{v}_{wh}) : \mathbf{t}$' derived from Δ'. The rule is restricted to a pair of databases Δ, Δ' containing respectively an arbitrary meta-variable of type $\mathbf{e}$ and a $\mathbf{v}_{wh}$ metavariable, and so will only apply in derivations leading to a restrictive construal of relative clauses.[21]

Applying (50) to the process of modelling the interpretation of (49), we have at the point at which the relative clause is completed in (49):

$\Delta = \{(\mathbf{u}_{the}, \text{door}(\mathbf{u}_{the})) : \mathbf{e}\}$
$\Delta' = \{\mathbf{u}_{wh}/\ (\mathbf{u}_{the}, \text{door}(\mathbf{u}_{the})) : \mathbf{e}, \text{open} : (\mathbf{e} \rightarrow \mathbf{t})\}$

These two combine to yield

$(\mathbf{u}_{the}, \text{door}(\mathbf{u}_{the}) \ \& \ \text{open}(\mathbf{u}_{the})) : \mathbf{e}$

The resulting complex restriction can then serve to identify the required name denoting an individual entity picked out by this predicate (possibly by constructing some new arbitrary name, m_j). With the addition of the predicate 'creak : $\mathbf{e} \rightarrow \mathbf{t}$' we finally complete the initial database to derive an interpretation for (45) as:

$\text{creak}(m_j, \text{door}(m_j) \ \& \ \text{open}(m_j)) : \mathbf{t}$

(51) provides a full display of the process of projecting an interpretation using rule (50). The interpretation is a restrictive construal of (40). The steps of derivation are listed in the left-hand column:

---

[21] This process serves to guarantee that variables introduced and free within a given proof domain are only available in that proof domain (witness the ungrammaticality of **Every man, who I admire, ignores me*). Cf. fn. 20 for the systematic variation in representation of metavariables as restricted and unrestricted.

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(51) STEP

s_1:

GOAL α:**t**

1 ($\mathbf{u}_{the}$, idiot($\mathbf{u}_{the}$)), $\mathfrak{G}$:**e**
8 ($\mathbf{u}_{the}$, idiot($\mathbf{u}_{the}$) & adore(Mary)($\mathbf{u}_{the}$)),$\mathfrak{G}$:**e**
9 CHOOSE $\mathbf{u}_{the} = m_j$ (for m_j constructed logical proper name)
10 leave:**e**→(**e**→**t**)
11 Sue:**e**
12 leave(Sue):**e**→**t**
13 leave(Sue)(m_j,idiot(m_j) & adore(Mary)(m_j)):**t**

2 s_2:

GOAL $\beta(\mathbf{v}_{wh})$:**t**

LINK (s_1(($\mathbf{u}_{the}$, idiot($\mathbf{u}_{the}$)):**e**), s_2($\mathbf{v}_{wh}$:**e**), $\mathbf{v}_{wh}$/($\mathbf{u}_{the}$,idiot($\mathbf{u}_{the}$)))

3 $\mathbf{v}_{wh}$/($\mathbf{u}_{the}$, idiot ($\mathbf{u}_{the}$)),$\mathfrak{G}$:**e**
4 adore :**e**→(e→t)
5 Mary :**e**
6 adore(Mary):**e**→**t**
7 adore(Mary)($\mathbf{v}_{wh}$/$\mathbf{u}_{the}$, idiot ($\mathbf{u}_{the}$)):**t**

At step 1, the determiner projects its associated metavariable and the accompanying nominal provides the restriction on the value to be assigned that variable (this combination of information projected by determiner + nominal is achieved through unification and not by type-deduction). At steps 2–7, a database is built to the format '$\beta(\mathbf{v}_{wh})$:**t**' with $\mathbf{v}_{wh}$ identified with some label α in the original database, here α = '$\mathbf{u}_{the}$, idiot($\mathbf{u}_{the}$)', taken from the label of the premise at step 1. (Notice at step 2, the required linkage between s_1 and s_2 is stated as an output condition that the overall derived structure must meet.) Once the linked database structure is built, then the next step, step 8, is to construct the resulting complex predicate on the variable α in the initial database. Once this step is taken, a value for the metavariable '$\mathbf{u}_{the}$,idiot($\mathbf{u}_{the}$) & adore(Mary)($\mathbf{u}_{the}$)' can be selected at step 9; and some logical proper name uniquely denoting an individual meeting the description 'idiot($\mathbf{u}_{the}$) & adore(Mary)($\mathbf{u}_{the}$)' is duly chosen (or constructed) as the value of the metavariable. Steps 10–13 complete the initial database. The result is an analysis of a restrictive relative clause construal in terms of a metavariable plus a restriction on the range of its chosen value as projected through a process of linked database construction.

We have an account of both restrictive and nonrestrictive relative construal, in terms of the projection of a linked database configuration in which information is transferred from one database into another. The difference between nonrestrictive and restrictive relative clause construals for a single sequence of words can now be seen to result solely from variation in the order of two tasks which the hearer has to carry out in projecting an

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interpretation for the string in the light of signals (characteristically prosodic) provided by the speaker. The two tasks are:

(i) the building of the linked database structure,
(ii) the identification of the meta-variable projected by the determiner.

The element of choice lies in which of these tasks the hearer should do first. If the hearer chooses to build the linked database-structure first, a restrictive construal results, as in (49). If the value of the metavariable $\mathbf{u}_{\text{the}}$ is chosen before the building of the linked database-structure, the identification of a value for the initiating metavariable will have to be made as an indexical choice immediately upon presentation of the nominal predicate, and a nonrestrictive construal results as in (52):

(52)

STEP	s_1	GOAL α:**t**
1		$\mathbf{u}_{\text{the}}$, idiot($\mathbf{u}_{\text{the}}$):**e**
2		CHOOSE $\mathbf{u}_{\text{the}}$ = Alan
3	s_2:	GOAL $\beta(\mathbf{u}_{wh})$:**t** LINK (s_1(Alan:**e**), $s_2(\mathbf{u}_{wh}$:**e**), $\mathbf{u}_{wh}$/Alan)
4		$\mathbf{u}_{wh}$/Alan:**e**
5		adore:**e**→(**e**→**t**)
6		Mary:**e**

The choice of 'Alan' in (52) is a relevance-driven choice, made, say, in the light of a context such as some utterance of *I came into the room with Mary and Alan was there with Sue*. In this case, all the database s_2 provides is additional information about Alan, the label for '$\mathbf{u}_{\text{the}}$, idiot($\mathbf{u}_{\text{the}}$)' already independently identified at step 2, exactly as though Alan had been picked out by use of the name *Alan*. In this case there is no collapsing of the database structure. The extra clause is not intended to be used as part of the process of identifying who is being talked about – hence its characteristic separation from the clause to which it is adjoined by a prosodic break.

Much more could be added about the preferred representation of referential construals of definite noun phrases.[22] But the purpose here is

[22] The analysis successfully predicts the restriction of restrictive relatives to adjunction on nominal heads, as opposed to the much freer coocurrence of nonrestrictives with clauses, verbs, verb phrases, and adjective phrases (Fabb 1990 and Borsley 1992):

(i) The cheese was bought by John, which was fortunate.
(ii) John luckily escaped, which I unluckily didn't.
(iii) John had finished his essay on time, which I had too.
(iv) John maltreated Mary, which I wouldn't my dog.
(v) John answered politely, which I thought was how he should have answered.

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merely to present a framework within which to model the underspecification of linguistic input vis á vis assigned interpretation in context and the process of mapping such input onto selected interpretations. It is, in particular, this emphasis on the interpretation process which led to the proposed analysis in which nonrestrictive modification is, controversially, taken as demonstrating the pattern for all relative clause construal. In both restrictive and nonrestrictive construals of a string, the process is seen as one of copying the value of the determiner from the head nominal into the structure to be projected from the relative as a target premise to be constructed – a transfer of information from the one structural domain into the new domain initiated by the relativiser *wh*. The difference between the two types of construal lies in the richness of the information so transferred.

2.3 *Preliminaries for a proof-theoretic account of quantification*

We have almost everything in place for an account of crossover, lacking only any general perspective on quantification. It might seem as though the account of relative clauses could not be generalised to all quantifiers, since the definite article is the only determiner with the anaphoric properties on which the account depends. However indefinites, which also allow both forms of relative construal, can be explained in similar terms. The clue to the analysis of indefinites lies in the use of skolem terms to capture the construal of an existentially quantified expression within the scope of some other (universally) quantified expression. In such cases, the force of the existential is represented without any intrinsic quantification of its own as a functionally dependent element in which a function maps the variable bound by the universal quantifier onto a new variable. The interpretation of (53),

(53) Every professor refereed a book.

as

(54) (∀x, professor(x)) (∃y, book(y)) referee(y)(x)

can be expressed by use of the skolem term 'f(x), book(f(x))' where 'f' is the

---

As the account here would predict, nonrestrictive relative constructions cannot be constructed on adjectives or nominals, since these project only a subpart of a label to a formula of type **e** and do not project a typed formula in their own right:

(vi) *The tailor, the which I had not seen for several years, was anxious.
(vii) *The most delapidated bus, the which bus I had been waiting for for twenty minutes, was dirty.

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choice function applying to the set of professors to yield the book that each refereed:[23]

(55) (∀x, professor (x)) referee(f(x), book(f(x)))(x)

The form of the name 'f(x), book(f(x))' explicitly records that it is dependent on x (and ranges over books). With the use of labels, and in particular database labels, we are able to extend this form of analysis to wide scope construal of existential expressions. In the narrow scope construal of the indefinite the skolem term is defined over some individual variable (as in (55)). In the wide scope case, the skolem term is defined over the database label, a choice function on a set of times picking out an individual relative to each time the database label ranges over. This will provide a representation of the wide scope construal of (53), namely:

(56) (∃y, book(y)) (∀x, professor(x)) referee(y)(x)

as (57)

(57) s_i: (∀x, professor(x)) referee(f(s_i), book(f(s_i)))(x)

with 'f(s_i), book(f(s_i))' as a name recording dependency on the database label. In words: "The choice function f applying to some world-time unit s_i yields a book such that every professor refereed it." By allowing in an element of underdeterminacy in the lexical specification for indefinites, we can then give the indefinite article a unitary characterization as invariably projecting a metavariable that ranges over dependent names f(α) with a choice of what α should be having to be made by the hearer as part of the process of utterance interpretation exactly analogous to anaphoric resolution. It is this choice that will give rise to the range of interpretations for the indefinite, not any intrinsic ambiguity in the determiner itself. In building linked database configurations, such a choice – just as with definite noun phrases – can be made before or after the projection of any linked database

[23] The restriction on the variables is specified only in the first occurrence of the variable for legibility reasons. We treat f(x) as just another name. So if x = John, f(x) could pick out the mother of John, which can be treated as though a constant 'Mary'. In such a case, if x is 'he_i', then f(x) is 'his_i mother'. We do not necessarily want to quantify over the function f. VP ellipsis data confirm this decision, since genitive NPs containing a pronoun are systematic exceptions to the otherwise general principle that sloppy readings of an elliptical VP involve abstraction across the board, allowing interpretations in which they are interpreted as fixed. Hence the asymmetry between (i) and (ii), with (i) but not (ii) allowing an interpretation in which only the second pronoun is interpreted as rebound by the new subject:

(i) John said that his mother had been with him all afternoon, and so did Bill.
(ii) John said that he had been with his mother all afternoon, and so did Bill.

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structure. Hence the ambiguity of (58) according as the relative clause is restrictively or nonrestrictively construed:

(58) A mistake that I should have spotted remained in the final manuscript.

It is then but a simple step to generalise the analysis, and assume that all quantifying expressions project a metavariable for which a value has to be chosen, with some choices being trivial. For example, for a regular quantifier such as *every*, any new free (individual) variable can be chosen with the locality restriction that its occurrence is licensed only within the proof domain into which it is introduced. The projection of NP meanings is thus uniform: all determiners project a metavariable of some distinguished form with varying constraints as to what type of label must be used to instantiate that metavariable (a free variable in the case of *every*, a dependent name in the case of the indefinite, either of these or names in the case of *the* and pronouns).[24] All variables are restricted, and the accompanying nominal expressions project a restriction on the name/variable to be assigned to the lexically projected metavariable. The recursively specified addition of further restrictions is achieved through the construction of linked databases defined to contain a label unified with the label projected by the determiner/name. The result is an account of natural language quantification projected from the surface sequence without any covert operations of operator movement such as Quantifier Raising (QR – May 1985).[25]

This account of quantification is transparently nothing more than a sketch and a lot more needs to be said. In particular an account of the semantics of $\mathbf{u}_{wh}$ will need to be formally defined (cf. Higginbotham 1995). However, in giving an analysis of *wh* in terms of a metavariable $\mathbf{u}_{wh}$ to be instantiated by expressions of the labelling algebra (rather than directly by their model-theoretic counterparts), one problem will be side-stepped. The analysis of the natural language expression itself will be weaker than any given type of answer and will not need to distinguish between regular questions and what

[24] In rounding out the details of this account, restrictions on anaphoric dependency on such constructed names will have to be stated in terms of the varying availability of those names. Free names (corresponding to universal quantification) are available only within the proof domain into which they are introduced. Dependent names (corresponding to existential quantification) are available within the domain into which the element on which they are dependent is introduced. Hence the restriction that quantifier scope variation for nonexistential quantifiers is clause internal, and the converse freedom of indefinites to give rise to very wide-scope effects, as displayed in (i)–(ii):

(i) A porter thought that everyone was in the building.
(ii) Everyone thought that a friend of Sue's was in the building.

For an independent proposal that indefinites correspond to choice functions, cf. Reinhart 1997, and for a related proposal within DRT assumptions, cf. Farkas (1997).

[25] We do not address the problem of plurals in this paper, so leave on one side the need for set-naming devices associated with all plural and numeral quantifiers, and the issues these raise.

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have been called 'functional questions' (Groenendijk & Stokhof 1984). On the more orthodox accounts in which the semantics of *wh*-questions is specified directly as a mapping from the natural language expression onto the set of model-theoretic counterparts of possible answers, a functional question must be distinguished from a question which is to receive a simple answer, since answers to the former must take the form of a function from individuals to individuals (of type '$\langle$**e,e**$\rangle$') and so cannot be reduced to a single individual (of type '**e**'). According to the present analysis in which *wh* is a place-holding metavariable instantiated by an expression of the labelling algebra, the problem does not arise. The prediction of question-answer pairs such as (59):

(59) Who does every student ignore? Her tutor.

arises from the possibility of substituting in place of the assumption '$\mathbf{u}_{wh}$:**e**' already projected in the database '{x, student(x):**e**, ignore:**e** $\rightarrow$ (**e** $\rightarrow$ **t**), $\mathbf{u}_{wh}$:**e**}' the replacement premise triggered by *her tutor* which we represent as 'f($\mathbf{u}_{pro}$), tutor(f($\mathbf{u}_{pro}$)):**e**' . With *every* projecting a new variable free within the proof domain into which it introduces a premise, such a choice of value as answer to the question allows $\mathbf{u}_{pro}$ contained in 'f($\mathbf{u}_{pro}$), tutor(f($\mathbf{u}_{pro}$))' to be subsequently identified as 'x, student(x)' within the domain in which 'x, student(x):**e**' is licensed, giving rise to the database configuration:[26]

(60) {x, student(x):**e**, ignore:**e** $\rightarrow$ (**e** $\rightarrow$ **t**), (f(x), tutor(f(x)):**e**}

The sentence boundary between question and answer is irrelevant: the process of interpreting the answer involves substituting the premise projected by the lexical items comprising the answer in place of the metavariable '$\mathbf{u}_{wh}$:**e**'. And in the case of an answer such as *her tutor* in (59), such a substitution contains a (pronominal) metavariable, which is itself subject to subsequent interpretation. Nothing idiosyncratic to this kind of answer needs to be specified in the interpretation projected by the *wh*-question itself. The analysis of *wh* thus remains simple without need of any tiered binding as proposed by Chierchia (1992).

3. Crossover – the basic pattern

This proof-theoretic format for presenting natural-language interpretation provides an unexpected bonus. Not merely does it capture the incremental way in which interpretation may be assigned to natural language strings, but in addition it shows potential for explaining data classically presumed to require strictly syntactic explanation. In particular we shall see that the analyses now set up for *wh*-expressions, anaphora and relative clauses – each of which is independently motivated – provide explanations of the array of crossover data without any auxiliary construction-specific principles. Three

[26] As before, all occurrences of the restriction on the variable are suppressed except the first.

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distinguishing features of the proposed LDS framework will provide the backbone of the explanation:

1. The model is defined on the assumption that projection of interpretation should be procedural in the sense of projecting not merely the content of component parts, but also how that content is incrementally built up on a left-to-right basis. In particular the difference in the two forms of relative clause construal will determine the different construal of pronominals contained within them according to the richness of information transferred from the head into the relative clause.

2. The format chosen to reconstruct this assumption is goal-directed labelled deduction. As we shall see, the goal-directedness provides the basis for maintaining a basic linearity account while allowing *wh*-expressions themselves to be systematic exceptions (contra Déprez (1990) who argued that the interaction between pronominals and *wh*-expressions demonstrated that no linearity account of crossover can be made viable).

3. The model reconstructs at each stage the asymmetry between some provided input specification and the choices that are made to fix the interpretation. The process of interpretation thereby reflects the partial nature of information at any stage during that process. According to this analysis, it is simply the different information that is available to the hearer in making interim choices that determines the different crossover effects. We take *wh*-questions first.

In *wh*-questions, the hearer is confronted with two tasks:

(i) constructing the proof to a certain pre-set format (to wit that it contain some 'gap' in its set of labels) and
(ii) identifying the value of the variable projected by the pronoun.

The general pattern – from a discourse processing perspective – is that the initial *wh*-expression in questions is invisible for purposes of establishing anaphoric dependency until after the gap is constructed. The goal-driven model gives an immediate answer to this problem: the initial *wh*-expression projects a goal specification. As a mere target on the outcome, it is but a license for some assumption to be constructed later, and cannot be visible for anaphoric dependency. There is no question of the information projected by the *wh*-expression violating or not violating any locality restriction associated with the pronominal for it does not constitute information within the database. Once the assumption necessary to meet that target has however been constructed, it is visible for purposes of anaphoric dependency within the domain within which that assumption has been constructed. Hence the pattern (23)–(26) (repeated here):

(23) *Who$_i$ does Joan think that he$_i$ worries e$_i$ is sick?
(24) Who$_i$ does Joan think e$_i$ worries he$_i$ is sick?

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(25) *Who$_i$ does Joan think that his$_i$ mother worries e$_i$ is sick?
(26) Who$_i$ does John think e$_i$ worries his$_i$ mother is sick?

The pattern is not a language-particular stipulation. To the contrary, the pattern is exactly that of natural deduction proofs. Having the goal of drawing a conditional conclusion of the form $Q \rightarrow R$, with Q specified within it, does not itself constitute the making of the assumption Q. But once the assumption Q has been made and entered in the proof as a premise, its status within the proof is that of any other assumption in the proof.

This preliminary analysis of the crossover phenomenon predicts successfully a number of the distributional properties listed in Lasnik & Stowell. It predicts the basic required pattern of '*wh* – gap – pronoun' rather than '*wh* – pronoun – gap' as above. It also predicts (along with the linking account of Hornstein 1995) that parasitic gap constructions should not constitute a counter example to the present account, as indeed they do not, because the pronoun follows the initial 'true' *wh* gap, so under this account the pattern of gap followed by pronoun is preserved:[27]

(61) Which book$_i$ did John read e$_i$ after having given it$_i$ to Mary to review e$_i$?

It further predicts that *easy-to-please* constructions will not give rise to crossover effects, because the subject of the construction preceding the pronominal is certainly available to provide a value for the pronominal, again not withstanding the following gap:

(62) John$_i$ is easy for his$_i$ friends to please e$_i$.

The problem for accounts of the restriction on operator-pronoun-gap sequences in terms of the hierarchical relationship between the three elements is that the restriction is not sensitive to the larger context within which such a configuration may occur. On this account to the contrary, it is not so much the structural relation that holds between *wh*, gap and pronoun but the environment in which that sequence is processed. (61) and (62) are predicted to be fully acceptable on the indicated interpretation, because a possible antecedent (the gap in (61), the subject *John* in (62)) precedes the pronominal element. Moreover, it correctly allows the prediction that a pronoun following a gap may only be construed as identical to the gap if the locality restriction of the pronoun precluding choice of any antecedent which labels

[27] Some account is of course needed to explain why such additional 'parasitic' elements are licensed at all. The framework here allows the possibility of multiple instances of $\mathbf{u}_{wh}$:**e** once the initial uniquely licensed assumption is constructed, through strategies such as anaphora resolution. In particular, these complex clausal adverbials suggest an analysis as a composite database acting as label to the database projected by the main clause, and as such project a domain within which secondary instances of such a variable would be licensed. But we leave this issue unresolved.

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a minor premise of type **e** to the same major premise is satisfied.[28] Hence one possible interpretation of (63) is displayed as (64):

(63) *Who$_i$ do you think e$_i$ likes him$_i$?

(64) STEP

1	s_1:	GOAL $\beta(\mathbf{u}_{wh})$:**t**
2		you, $\mathfrak{G}$:**e**
3		think:**t**→(**e**→**t**)
4	s_2:	SUBGOAL $\beta'(\mathbf{u}_{wh})$:**t**
5		$\mathbf{u}_{wh}$, $\mathfrak{G}$:**e**
6		like:**e**→(**e**→**t**)
7		$\mathbf{u}_{pron}$(for $\mathbf{u}_{pro}$: **e** ∈ s_i, CHOOSE $\mathbf{u}_{pro} \neq \alpha$, α:**e** ∈ s_i):**e** CHOOSE $\mathbf{u}_{pron}$ = Tom
8		like (Tom):**e**→**t** MP 6,7
9		like(Tom)($\mathbf{u}_{wh}$):**t** MP 5, 8
10		think (s_2,like(Tom)($\mathbf{u}_{wh}$)):**e**→**t** MP 3,9
11		think (s_2,like(Tom)($\mathbf{u}_{wh}$))(you):**t** MP 2, 10

Though in following the assumption $\mathbf{u}_{wh}$ constructed as subject of the subordinate predicate 'give', the value of $\mathbf{u}_{pron}$ might in principle be taken to be $\mathbf{u}_{wh}$, the locality restriction constraining the process of identifying $\mathbf{u}_{pron}$ to preclude minor premises within the same database guarantees that such an interpretation is excluded.

3.1 *Crossover and relative clauses*

Despite its relative success in predicting the above array of data, the account as it stands is, nevertheless, clearly too strong. The analysis in terms of *wh* as merely a goal specification suggests that the restriction prohibiting the sequence *wh*-pronoun-gap should always be illicit across strong and weak crossover constructions, and for all *wh*-initial languages. Yet this is clearly false, given the range of constructions in which in English it doesn't hold, of which non-restrictive relatives remain as the primary case:

(3) John, who$_i$ his$_i$ mother had regularly ignored e$_i$, fell ill during the exam period.

[28] Since no formal specifications are given in this paper, we leave the characterisation of the locality restriction on the pronominal entirely informal. Cf. fn.15.

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Moreover not only are there many languages with *wh*-in situ constructions for which no weak crossover effects are displayed (cf. Georgopoulos 1991), but there may be variation between closely related languages such as English and French. Strong crossover effects are universal, but weak crossover effects are highly variable. In the French/English difference, it is in relative clauses in particular that there is variation as to whether or not crossover effects can be suppressed. The analysis apparently needs to predict that sometimes the relative pronoun is visible and interacts with pronoun construal, but sometimes it is not visible and there is no interaction.

To achieve this result, all we need to do is put together the $\mathrm{LDS}_{\mathrm{NL}}$ accounts of *wh*, pronominal and relative clauses. We take the strong crossover data first.

(65) *John_i, who_i Sue thinks he_i worries e_i will fail, left.

The properties involved in processing *wh*-initial constructions, nonrestrictive construals and pronouns all play a part in the explanation. First, a *wh*-initial expression in English does not project a premise in its own right, so the hearer has the task of constructing the appropriate assumption at some suitable point. Secondly, the nonrestrictive construal of a relative results in the goal specification that has to be met being fully identified as to the type and content of the premise. All that is missing is the information as to what role in the database it is to play. And finally, pronouns have an associated locality constraint that if they project a minor premise of the form '$\mathbf{u}_{\mathrm{pro}}:\mathbf{e}$', then – in what is otherwise a free process of construal – the value of $\mathbf{u}_{\mathrm{pro}}$ may not be chosen from a discrete label of type **e** occurring in the database under construction (= not an argument in its own clause). These three properties combine to preclude any dependence of the pronominal on the variable projected by the *wh* in cases such as (65). Processing of the *wh* in (65) induces the building of a new database s_2 with new target. So processing of *John* in some database s_1 followed by *who* leads to:

(66)

s_1:	John:**e** GOAL α:t
s_2:	GOAL $\beta(\mathbf{u}_{\mathrm{wh}})$:**t** LINK $(\mathrm{s}_1(\mathrm{John}:\mathbf{e}), \mathrm{s}_2(\mathbf{u}_{\mathrm{wh}}:\mathbf{e}), \mathbf{u}_{\mathrm{wh}}/\mathrm{John})$

As a target specification, this information about the GOAL will get carried down the tree until such point as the assumption associated with the gap can be constructed. Given the presence of premises 'Sue:**e**', 'think:$\mathbf{t}\rightarrow(\mathbf{e}\rightarrow\mathbf{t})$'

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projected by the words *Sue* and *think*, the target that the *wh* imposes cannot be satisfied in s_2:

(67) s_1: John:**e** GOAL α:t

s_2: GOAL $\beta(\mathbf{u}_{wh})$:**t**
LINK(s_1(John:**e**), $s_2(\mathbf{u}_{wh}$:**e**), $\mathbf{u}_{wh}$/John)
Sue: **e**
think:**t**→(**e**→**t**)

So having processed the sequence *John who Sue thinks*, the database s_3 will be constructed in accordance with the type specification encoded in *think*. In the light of the overall goal not yet being satisfied, this further database will itself be assigned as a subgoal the requirement of constructing the requisite gap linked to 'John':

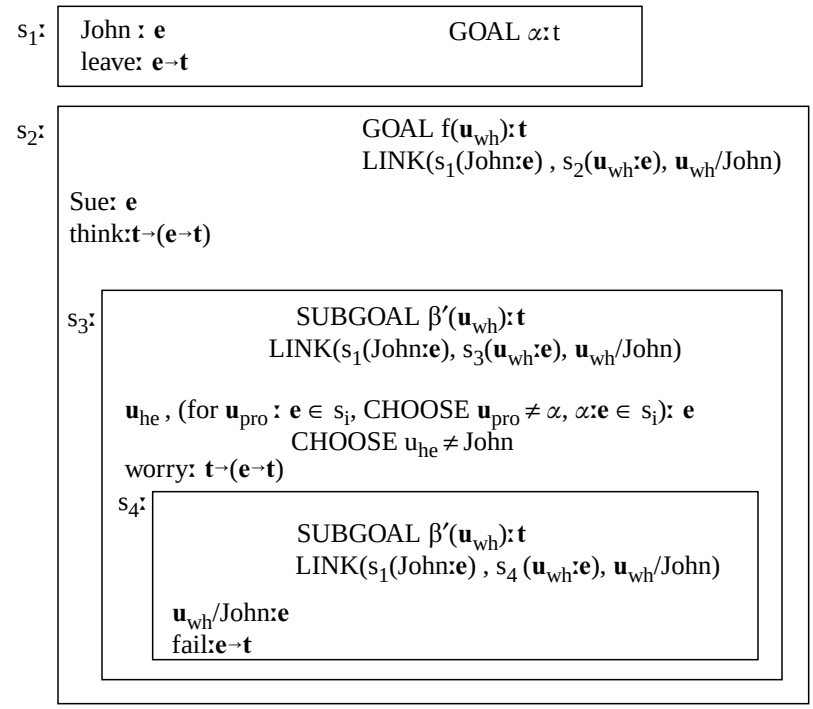
(68) s_3: SUBGOAL $\beta'(\mathbf{u}_{wh})$:**t**
LINK(s_1(John:**e**), $s_3(\mathbf{u}_{wh}$:**e**), $\mathbf{u}_{wh}$/John)

So the task in s_3 is to construct a premise of the form '$\mathbf{u}_{wh}$/John:**e**' – that is, with $\mathbf{u}_{wh}$ unified with 'John'. (The carrying down of this target as a task to be completed in s_3 is essential if the overall goal of providing a conclusion to s_2 that contains the label '$\mathbf{u}_{wh}$/John' is to be realised.) But now the completeness of the label $\mathbf{u}_{wh}$ unified with 'John' means that the premise '$\mathbf{u}_{wh}$/John:**e**' is fully determined as a premise playing a part in that database. The assumption does not have to be constructed: on the contrary it is given. All that has to be clarified is what its role should be. The information encoded by *he* now comes into play. Recall that the restriction on the interpretation of the metavariable $\mathbf{u}_{pro}$ (the label projected by the pronoun) is that if it is contained within a declarative unit of the form '$\mathbf{u}_{pro}$:**e**', it may not be construed as identical to any label of type **e** in the database currently under construction. But, given the goal specification requiring the presence in this very database of '$\mathbf{u}_{wh}$:**e**' with $\mathbf{u}_{wh}$ identified as 'John', the choice of value for the pronoun will not be able to be that of the label 'John', for this label meets the description precluded by this locality condition. Hence the dependence of *he* on *John* is precluded, and (65) is unacceptable on the indicated interpretation. The clash induced as a principle B effect is caused by the transfer of fully identified information down through the proof tree, even though there is no local relation between the two expressions in the

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surface string. We give the specification of the interpretation for (65) as (69) (omitting the steps of Modus Ponens):

(69)



Should either the selected antecedent or the pronoun itself not be an argument, no such clash will arise and the relevant interpretation for (67) will be licensed:

(70) Joan$_i$, who her$_i$ mother worries about e$_i$ all the time, is sick again.

As before, the identification of the goal specification induced by the *wh* expression as a completely identified premise 'Joan:**e**' has the effect of rendering it visible for purposes of anaphoric dependency. But, in these cases, one or other of antecedent or pronoun is not a premise (= argument), and so the locality principle intrinsic to the pronominal is satisfied. The interpretation process is displayed in (71). At the point at which the value of the pronominal is fixed, there is nothing to debar the instantiation of $\mathbf{w}_{pro}$ as 'Joan' given its projection as a mere sub-part of the premise 'f($\mathbf{w}_{pro}$), mother(f($\mathbf{w}_{pro}$)): **e**' projected from *his mother*:[29]

[29] The characterisation of the genitive is informal at best.

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(71) STEP

	s_1:	GOAL α:t
1		Joan : **e**
2	s_2:	GOAL $\beta(\mathbf{u}_{wh})$:**t** LINK (s_1(Joan:**e**), $s_2(\mathbf{u}_{wh}$:**e**), $\mathbf{u}_{wh}$/Joan)
3		f($\mathbf{w}_{pro}$), mother(f($\mathbf{w}_{pro}$)): **e** For $\mathbf{w}_{pro}$: **e** $\in s_i$, CHOOSE $\mathbf{w}_{pro} \neq \alpha$, α:**e** $\in s_i$
4		worry-about : **e**→(**e**→**t**)
5		$\mathbf{u}_{wh}$/Joan :**e**

Hence the acceptability of (70). An exactly similar explanation will extend to the extended strong crossover data of (10) and (12) (repeated here):

(10) John, whose$_i$ mother$_j$ I told him$_i$ e$_j$ had refused the operation, was very upset.
(12) John, whose$_i$ exam results$_j$ he$_i$ had been certain e$_j$ would be better than anyone else's, got a nasty shock when they came out.

This analysis predicts the following patterns. (72) should pattern in parallel with (73):

(72) the bastard$_i$ who$_i$ his$_i$ mother worshipped …
(73) The bastard$_i$ worships his$_i$ mother.

In (73) the premise projected by *the bastard* is a minor premise of the database. In (72), it is AS THOUGH the premise projected by *the bastard* were a minor premise of the database projected from the relative clause, for the goal specification of the database initiated by *who* is fully identified as containing a premise with the very same label as projected by *the bastard*. In both cases then, the information projected from *the bastard* can be used to complete the incomplete label projected by *his*, *his* not being a premise of the form '$\mathbf{u}_{pro}$:**e**' in the database (it is 'f($\mathbf{u}_{pro}$), mother(f($\mathbf{u}_{pro}$))' that is). Similarly, (12) should pattern with (74):

(74) John's exam results gave him a nasty shock.

In both (12) and (74) the pronoun corresponds to a premise of the form '$\mathbf{u}_{pro}$:**e**' in the database, but neither *whose* (identified as 'John's') in (12) nor *John*'*s* in (74) correspond to any such premise. It is 'f(John),exam-results(f(John)):**e**' that constitutes the premise. Hence the locality restriction on the pronoun cannot cause a clash with the $\mathbf{u}_{wh}$ metavariable identified as 'John' in (12) despite the guarantee of its presence at some point in the

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same database.[30] On the other hand, *wh* in a PP adjunct will be predicted to DISallow an interpretation with a following dependent subject pronoun as in (75), because PP adjuncts containing a name cannot provide an antecedent for a following subject pronominal:

(75) Joan_i, behind whom_i she_i looked e_i nervously, coughed.
(76) *Behind Joan_i. she_i looked nervously.

Notice that the analysis does not turn on the expression being in any semantic sense referential (denoting a fixed individual in the model). What is critical is whether the *wh*-expression is construed ab initio as projecting a fully identified logical expression whether as a variable or as a name. Hence the analysis provides a semantic base to the explanation without narrowing it to the concept of referentiality. It thus avoids the problem cases facing the Lasnik & Stowell reference-based account of weak crossover (cf. section 1) while preserving an account which cross-cuts the weak/strong/weakest crossover distinctions made there.

Setting aside the *wh*-question cases as maybe meriting a treatment along lines suggested here, it might seem that a principle C explanation (resting on properties of the gap) still has a role to play, preserving the spirit of the original crossover account. For, in these nonrestrictive relative cases, a principle C account would correctly rule out the cases where both gap and pronominal are arguments, and yet, also correctly, not preclude cases in which either the *wh*-element or the pronominal are not arguments. However the proposed principle B style of account and a principle C form of explanation differ over cases such as (77) in which, despite not being an argument, the pronominal is nevertheless precluded from being dependent on a provided local antecedent:

(77) *John_i saw a picture of him_i.

And, as the present analysis would predict, (78) parallels (77) and also precludes an interpretation of *him* on *who*. This prediction is not made by a principle C based explanation (there being no c-commanding antecedent intervening between the gap and *who*):

(78) *John, who_i a picture of him_i dropped on, was badly shaken.

There are two further reasons not to adopt this more conservative position.

---

[30] For many speakers, sentences such as (12) are not as acceptable as the weak crossover cases such as (72). There is interference here from the fact that in many cases, as in (12), such complex possessive relative structures can almost invariably be expressed more directly given this construal of the pronoun. eg for (12) as (i):

(i) John_i, who_i had been certain that his_i exam results would be better than anyone else's, failed dismally.

Where no such more direct means is acceptable, as in (10), judgments are more solid.

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First, it has the curious property of accepting the force of the goal-based account (the invisibility of a goal specification) but not its immediate consequence (the progressive transfer of information down through the tree clause by clause). Secondly, such an account would require stipulation in order to prevent a principle-B style of explanation of the form given here from applying. Such a stipulation would lack a principled basis. There is strong independent evidence from radical reconstruction data that information associated with a *wh*-expression must be transferred progressively through the structure linking the initial position with the position of the gap in virtue of the acceptability of the indicated interpretation of (79) (Barss 1986):

(79) [Which picture of herself$_i$]$_j$ did John say that Sue$_i$ was cross that Bill was selling e$_j$?

And, equally, there is evidence that expressions contained within a *wh*-expression that are construed referentially are invariably visible for purposes of anaphoric dependency, as witness (80) which fully licenses an interpretation in which *he* is construed as dependent on *John* (Lebeaux 1991):

(80) [Which of John$_i$'s pictures]$_j$ is he$_i$ thinking of selling e$_j$?

So there is no non-ad hoc way of preventing the *wh*-expression from providing an antecedent for a pronominal when it itself is construed as referential, information about which will be locally available for the projection of each nested database intermediate between the initial goal specification and the point at which its associated assumption is constructed. A principle B form of explanation within this style of analysis will therefore automatically apply, rendering vacuous any application of a principle C account in all the cases for which they make common predictions. At best a principle C form of explanation for relative clauses would be otiose. And since it was the assumption of the correctness of the principle C explanation for the primary crossover restriction that led to the bifurcation into strong and weak crossover, and from that into weak and weakest crossover with a new epithet type of empty category, we take it that an analysis not requiring any such bifurcation of the data is to be preferred.

It might be counterargued that a principle B form of explanation would contrarily lead to the incorrect prediction that (81) is acceptable:

(81) *John, who$_i$ himself$_i$ ignored, cursed roundly.

However, all that is required to ensure the correct prediction is to impose as a restriction on anaphor-antecedent dependence that the antecedent has to be selected from some labelled premise that is later in the sequence of minor premises to project onto 'α:**t**' within the given local database (in more familiar terms, higher in the thematic hierarchy). In other words, the restriction is

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more stringent that just being within the same local database of premises. Such a condition cannot be met in (81) since the anaphor is the subject, by definition the last minor premise in the series of steps of Modus Ponens projecting onto 'α:**t**'. Hence dependency of *himself* on *who* in (81) is precluded.[31] We thus retain an account of crossover phenomena in terms of the way locality principles associated with the intervening pronominal constrain the interpretation of the whole as it is incrementally built up.

In this simple interaction of procedures for dynamically building an interpretation comprising a relative and a pronoun, we have, then, the main body of data – the unvarying imposition of strong crossover effects (due either to the locality condition on the pronominal in the relative clause or to the invisibility of the goal specification), the presence of weak crossover effects in questions (there being no linkage to fix the assumption to be constructed), and the lack of weak crossover effects or extended strong crossover effects when the construal of the relative clause is nonrestrictive (because the locality condition on the pronominal is satisfied).[32]

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[31] Problems remain with picture noun phrases such as in (i),

(i) *John, who the picture of himself dropped on, cursed roundly.

for though the account suggested predicts the unacceptability of (i), arguably correctly, it also implies the unacceptability of (ii):

(ii) The picture of himself fell on John's head.

Since the occurrence of such NP-contained anaphors is sensitive both to the particular determiner selected and the choice of matrix predicate, we shall leave these on one side pending a detailed analysis of these constructions. Notice in this connection, the acceptability of (iii)–(iv):

(iii) John, who the picture of himself upset, left abruptly.
(iv) John dislikes the picture of himself.

[32] This asymmetry between nonrestrictive relatives and questions is inexplicable on an otherwise similar explanation of crossover effects given in categorial grammar terms (Hepple 1990, Dowty 1993). Under the Hepple analysis, *wh*-expressions are assumed to involve the construction and discharge of additional assumptions (much as in the present account). Pronouns likewise are assumed to involve an extra assumption that has to be discharged, but without change of type assignment. This analysis predicts correctly that only the order *wh*-gap-pronoun is licensed, since the assumption created by the pronoun can be discharged by identity with the assumption corresponding to the gap, which can then be discharged prior to combining with the *wh*-expression. In the reverse order, the pronoun would discharge the gap, but this would leave nothing to be discharged by the *wh*-operator since the pronoun being merely identified with some antecedent would not alter its type as is required for the *wh*-operator. The asymmetry in nonrestrictive relatives between weak and strong crossover effects, the latter remaining but not the former, cannot however be predicted. On the categorial analysis in which indexical interpretations of a pronoun and principle B effects are dismissed as pragmatic and not part of the analysis, there is nothing to preclude (i) in which the pronoun *his* is indexically identified with the independently identified referent of *the man*:

(i) *the man$_i$, who$_i$ his$_i$ mother thinks e$_i$ is happy

but this leaves no way of precluding the strong crossover case, (ii):

(ii) *the man$_i$, who$_i$ Sue thinks he$_i$ knows e$_i$ is happy

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3.1.1 *Restrictive Relatives and the French Puzzle*

The final problem for a language such as English is posed by restrictive relative clauses, where the problem is that the data are somewhat unclear even in English, and do not appear to exist in closely related languages. Sometimes the data suggest that a restrictive relative is not a structure that licenses anaphoric dependency on the structure projected by the *wh*-expression, sometimes they suggest that it does. In restrictive relative clauses the relative clause is construed as delimiting the domain over which the variable ranges. The prediction made by this analysis is in principle clearcut, but we have a margin of doubt that mirrors the unclarity and displayed parametric variation in the data.

According to the analysis so far set out, if the projection of content for a relative clause involves building a linked database to be used to provide a restriction on some variable projected by the determiner, the process of linkage will involve unifying (= identifying) one place-holding metavariable with another as in (50) above: the determiner projects from the lexicon a place-holding metavariable, $\mathbf{u}_{\mathrm{det}}$, the *wh*-expression involves constructing a premise with metavariable $\mathbf{u}_{\mathrm{wh}}$ as label, together with whatever restriction has been imposed to date in the interpretation process. By definition metavariables are placeholders and have no content of their own. A metavariable in a goal specification indicates a target to be met, an assumption of appropriate form to be constructed. It is not an entry in the database. Unifying one metavariable with another will accordingly not change the status of the metavariable vis á vis the new database to be constructed: the appropriate assumption remains to be constructed, it is not an entry in the database in its own right. Restrictive relative clauses should therefore give rise to weak crossover effects exactly as in questions, because the goal specification in the database in question specifies what sort of assumption is to be constructed – it does not itself provide it. We predict correctly the unacceptability of the indicated interpretation in (6) (repeated here):

(6) *Every student who$_i$ his$_i$ mother had regularly ignored e$_i$ fell ill during the exam period.

Cf. also:

(82) *No-one who$_i$ her$_i$ mother helped e$_i$ got a distinction.

However we still face the puzzle as to why a closely related language such as French should systematically fail to give rise to weak crossover effects in relative clauses:

(83) le médicin que$_i$ sa$_i$ femme a presenté e$_i$ a cette infirmière charmante … (Postal 1993)
'the doctor that his wife introduced to that delightful nurse'

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(84) Chaque enfant$_i$ que$_i$ son$_i$ père a récupéré e$_i$ aux grilles de l'école est dans de bonnes mains.
'Each child that his father picked up from the school gates is safe.'

(85) chaque enfant$_i$ à qui sa$_i$ mère a donné un livre ....
'each child to whom his mother gave a book'

As (84)–(85) demonstrate, this phenomenon is entirely independent of the referential properties of the determiner, for it is available for all types of determiner.

The clue to the analysis required comes from the structure made available at the point at which the value of a label for the pronoun is chosen.[33] We take the English example (86):

(86) The woman$_i$ who$_i$ her$_i$ mother ignored e$_i$ failed.

and display the configuration (87) at the point at which choice of value for the metavariable projected by *her* has to be made:

(87)

STEP		
	s_1:	GOAL α:t
1		($\mathbf{u}_{det}$, woman($\mathbf{u}_{det}$))
2	s_2:	GOAL $\beta(\mathbf{v}_{wh})$:**t** LINK (s_1(($\mathbf{u}_{det}$,woman($\mathbf{u}_{the}$)):**e**), s_2($\mathbf{v}_{wh}$:**e**), $\mathbf{v}_{wh}$/($\mathbf{u}_{det}$,woman($\mathbf{u}_{the}$)))
3		(f($\mathbf{w}_{pron}$), mother(f($\mathbf{w}_{pron}$))):**e**

The next step required, step 4, is to identify $\mathbf{w}_{pron}$ so that the label projected from *her mother* can be fully identified. By analysis, the metavariable specified as required by the target is certainly invisible. But what of '$\mathbf{u}_{det}$, woman($\mathbf{u}_{det}$)' specified in s_1? This too is a metavariable, without as yet a fixed value; but it is entered in the database s_1 as an incomplete label to a premise. Can it count as a value from this position? There are two possible answers. One is that premises in a database are only available for identification purposes when their entry into the database is complete whether by lexical or constructed assumption. This is in effect a semantically driven criterion. An entry in a database only constitutes an entry if either it is name-like with a fixed semantic value, or some assignment of values to variables has given it a value protem. By this criterion, the premise of the form '$\mathbf{u}_{det}$, woman($\mathbf{u}_{det}$):**e**' in s_1 is not complete because the very purpose of the linked

[33] We are presuming on a linearity account of anaphoric dependence. Cf. Kempson, 1988, 1990, and Williams 1994 for a defence of this position.

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database currently under construction is to provide a further restriction on the placeholding metavariable $\mathbf{u}_{\text{the}}$ so that a value for the metavariable can duly be made. The process of providing that restriction has been initiated by the *wh* by the building of s_2 but it is not at this stage complete; and so there is no complete assumption in the database s_1 to count as providing a value for the pronoun's metavariable in s_2. Hence by this criterion the label '$\mathbf{u}_{\text{det}}$,woman($\mathbf{u}_{\text{det}}$)' cannot provide a value for the pronoun. This predicts that weak crossover effects are maintained in restrictive relative clauses.

However there is an alternative criterion. Suppose the very presence of $\mathbf{u}_{\text{det}}$ in s_1, despite being only an interim computational device, is taken to be sufficient for providing a value for $\mathbf{w}_{\text{pron}}$ in s_2, independent of $\mathbf{v}_{\text{wh}}$ (with which it will ultimately be linked), in virtue of having been entered as a premise in s_1. If such a choice procedure is licensed, it will be used as a purely syntactic means of identifying the label to be assigned the pronoun, and in consequence there will be no weak crossover effects, for the pronoun will be identified with a place-holding metavariable $\mathbf{u}_{\text{det}}$ that turns out to be the unifier replacing $\mathbf{v}_{\text{wh}}$ when the assumption required by the target imposed on s_2 is duly constructed. Given the subtlety of this distinction, one might well expect unclarity in the data with speaker variation according as the process of instantiating the variable for the pronoun is or is not semantically driven. Moreover one might expect variation across languages/dialects according as they do or do not allow metavariables to be instantiated by syntactic devices independent of the content assigned to that device. And French, indeed, seems to systematically adopt the weaker syntactic criterion, English dialects/speakers differing as to which criterion is adopted.[34]

This analysis leads to a further prediction. If French is a language that licenses such a purely syntactic base from which to identify the pronominal using the variable introduced by the determiner, we should predict that weak crossover effects in French are not symmetrical in questions and relatives. While in relative clauses weak crossover effects will be completely absent given the presence of the determiner head, *wh*-questions which lack any such determiner head with its consequent LINK procedure should provide no basis for identifying the pronoun, and weak crossover effects are predicted to re-emerge. This prediction is partially confirmed, though the data are clouded by an additional property distinguishing French and English. The interpretation of *wh*-relatives and *wh*-questions are certainly not symmetric. In

[34] An alternative account suggested by an anonymous referee is to invoke an additional implicit argument of the head noun as a means of identifying the pronominal, hence allowing the pronoun in *her mother* to be identified from the additional argument projected by the concept 'mother' [viz. 'y' in 'mother(y,x)']. Though such arguments can be made accessible given particular indication of the type of pronominal search required (cf. fn. 39 where it is suggested that this type of search is triggered by the use of *even*), such an account would wrongly predict symmetry of interpretation of relative clause configurations and questions, with both entirely lacking weak crossover effects.

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French relatives, as we have seen, potential crossover effects are completely suppressed, and a pronominal intervening between the *wh*-relatives and the point at which its assumption is constructed fully licenses an interpretation as dependent on the variable projected by the determiner and linked to the gap. In *wh*-questions, there is much greater hesitancy over acceptability judgments with questions so construed:

(88) *Qui$_i$, si'il ya quelqu'un, crois-tu que sa$_i$ mère a appelé e$_i$?
'Who, if there is someone, do you think his mother called?'
(89) *Quel homme$_i$ crois tu que sa$_i$ mère a appelé e$_i$?
'Which man do you think his mother called?'
(90) *Qui$_i$ crois tu que sa$_i$ mère a appelé e$_i$?
'Who do you think his mother called?'

(88) is completely unacceptable, and (89)-(90) are said to be marginally acceptable but only when contextualised to a scenario in which a fixed individual is presumed to be picked out by the *wh*-expression for whom the speaker needs identification.[35] These data conform to the general prediction that on the one hand a *wh*-expression, unless in some sense fully identified, counts as a goal and is invisible, but on the other that if such a goal can independently be fully specified, it will count as visible for purposes of anaphoric dependency. In these cases, the person denoted by the *wh*-expression is taken to be conceptually fully identified – all that is being asked for is how they are named. What appears to distinguish French and at least some dialects of English is that French allows enrichment of *wh*-expressions to yield such referential uses; English apparently does not.[36] With this one added auxiliary statement, we take the general prediction to be confirmed.[37]

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[35] In a toddlers' playground for example, in which little Harry (whose identity is not known to the speaker) wanders away from his mother, settles in the sandpit at the feet of speaker and hearer, and is subsequently desperately called for by his mother, it is reported by some speakers to be acceptable for the speaker to turn to the hearer and utter (90) intending dependence of the pronominal *sa* on *qui*.

[36] One referee reports that he finds examples such as (i) fully acceptable with the construal as indicated:

(i) Exactly which artist$_i$ do you think his$_i$ mistress should have murdered e$_i$?

As in the analogous French data, he reports that such uses are only available if the artist in question is taken in some sense to be independently identifiable, albeit not as yet named. This French/English difference thus, unsurprisingly, appears to correspond to dialectal variation in English also.

[37] Hornstein (1995) cites as evidence for a nonlinear analysis (in terms of linking) the acceptability of (i):

(i) His$_i$ mother introduced every child$_i$ to his$_i$ teacher.

in which the first occurrence of *his* is said to be linked to the second, thus allowing the

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The analysis given distinguishes *wh* from other binding operators in that amongst all determiners, only it encodes the projection of a goal specification. This has a consequence already suggested by Postal – that the generalisation between *wh* phrases and quantifier phrases such as *every N* on which the original weak crossover account was based (Chomsky 1981) (achieved by s-structure movement in the first case and LF movement in the second) is spurious (cf. also Williams 1994). As Postal (1993) observes, the parallelism breaks down in French since French fails to manifest weak crossover effects in restrictive relative clauses but apparently fully retains them with quantified expressions. The contrast is between (83) and (91):

(83) le médicin que$_i$ sa$_i$ femme a presenté e$_i$ a cette infirmière charmante
'the doctor who his wife introduced to that delightful nurse'
(Postal's (33b))

(91) *Sa$_i$ femme n'a presenté aucun homme$_i$ a cette infirmière charmante.
'His$_i$ wife did not introduce any man$_i$ to that delightful nurse.'
(Postal's (iv) in fn. 14)

On this analysis, the structures in (92) and (93) are clearly distinct:

(92) *Who$_i$ does his$_i$ mother love e$_i$?
(93) *His$_i$ mother loves every man$_i$.

Initial *wh* projects a look-ahead device requiring the construction of a premise at some point, but not itself providing such a premise. *Every*, in situ, projects a premise into the database. What *wh* and quantifiers have in common is that they both lead to the introduction of a newly constructed variable (as label) into a given proof domain viz. the minimal domain for which some conclusion 'α:**t**' is required. The difference lies in the manner of the introduction of that variable. Pronouns on the other hand do not introduce a new variable. To the contrary, they rely on identifying the label to the premise they project from labels independently made available. In so far as there is parallelism between (92) and (93) it is due to different causes. The label to be associated with the premise projected by *his* in (92) cannot be identified as identical with that projected by *who*, because initial *who* has the special property of not providing a database entry. On the other hand, the only reason why *his* in (93) cannot be identified with a variable projected by *every* is for linearity reasons – the information projected from the lexical

indicated interpretation through linking of the second pronoun to the variable (corresponding to the trace of the moved quantifier phrase). These data are however highly marginal, and are excluded by the present account. The borderline judgements can be explained in terms of the conflict between the first occurrence of *his*, which clearly indicates a construal of the pronominal that is independent of what follows, and the second occurrence, whose natural construal is dependent on the quantifier, with nothing to make salient the necessary disjointness of the two pronominals. Hence the tension and uncertain judgements.

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entry from *every* is, simply, not available at the point at which a value for the label has to be selected for the pronoun. Thus the similarity between (92) and (93) is not an argument for explaining the similar lack of indicated anaphoric dependence in terms of identity of structure. Characterising the particular properties of *wh*-initial in a language such as English and its manifest parallelism with goal-directed reasoning tasks is sufficient.[38, 39]

3.1.2 *Crossover and French cleft constructions*

Confirmation of this natural-deduction style of analysis comes from what Postal took to be the additional puzzle posed by cleft constructions in French. Despite showing no weak crossover effects in relative clauses, French shows weak crossover effects as in English in cleft constructions. If the expression is referential, no crossover effects are displayed:

(94) C'est Jeanne$_i$ que sa$_i$ mère admire e$_i$.
'It's Jeanne who her mother admires.'

(95) It's John$_i$ that his$_i$ mother told me e$_i$ was guilty.

If the expression is a quantifier however, crossover effects emerge. Though quantified expressions can occur in a focussed position, they cannot be used for establishing anaphoric dependency:

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[38] An alternative analysis of the French question data is that the initial expression, rather than being a goal specification, projects information about the topic, and as such provides information which anaphora resolution can pick up on. In so far as *wh*-expressions are acceptable in this position, this analysis would predict that they would always have to be construed as denoting entities which are in some sense independently identified in the discourse and all that is being asked about is the name of the individual in question. Pending an account of topic in LDS terms (cf. Kempson 1995c for a preliminary sketch of topic expressions as contributing to the specification of the database label), we leave this alternative on one side, other than noting that such an analysis would predict that *wh*-initial expressions did not give rise to island restrictions under such construal, being topic expressions, an account which is totally implausible when applied to those English dialects which parallel French in allowing such marked construals of *wh*-questions.

[39] The one genuine set of problems remaining of those posed by Postal is the apparent ability of focus-sensitive items to license dependency betwen pronominals and *wh*-expressions in questions, even in English:

(i) Who$_i$ did even his$_i$ mother ignore e$_i$?

This analysis however is we suggest not what is going on. Rather the pronominal is picking up its value from the argument structure of the nominal *mother* which inherently expresses a two-place relation between mother and child. Such information is straightforwardly manipulated for the purpose of establishing extra pragmatic implicatures, indeed such a choice depends on accessing information about the concepts expressed (cf. Sperber & Wilson 1986), but it is normally not accessible for purposes of establishing anaphoric dependence. However words such as *even* encode information that encourages the hearer to pick out a larger context set of premises than would be selected in interpreting the same sequence modulo the occurrence of *even*. Hence the potential for manipulating such information in cases such as (i). The relation between *who* and *his* in (i) as construed is therefore one of coreference not referential dependence.

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(96) It's every Linguistics book that I asked you to catalogue – not every History book.
(97) *It's every student$_i$ that his$_i$ tutor expects to see e$_i$ at midday.
(98) *C'est quelqu'un d'autre$_i$ que sa$_i$ mère a présenté e$_i$.
'It's someone else that his mother had introduced.'

This framework immediately suggests an explanation: focus constructions in French as in English are goal specifications – a specification of a premise, fully identified, to be used at some later point in the proof sequence. The parallelism between focus constructions and *wh*-expressions follows at once. A focussed element, like a *wh*-expression will not itself constitute an entry in the database. Unlike a *wh*-expression in questions however, a focussed element will characteristically be a fully identified premise, in which case the only information lacking will be where in the combinatorial process it is to play a role. In such cases, it will be exactly like *wh* in nonrestrictive relative construals – there will be some fully identified premise and some domain within which it has to be constructed. A pronoun in the clause following will therefore generally be able to identify with the label there listed as long as no locality clash with the pronominal ensues. This yields the data (94)–(95). Suppose however the expression in the goal involves a quantified expression, itself a license to construct a new name at the point of its introduction in the proof. We then predict that such an expression, while still a specification in the goal only, cannot provide a name for purposes of establishing anaphoric dependence, for it is not yet introduced into the proof. This predicts exactly the results we want. Quantifiers may occur as focussed elements, but they cannot be used as a source of anaphoric dependency from that position. Unlike in relative clauses, there is no premise in a database already set up to which the element in the goal corresponds: there is only the focus expression, and that itself constitutes the goal exactly as is *wh*. Hence the invisibility of an expression in the focus position unless fully identified, and in particular the invisibility of quantified expressions occurring in that position for purposes of anaphora resolution – even in French.[40]

[40] As one referee reminds us, there is an asymmetry in the cleft constructions (i)–(ii) in that only the former allows a sloppy interpretation to the elliptical form:

(i) It's John that loves his mother, not Bill.
(ii) It's John who his mother loves, not Bill.

Given certain assumptions about how both focus constructions and elliptical constructions such as these involve a process of substitution into an independently constructed database (cf. Kempson 1995a), this asymmetry follows. In (i) the construction of the database involves the construction of the gap premise which duly provides an antecedent for the pronominal, and the substitution of the concept projected from *John* into the constructed database involves abstraction over the two occurrences of the variable $\mathbf{u}_{wh}$ occurring both as label to the premise labelled as subject where the gap premise has been constructed and in the position projected by the pronominal. In (ii) to the contrary, the pronominal is identified as 'John' prior to the introduction of the gap as driven by the goal specification,

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We thus finally reach a familiar conclusion – that *wh*-initial expressions are focus constructions, in all these cases corresponding to a meta-level instruction on the projection of interpretation in the form of a goal specification.

4. The case of Chinese relatives

This analysis of *wh*-expressions as projecting a goal specification clearly needs to be set within a more general account in which *wh*-in situ constructions are incorporated. However, pending this more general account (cf. Kempson, Meyer-Viol & Gabbay forthcoming), this analysis of crossover is nevertheless buttressed by a further prediction contrary to all other analyses of weak crossover phenomena. In virtue of its reliance on the linear way in which information is built up, it predicts that in a language in which relative clause modification precedes the head, a pronominal contained within that clause could not be identified with the following head unless some representation associated with that head is available to provide a value for the interpretation of the the pronominal.[41] Chinese provides just such a case. Anaphora (and scope choices) are strongly constrained by linear order in Chinese (cf. Jiang 1993, 1995); and relative clauses come in two forms – strategy I, with the determiner following the entire complex, and strategy II in which the determiner precedes the relative clause, with the nominal following:[42]

Strategy I

(99) Zhangsan hushi de nei ge ren kaoshi mei jige.
Zhangsan ignore REL that-CL man test not pass
'The man Zhangsan ignored failed the test.'

Strategy II

(100) Nei ge Zhangsan hushi de ren kaoshi mei jige.
that-CL Zhangsan ignore REL man test not pass
'The man Zhangsan ignored failed the test.'
CL is a classifier, REL a relativiser.

(99) and (100) are equivalent in meaning. In the structure assigned to these sentences, the c-command relation between gap, the final relativiser *de*, and

but it is the point at which the gap premise is introduced that identifies the locus of the abstraction, hence ensuring that in (ii) 'Bill' is substituted only into the object position.

[41] We are grateful to Andrew Simpson for bringing this prediction and the data to our attention – and, too, for many subsequent conversations about the problems the data raise.

[42] There are also mixed strategies, but they preserve the patterns in these simpler cases.

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the determiner head is, arguably, constant. Certainly, the semantic relation of the relative clause with respect to its head is identical in the two strategies. All that varies is the order. There is therefore no reason on either principles and parameters analyses or Categorial Grammar analyses of cross-over phenomena to predict any potential for variation in the interpretation of the two relative clause types. However, according to the LDS_{NL} style of analysis, the projection of the interpretation of the two sentences proceeds very differently. In the processing of the relative clause sequence in (99), no indication is given to the hearer even that a linked database is to be established, so no representation either of any nominal head, or of any goal specification for a linked database is available as the sequence *Zhangsan hushi* is processed. If any pronominal occurs within the relative sequence, it will not be able to be identified with any nominal head, since there is none there. In (100) however, the relative clause sequence is signalled initially by the presence of the determiner which projects a partial specification of a premise, albeit incomplete. In this latter case, then, the analysis so far set up would predict that the determiner MIGHT allow dependence of a pronominal inside the relative on the determiner, depending on whether the language conformed to the French pattern in allowing incomplete specifications to count as an antecedent for the pronoun, or not, as English seems to suggest. This set of predictions is borne out. Strategy I precludes anaphoric dependence of a pronoun in the relative clause on the head noun altogether; the interpretation indicated in (101) is debarred. Strategy II parallels the English data: no dependence of the pronominal on the determiner head is possible in (102) because the determiner is a regular quantifier. Dependence on the head is marginal in (103).

(101) *Ta$_i$ muqin hushi e$_i$ de mei ge$_i$ ren dou mei kao jige.
he mother ignored REL every-CL man all not test pass
Everyone$_i$ his$_i$ mother ignored e$_i$ failed the test.'

(102) *Mei ge$_i$ ta$_i$ muqin hushi e$_i$ de ren dou mei kao jige.
every-CL he mother ignore REL man all not test pass
'Everyone$_i$ his$_i$ mother ignored e$_i$ failed the test.'

(103) ??Nei ge$_i$ ta$_i$ muqin hushi e$_i$ de ren mei kao jige.
that-CL he mother ignored REL man not test pass
'That man who$_i$ his$_i$ mother ignored e$_i$ failed the test.'

This phenomenon is in fact part of a larger pattern which is entirely independent of the weak/strong crossover distinction, further buttressing this account.[43] The restriction which precludes dependency of the pronominal

[43] We are grateful to a comment of an anonymous referee which led to the discovery of these new data.

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on the following head in (101) holds irrespective of the relation between the pronominal within that relative clause sequence and any extra 'gap' construction that has to be constructed as bound by the following relativising particle *de*. The restriction is that a pronominal cannot be identified as having a value by something that is not there. This restriction holds both for clauses with a subject gap, with an object gap, with a pronominal in argument position, and with a pronominal in a non-argument position:

(104) *e_i ai ta_i muqin de nei ge_i ren
loves he mother REL that-CL man
'*the man who_i e_i loves his_i mother'

(105) *e_i ai ta_i muqin de mei ge_i ren
loves he mother REL every-CL man
'every man who_i e_i loves his_i mother'

(106) *ei xiang-sin Mary chong-bai ta de mei-yi- ge ren dou
e_i believes Mary admires him_i REL everyone-CL_i man all
cuo-le.
mistaken
'Everyone who_i e_i believes Mary admires him_i is mistaken.'

The issue solely turns on whether the initial relative sequence contains a lexically projected antecedent or not. (104)–(106) do not display a crossover phenomenon at all, yet follow exactly the same pattern. This order precludes any interpretation of the pronominal on the following head. So we have one strategy which is like English, one which is superficially quite different. This difference between the two strategies is predictable. With strategy I, no indication is given that the presented sequence is a relative structure until the final relativising particle *de*. Until that point, the sequence simply involves the processing of information from the words as they provide input. There may be the general goal-directed task of seeking to derive a propositional formula of type t, but there is no extra imposition of a more precise goal. In particular, there is no initial relativising expression to drive the search for a position at which some assumption can be constructed. Thus in (104)–(107) there is no reason to assume the initial expression projects anything other than a two-place predicate of type $\mathbf{e} \rightarrow (\mathbf{e} \rightarrow \mathbf{t})$. It is only when the particle *de* is reached that the sequence of words projects the information that the sequence of premises set up so far forms an independent database of type **t** to be linked to some host structure through one itemised premise; and it is this final step which leads to the construction and identification of that premise.

The other relative clause strategy, to the contrary, is driven by a strategy much as in English – associated with some initial determiner is the option of building a linked database, for which some special $\mathbf{u}_{wh}$ assumption has to be constructed. This option is triggered by the clash between a determiner, requiring some following nominal, and the given input – in (107)

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a verb. As a result, a linked database is duly initiated, together with the goal specification that some particularised $\mathbf{u}_{wh}$ assumption be constructed with its label identified as the same metavariable induced by the determiner. Given that such assumptions are only constructed in the face of the input providing a type specification which cannot be used to satisfy the goal specification, the construction of the required assumption will be triggered by the declarative unit projected by the verb.[44] Once this is constructed, resolving the search induced by the goal specification, the constructed premise will provide an antecedent for a following pronominal. Hence the contrast between (104)–(106) and (107)–(109):

(107) mei ge$_i$ e$_i$ ai ta$_i$ muqin de ren …
every- CL e$_i$ loves he mother REL man
'every man who$_i$ e$_i$ loves his$_i$ mother'

(108) nei ge$_i$ e$_i$ ai ta$_i$ muqin de ren …
that- CL loves he mother REL man
'that man who$_i$ e$_i$ loves his$_i$ mother'

(109) Mei- yi- ge$_i$ e$_i$ xiang-xin Mary chong-bai ta$_i$ de ren dou
everyone- CL believes Mary admires he REL man all
cuo-le.
mistaken
'Everyone who$_i$ e$_i$ believes Mary admires him$_i$ is mistaken.'

These data are extremely puzzling for any account dependent on the configurational relation between gap, pronominal and binding operator because there is no independent motivation to postulate any difference in the relation between these in the two construction types displayed in (101)–(103); and with the division created between cases in which the gap is superordinate to the pronominal and cases in which the reverse relation holds, there is no possible basis for unifying (101), (103)–(106) as against (107)–(109). On an analysis driven by linearity considerations, to the contrary, the data form a subpart of the general case. Hierarchical relations between the parts of some complex expression do not exclusively determine the interpretation of elements contained therein. Rather, interpretation of such elements depends on the way in which structure is built up on a left to right basis, with *wh*-initial expressions unless appropriately identified providing a systematic exception.

5. Summary

The starting point of this paper was the observation that crossover phenomena had become a mystery. For the solution, we have taken a very

[44] In the more developed notation of Kempson, Meyer-Viol & Gabbay forthcoming, the asymmetry between the head initial and head final relative clauses is an immediate consequence of the way the formalism is set up.

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simple and intuitive idea from natural deduction – that of having a goal to be achieved within a given reasoning task. This concept, when taken as the starting point for a general framework for modelling natural language understanding, has provided a uniform explanation to the crossover phenomenon. Unlike the Principles and Parameters family of explanations which project the data as a number of unrelated phenomena, invoking a principle C explanation for strong crossover, and a discrete explanation for weak and weakest crossover phenomena, the proposed analysis has required no bifurcation of the data. It has only posited a single characterisation of the empty category associated with *wh*-expressions, and no extra construction-specific principles particular to the phenomenon have had to be posited. Moreover it has extended to a broader set of data for which a crossover analysis is inapplicable.

Intrinsic to the explanation has been the emphasis on the process of compiling structure as interpretation, with predictions of data varying according to the information available at the different stages of the interpretation process. Initial *wh*-expressions in questions were said not to project information available for pronominal identification in virtue of their status as a goal specification, thus enabling a linearity account of crossover to be preserved with initial *wh*-expressions as a systematic exception. Restrictive and nonrestrictive construals of relative clauses were said to vary according as to whether the metavariable projected from their associated determiner was instantiated before the building of the linked database configuration, or after it, a decision which provided a natural explanation for why a non-restrictive construal of a relative clause succeeds in providing an antecedent for pronominal resolution, where a restrictive construal of the same sequence may fail. These cases prove particularly problematic for the more orthodox explanations (as do the parasitic gap data), as there is no distinction in the hierarchical relation between the *wh*-pronominal and gap in the two types of relative construal. The only possible explanation of the difference, while maintaining that the explanation is in terms of the syntactic elements in a given hierarchical configuration, is therefore to posit some distinct empty category type or operator specific to this construction. No such construction-specific analysis was required under the proposed analysis. Finally, the interpretation of pronouns was also taken to be an on-line decision sensitive to any prior steps of interpretation, with principle B analysed as a constraint on this process; and it was the interaction of this with the process-oriented explanations of *wh*- and relative clauses which predicted the full range of crossover phenomena while assuming nothing more than the characterisation of the three processes, independently motivated.

The consequence of this form of explanation is the implication that the concept of structure underpinning natural language needs to be defined in terms relating at least in part to general properties of labelled deduction and

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not in terms exclusive to natural language structure. In particular, the phenomenon of long-distance dependence is not on this account some irreducible property of the computational device (Chomsky 1994) but a phenomenon directly explicable in terms of goal-directed reasoning. This strongly suggests that our capacity for language is not some entirely separate module within the cognitive system which bears no relation to the other modules with which it interacts, but is rather a member of a family of logical systems each a purpose-directed specialization sharing properties with neighbouring modules.

The primary motivation for developing this system has not, however, been its potential as a theory of syntax, nor indeed of semantics, but as a model of the interpretation process. At its heart is a reconstruction of the under-specification intrinsic to the content of natural language elements and the modelling of how such content is enriched in the process of natural-language understanding. The challenge that this account of crossover poses is to what extent this dynamic system projecting structure linearly onto a string from left to right as a model of the interpretation process should replace more orthodox concepts of syntax. This challenge cannot be properly explored without full definitions of the proposed system and detailed lexical specifications for particular language fragments (Gabbay, Kempson & Meyer-Viol in preparation). However this preliminary success in explaining crossover phenomena suggests that the incremental articulation of the process whereby interpretations for natural language strings are structurally projected provides the basis for a theory of natural language syntax. An immediate consequence, should this proposal be substantiated, will be the need to rethink the competence-performance distinction, replacing it with a view in which our linguistic competence is seen as a direct abstraction from the principles of performance whereby we interpret natural language input.

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Authors' addresses: (*Kempson*)
Department of Linguistics,
School of Oriental & African Studies,
Technology & Medicine,
Thornhaugh Street,
Russell Square,
London, WC1H 0XG
U.K.
E-mail: rk@soas.ac.uk

(*Gabbay*)
Department of Computing,
Imperial College of Science,
Huxley Building,
180 Queen's Gate,
London, SW7 2BZ,
U.K.
E-mail: dg@doc.ic.ac.uk

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