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Growth of Logical Form

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Anaphoric Processes of Interpretation: Growth of Logical Form

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In this paper, we present analyses of anaphora, relative clause and quantifier construal, modelling them all as processes of growth of logical form. What we show is how, if we model logical forms as trees, and growth of interpretation as growth of such trees along the left-right dimension provided by the sequence of words – taking a full-blown representationalist view of interpretation – then the cross-linguistic variations in relative-clause structure can be seen as different forms of tree growth, yielding a typology of relative clause types. With these results as a promissory note for a new way of looking at syntactic properties of natural language, the old question of whether we need structures in representing interpretation in semantics is transformed into a new question: 'Do we need any mode of representation other than growth of logical forms in order to express generalisations about natural-language syntax?'

First we introduce the Dynamic Syntax framework (Kempson et al 2001), summarising the account of long-distance dependency in terms of underspecified tree relations and tree growth, a substitutional account of anaphora resolution, and an account of relative clause construal that involves a process of copying information from one structure to another during the construction process, an account which reflects directly the anaphoric properties of "relative pronouns". As preliminary evidence, we show how these assumptions make possible an account of resumptive pronoun construal, normally taken to be an entirely independent grammar-internal mechanism, as part of a unitary analysis of anaphora. Secondly, we introduce the DS account of quantifier construal in terms of variable-binding term operators (i.e. invariably of type e) which enables us to directly reflect the parallelism in mode of construal displayed by pronouns and indefinites (whose notorious variation in scope potential has proved controversial over the years). Thirdly, with each of these phenomena expressed as different aspects of logical form growth, we explore the feeding relations between them. Two phenomena in particular, which constitute puzzles in other frameworks, emerge as unproblematic. The distinctive properties of nonrestrictive relative clauses in

English, and the head-internal relative clauses of verb-final languages such as Japanese will emerge as a natural consequence of this shift in perspective, as will the E-type properties of their construal. These are welcome results, in particular because these phenomena are seen to form a natural subpart of an overall typology; and in all other frameworks an integrated account of relatives that is nevertheless sensitive to their distinctive semantic properties remains elusive.[1] We shall close by arguing that the success of this result suggests a more general conclusion, that cross-linguistic variation be seen as the reflex of variation in the incremental and left-right projection of logical form structures from the words as input, with this conclusion providing a new twist to the representationalism debate in semantics (see Heusinger et al 2001 for recent representatives).

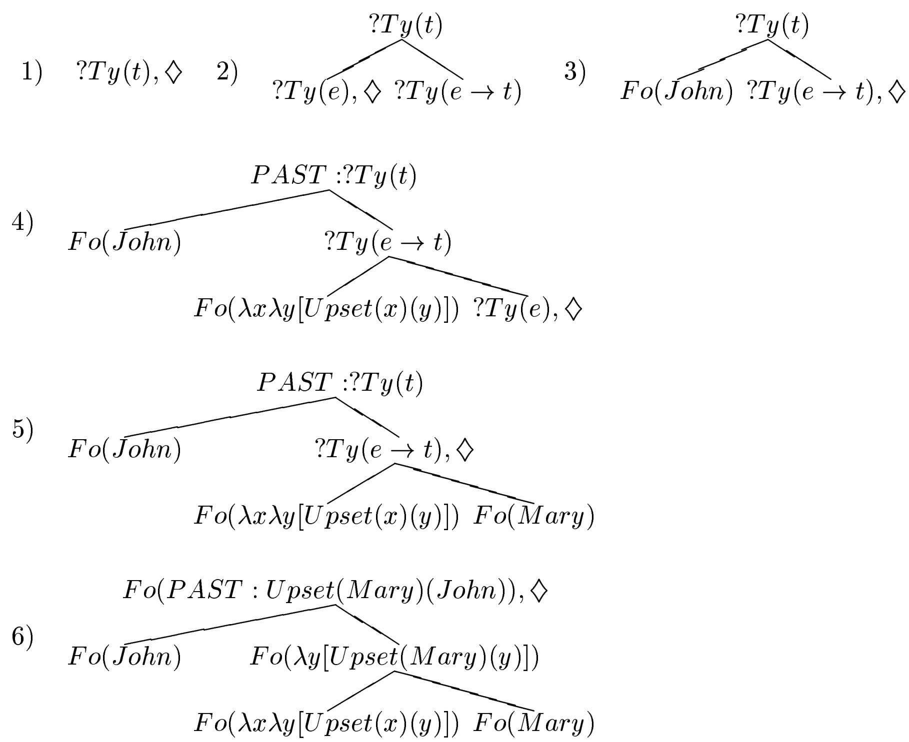
1 The Flow of Language Understanding

According to Dynamic Syntax, the process of natural language understanding is a monotonic process of building up a logical form following the left-right sequence of words, where the goal is to establish some propositional formula as interpretation ($= ?Ty(t)$) as the root of a tree. The goal is a formal reflection of the pragmatic assumption that language processing is a goal-directed enterprise, the goal being to establish the propositional structure the speaker has intended to express. The propositional formula once established is taken to decorate the root node of a tree, each of whose nodes is decorated with a sub-term of this propositional formula, together with its corresponding type specification. These decorations are not words of the language under analysis; they are expressions of a typed lambda calculus – representations of content, each a value of the *Fo* predicate, (*Fo* for 'formula'). The process is one of incrementally building up interpretation in two stages: first, setting out the tree structure as directed by the overall goal and additional subgoals (so-called 'requirements'); second, annotating non-terminal nodes in the tree by steps of labelled type deduction defined over values of the *Ty* predicate (*Ty* for 'logical type') once there are appropriate decorations on the terminal nodes.

Intrinsic to this process are three forms of underspecification, each of

[1]Kayne 1994 is one of the few authors to propose an account of relative clauses that straightforwardly extends to head-final, head-internal, and nonrestrictive relatives, but his analysis signally fails to provide the required range of interpretations, relying on a copy and delete form of analysis in which either the copied term or the source of the copy are deleted, a basis which in principle provides an insufficient base for the range of interpretations available (see section 3.1-3.3).

which has to be resolved during the construction process. First, nodes are introduced with requirements to be fulfilled later, as displayed in Figure.1, starting with a single node decorated a requirement indicating the overall goal to be achieved – $?Ty(t)$. Each node then introduced has some such requirement (the node marked with the pointer $\Diamond$ is the node currently being developed). Notice how in figure 1 each partial tree in the sequence is a



Note	$Ty(e)$	the semantic type of DP
	$Ty(e \rightarrow t)$	the semantic type of VP.

Figure 1: Parsing *John upset Mary*

development of the previous one, as driven by the attempt to satisfy imposed requirements relative to input provided by the words. It is characteristic of these requirements that they may be satisfied substantially later in the construction process than the point at which they are introduced. To pick out just the most extreme case, notice that the goal $?Ty(t)$ introduced at step (1) in figure 1 is not met until the final step.

A second form of underspecification is that nodes can be introduced into a tree as initially unfixed, characterised only as dominated by the top node, their position in the tree being fixed later in the construction process. This is the analysis proposed for the core cases of long-distance dependency.[2] Again, we display the phenomenon graphically – in figure 2.

(1) Mary, John upset

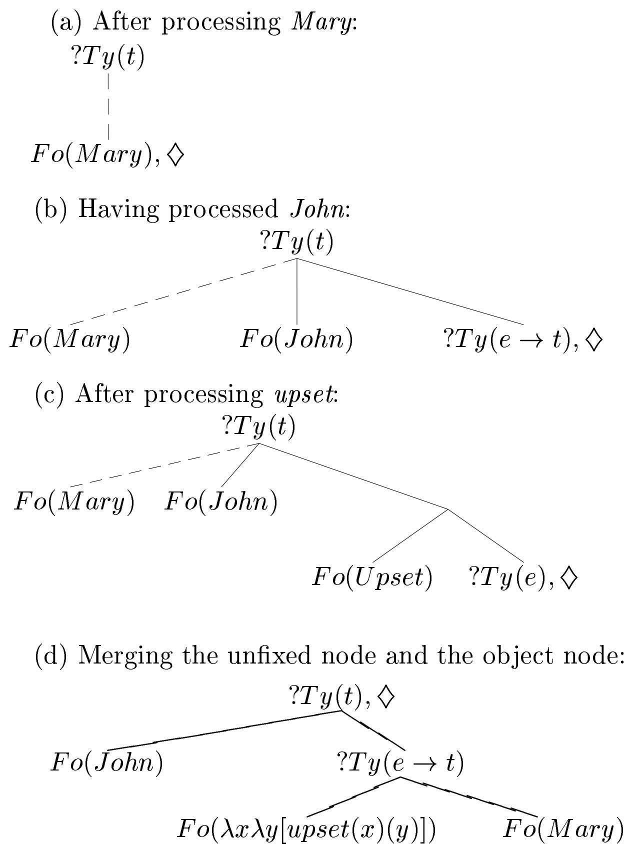


Figure 2: Parsing left-dislocation structures

At step (a), the node annotated by the word *Mary* is introduced as dominated by the top node without fuller specification of its relation to the topnode (hence at that juncture 'unfixed' within that tree). At step (d),

[2]This process bears close formal resemblance to the concept of 'functional uncertainty' of Kaplan and Zaenen 1989, articulated within LFG, but that framework lacks the dynamics of updating such uncertainty as part of the structural characterisation.

this node is merged with some further node whose relation to the topnode is determined, hence establishing its precise role in the logical structure. As figures 1 and 2 jointly display, different strings may lead to the same decorated tree, the difference between them arising from the different sequence of steps leading to that result.

Interacting with both these structural forms of underspecification is the third form of underspecification, in which the lexical specification provided by a word under-determines the denotational content assigned to it in any individual context. Such underspecification is characteristic of the interpretation lexically provided by a pronoun. Given that all interpretation is represented in this framework as decorations on tree structures, a pronoun is defined to annotate a node with a meta-variable as *Fo* value to be substituted by a copy of some selected term. This substitution process is taken to be pragmatic, restricted only in so far as locality considerations distinguishing individual anaphoric expressions preclude certain formulae as putative antecedents for any such copy process:[3]

(2) Q Who upset Mary? Ans: John upset her.

Thus in processing the pronoun in (2), the object node is first decorated with a meta-variable **U** within $Fo(\mathbf{U})$, this being replaced by a copy of some other term, eg $Mary$, copied from the structure constituting the interpretation of the previous sentence. Notice that the substituend for the meta-variable is not the English word *Mary* but the term taken to represent the individual referred to by that word in the given context.

1.1 The Formal Framework

1.1.1 Decorated Partial Trees

As figures (1)-(2) have informally displayed, decorated partial trees are progressively constructed, each node of which is initially decorated with requirements and subsequently with annotations. Such trees are described by a modal logic of finite trees (LOFT - see Blackburn and Meyer-Viol 1994), with three basic operators (denoting daughter and mother relations, and a "Link" relation between one tree and another) and further operators defined in terms of these:

$$\langle\downarrow\rangle, \langle\downarrow_0\rangle, \langle\downarrow_1\rangle, \langle\uparrow\rangle, \langle\downarrow_*\rangle, \langle\uparrow_*\rangle, \langle L\rangle, \langle L^{-1}\rangle, \langle D\rangle, \langle U\rangle$$

[3] The analysis of pronoun construal as a process of substitution is argued for in several different frameworks: see Kamp and van Eijck 1997, Ranta 1994, Fernando 2001, Kempson et al 1999, 2001.

Each operator is interpreted by a discrete relation between nodes in a tree: e.g. the modality $\langle\downarrow\rangle$ is evaluated over the daughter relation – $\langle\downarrow\rangle Ty(e \rightarrow t)$ 'holds' on a node n if there is a daughter where $Ty(e \rightarrow t)$ holds; $\langle\uparrow\rangle$ over the mother relation. More specifically, LOFT has $\langle\downarrow_0\rangle$ $\langle\downarrow_1\rangle$ interpreted over daughters corresponding respectively to nodes decorated with argument and functor types, $\langle\downarrow_*\rangle$ is interpreted over the dominance relation (the reflexive transitive closure of the daughter relation), $\langle\uparrow_*\rangle$ over the inverse of dominance, $\langle L\rangle$ over a relation of LINK between trees (see section 1.2 of this chapter), $\langle L^{-1}\rangle$ over its inverse, and finally $\langle D\rangle$, the weakest relation, is interpreted as picking out any relation between nodes (the reflexive transitive closure of the union of daughter and LINK relations). The decorations that may hold at a node include specification of a value for the formula predicate Fo, a type specification, expressed as an argument of the predicate Ty, a tree-node position – represented as an argument of the predicate Tn. Thus if $\langle D\rangle Fo(Run)$ holds at a node n, there is some node m that can be reached from n following daughter and link relations arbitrarily far, and $Fo(Run)$ holds at m. Conversely, at node m, $\langle U\rangle Tn(n)$ holds. Included within possible specifications are meta-variables, being place-holders for some fixed value to be provided.

The specific and novel advantage of LOFT emerges from the use of the LOFT operators in combination with a generalisation of the concept of requirement $?X$ to any decoration X. This combination makes it possible to describe partial trees which have requirements on a treenode which are modal in form, which will be fulfilled by some OTHER node having a given annotation: a lexically defined restriction may be imposed upon one node that to be satisfied must involve a decoration of some distinct node possibly arbitrarily far. The requirements that may be imposed are thus by no means restricted to nonmodal requirements such as $?Ty(e)$, or simple modal requirements, such as $?\langle\downarrow_1\rangle Ty(e \rightarrow t)$. To the contrary, any formula may be used to express a requirement. For example, while $\langle\downarrow_*\rangle Fo(\alpha)$ decorating a node n as an annotation implies that n dominates a node where $Fo(\alpha)$ holds, $?\langle\downarrow_*\rangle Fo(\alpha)$ decorating node n implies that $Fo(\alpha)$ is REQUIRED to hold at a node dominated by n (literally, there is a requirement on successful completion of node n that there be a node dominated by n annotated by $Fo(\alpha)$). By this means, requirements may constrain subsequent development of the tree from a node at some arbitrary remove; and this provides an additional mechanism for pairing noncontiguous expressions according as one expression imposes some requirement on a node which is secured by a decoration on some discrete node by the other. This gives a much greater flexibility than is standard. For example, it can be used to express "agreement" properties on complementisers, whereby a complementser may impose some complex requirement on the topnode of a newly introduced tree, to be met in virtue of some annotation on a node in the subsequent construction of that tree.

1.1.2 The Dynamics of Tree Growth

LOFT is a language for describing (partial) trees. To describe the tree growth process, we define transitions between partial trees. There are three types of action: computational actions, which are general (albeit possibly language-specific); lexical actions, which are associated with individual words; and pragmatic actions, which are substitution operations, using terms/structure antecedently available. To exemplify the pattern of computational actions defined, we list **Adjunction* which licenses the introduction of an unfixed node:

***Adjunction**

$$\frac{\{\{Tn(a), \ldots ?Ty(t), \diamondsuit\}\}}{\{\{Tn(a), \ldots, ?Ty(t)\}, \quad \{\langle\uparrow_*\rangle Tn(a), ?\exists x Tn(x), \ldots, ?Ty(e), \diamondsuit\}\}}$$

A rule like this should be read as follows: this transition is defined as starting from a partial tree (described as a structured set of nodes) containing only one node (described by the set of formulae holding at that node), here some arbitrary tree node a with requirement $?Ty(t)$. The transition then adds to that one-member set the node described as being dominated by a, $\langle\uparrow_*\rangle Tn(a)$, requiring a type e decoration, with the pointer indicating that it becomes the node currently under development. Notice the introduction of a requirement $?\exists x.Tn(x)$m reflecting the requirement for a fixed treenode value. This is an instance of the general principle that all aspects of underspecification are associated with a requirement for update to a fixed value. This rule conforms to what is an invariant pattern of defining information-preserving transitions from partial tree to partial tree. Any node introduced by this rule has ultimately to be assigned a fixed tree position by a process, *Merge*, which unifies tree nodes. Characteristically *Merge* takes place (as displayed in the step from (c) to (d) in figure 2), where co-present in a tree are an unfixed node annotated with a formula of a certain type and a fixed node requiring that type.

Lexical actions defining the contribution of individual words are, equally, procedures for updating partial tree descriptions. The lexical specifications are of the form $\langle\ IF\ \Sigma, THEN\ \alpha_1,\ ELSE\ \alpha_2\ \rangle$, with the 'IF' condition specifying that Σ must hold on the node at which the pointer resides if the possible compound action given by 'THEN' is to be carried out - viz. α_1. If Σ does not hold, then the action α_2 is carried out For example, the conditions for the actions induced by the English verb *upset* require the pointer to be at a node decorated with the requirement $?Ty(e \rightarrow t)$, from which it initiates the addition of a subtree – a daughter node annotated with $Fo(Upset)$ – and the addition to its mother of the requirement for a daughter decorated by an argument:[4]

upset	
IF	$\{?Ty(e \rightarrow t)\}$
THEN	go($\langle\uparrow\rangle$), put(Tns(PAST)), go($\langle\downarrow_1\rangle$), make($\langle\downarrow_1\rangle$); $\mathtt{go}(\langle\downarrow_1\rangle)$; $\mathtt{put}(Fo(Upset), Ty(e \rightarrow (e \rightarrow t)), [\downarrow]\bot)$; $\mathtt{go}(\langle\uparrow_1\rangle); \mathtt{put}(?\langle\downarrow_0\rangle(Ty(e)))$
ELSE	ABORT

If the condition is not met, the sequence of actions aborts.

Pronouns illustrate how the structure projected by a word may underdetermine content. They supply a meta-variable which has to be replaced by some fixed value to yield a wellformed output.[5] Notice the specification of case, here nominative, as imposing a constraint on tree position that the mother node in the resulting tree be of type t:

he	
IF	$\{?Ty(e)\}$
THEN	put($\{Fo(\mathbf{U}), Ty(e), ?\exists x.Fo(x)$, $?\langle\uparrow_0\rangle Ty(t), [\downarrow]\bot\}$)
ELSE	**ABORT**

Both lexical specifications determine through the annotation '$[\downarrow]\bot$' that the annotated node in question is the terminal node of a tree, a general property of lexical items, this a reflection of the conventional form of the compositionality assumption for natural languages, that the meaning of a sentence is built up by combinatorial operations defined on the meanings of the words. Notice the requirement of $?\exists x.Fo(x)$, the requirement that the metavariable must be replaced as part of the construction process.

[4]The detailed specification of condition and actions in the lexical specifications of verbs, including numbers of nodes to be constructed, varies from language to language, and indeed from verb to verb. This lexical description highlights the various basic actions DS uses to construct trees: put, go, make....

[5]The pragmatic process of substitution is also used to model the incremental way in which some scope choices are established (see Kempson et al 2001).

It is the interaction of computational, lexical and pragmatic processes which determines the interpretation of a string. A wellformed string is one for which at least one logical form can be constructed from the words in sequence within the context of a given class of computational and pragmatic actions WITH NO REQUIREMENTS OUTSTANDING. In consequence, as we shall see, the imposition of requirements and their subsequent satisfaction are central to explanations to be given.

1.2 Linked Structures and Relative Clauses

The Dynamic Syntax framework also licenses the construction of pairs of trees in tandem connected by a 'LINK' relation, described by the operator $\langle L \rangle$. This adjunction introduces the top node of a new tree and copies information from one tree to the other. Taking nonrestrictive relatives as the most transparent case, consider the steps involved in projecting the construal of (3) (displayed in figure 3):

(3) John, who I like, chain-smokes.

Having processed the word *John* to yield a partial tree in which the formula $Fo(John)$ annotates a subject node in some tree (the 'head' node), a transition is licensed which builds a LINK relation from that node, introducing a new (LINKed) tree with topnode decorated with the requirement $?Ty(t)$ PLUS the requirement for an occurrence of the formula $Fo(John)$ at some node, without further specification as to where in the newly introduced tree that might be:[6]

Link Adjunction (English)

$$\frac{\{..\overbrace{\{X, Fo(\alpha), Ty(e), \Diamond\}}^{\text{head}}\}}{\{..\underbrace{\{X, Fo(\alpha), Ty(e)\}}_{\text{head}},}$$

$$\underbrace{\{\langle L^{-1}\rangle X, ?Ty(t)\}}_{\text{linked node}}\underbrace{\{\langle\uparrow_*\rangle\langle L^{-1}\rangle X, ?Fo(\alpha), ?Ty(e), \Diamond\}}_{\text{unfixed node}}\}$$

The relative pronoun *who* duly provides the necessary copy, in (3) construed

[6]The rule here does not extend to pied-piping cases, but this minor simplification is for purposes of exegesis. See Kempson et al 2001 for a fuller definition which applies to such more complex cases:
(i) A Givenchy shirt, the collar of which was faded, was in the sale.

as $Fo(John)$:

$$\begin{array}{lll} who_{rel} & \textbf{IF} & \{?Ty(e), \langle\uparrow_*\rangle\langle L^{-1}\rangle Fo(\mathbf{x})\} \\ & \textbf{THEN} & \text{put}(Fo(\mathbf{x}), Ty(e), [\downarrow]\bot) \\ & \textbf{ELSE} & \textbf{ABORT} \end{array}$$

Notice how the rule feeds the update provided by the relative pronoun. The

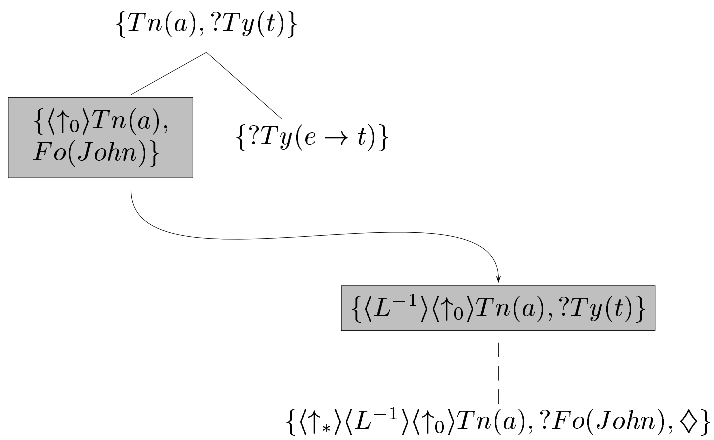


Figure 3: Building a *LINK* transition with *LINK Adjunction*

process of tree construction then proceeds as in the simpler case, with the initially unfixed node having its position in that tree established in due course through the process of Merge.

This construction process applies equally to restrictive relative clause construals. The internal structure resulting from construal of NP sequences contains TWO nodes of type e: a node annotated by a variable, (which is introduced in parsing the noun), and a node projected by the NP as a whole (see figure 4).[7] In both restrictive and nonrestrictive construals, the *wh* relativiser serves the anaphoric function of ensuring the presence of the copy in the LINKed structure. Restrictive relatives involve a copy of the variable, nonrestrictive relatives involve a copy of the formula decorating the containing node of type e, a formula built up from the subparts of that NP sequence (see Kempson et al in preparation for a detailed account of nonrestrictive relatives.). Figure 4 displays the process of *Link Adjunction*

[7]Nonstandardly all NPs are taken to project expressions of type e with quantified expressions characterised as variable-binding term operators (see section 2, Kempson et al 2001 ch.4,7). See section 2.1.

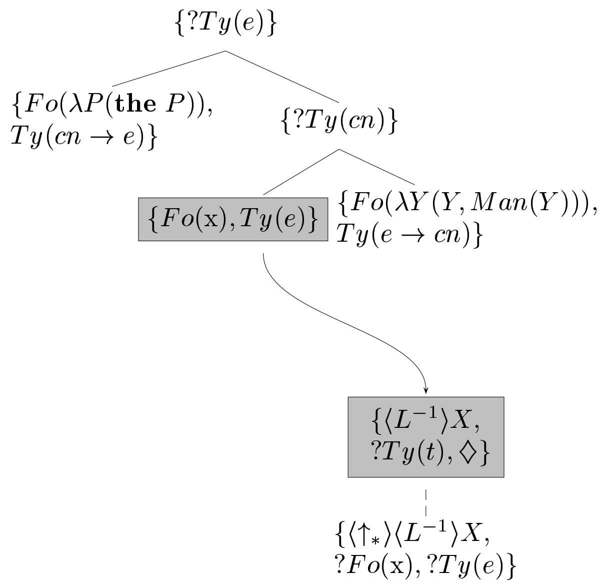


Figure 4: Structure resulting from *LINK-Adjunction* in (4)

for the case of restrictive relative construal, imposing a requirement on an unfixed node in the newly introduced linked structure, as in figures 3 and 4, a requirement fulfilled by the relative pronoun *who* which copies the variable as the head.

(4) the man$_i$ who$_i$ Sue likes e$_i$

The output of any such construction process is a pair of linked structures, the secondary LINKed structure once complete leading to the construction of a complex predicate decorating the type *cn* node as in figure 5.[8] This rule is available for restrictive construals only. In a nonrestrictive relative construals, the LINKed structure remains to be compiled as a second conjunct in the construction of the propositional formula.

An alternative form of construction process for relative clause construal involves the obligatory resumptive use of pronouns, as is displayed by Arabic.

[8]This rule reflects the semantics of restrictive relative construals which, as standardly, we take to constitute a complex restriction on the domain of the variable bound by the determiner. Quantification is represented by term-binding variable operators (see Kempson et al 2001, ch.7).

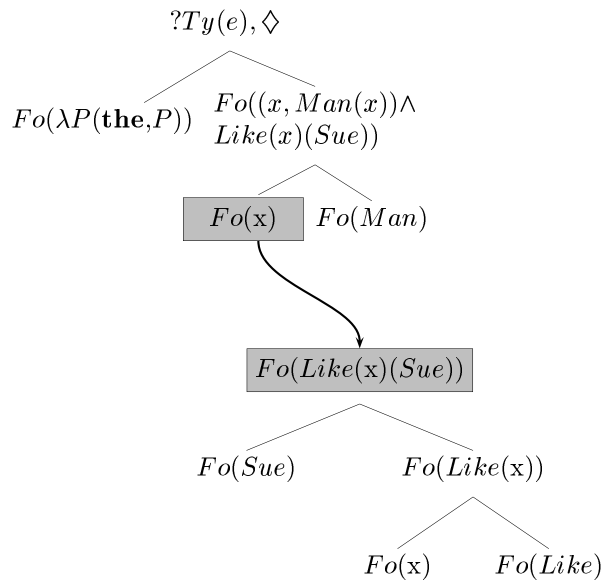


Figure 5: Completing interpretation for a restrictive relative

In (Egyptian) Arabic, a pronoun is essential in all non-subject positions for the strings to be wellformed:[9]

[9] $-u$ is a (reduced) pronoun that in all semantic respects functions as a full pronoun, with a regular array of interpretations when occurring in contexts in which no resumptive construal is forced, though arguably, such weak pronouns have no associated terminal-node restriction (see footnote 11). There is in addition a strong form of pronoun which, as reported in Aoun, Choueiri and Hornstein 2001, occur in subject position and left-dislocated structures:
(i) irra:gil mabsu:t
the-man happy
'The man is happy.' [Egyptian Arabic]
(ii)?irra:gil, HUWWA mabsu:t
the-man HE happy
'The man, HE is happy.'
(iii) huwwa, Magdi darab-u
He, Magdi hit-him
'He, Magdi hit him.'
This suggests an analysis of such strong pronouns as restricted to occurring in contexts which are used to indicate some additional pragmatic effect, viz at the head node of an independent LINKed structure (i.e. a hanging topic position), and an unfixed node

(5) *il* *mudarris* *illi* *Magdi* *darab-u* [Egyptian Arabic]
the teacher who Magdi hit him
'the teacher who Magdi hit'

To reflect this distribution, we propose an analysis in which the complementiser induces the introduction of the required linked tree with its associated requirement for a copy (see figure 6): it does not provide either an unfixed node or the required copy.[10] This requirement, which singularly lacks any locality restriction requiring the copy to occur in some subtree of the total structure, is expressed using the $\langle D \rangle$ operator, which is satisfied by an arbitrary sequence of daughter or LINK relations.

illi	IF	$\{Fo(\mathbf{x}), Ty(e), Def(+), [\downarrow]\bot\}$,
	THEN	make($\langle L \rangle$); go(L); put($?Ty(t), ?\langle D \rangle(Fo(\mathbf{x}), Ty(e))$),
	ELSE	ABORT

The consequence of defining *illi* in this way is that, with no particular lexical item defined in the language as projecting the required copy in such structures,[11] the only way of meeting this requirement is to use the regular substitution process of the language, selecting as interpretation for some pronoun ($-u$ in (5)) the value of the formula provided by the head node. Such a construal is essential, since any other substituend (replacing the pronoun's meta-variable with some independently available term e.g. *Tom, Dick* ...) will leave the LINKed structure with a requirement outstanding, hence not wellformed. In consequence, a pronominal MUST occur in the subsequent string in a position from which an argument to the predicate can be directly constructed, and, moreover, MUST be interpreted as providing a

(which is the canonical position for contrastive "focussed" forms), and furthermore as, unlike the weak clitic form of pronoun, retaining the terminal-node restriction. This is compatible with a distribution which includes subject position (i)-(ii), as in all subject pro-drop languages, full subjects may be taken to decorate an unfixed node which then merges with the subject node induced by lexical actions of the verb. It is also compatible with optional co-referring co-occurrence of the strong form of pronoun and a reduced clitic object pronoun, (iii), in which *huwwa* can be taken to decorate an independent structure, for which the resumptive pronoun provides the required copy in the second LINKed structure.

[10] As a subject prodrop language, we take verbs in Arabic to have a condition for lexical action of $?Ty(t)$ from which node the subject node is constructed as well as the predicate-internal structure, annotating that subject node with a meta-variable needing substitution exactly as a lexical pronominal.

[11] In variants of Arabic except classical, *wh*-questions are the only form which license a left-dislocated expression with no resumptive pronoun. This suggests that *Adjunction in Arabic should be defined to be sensitive to the presence of a +Q feature relative to which the unfixed node is required to have a +WH feature (see Kempson et al 2001, ch.5).

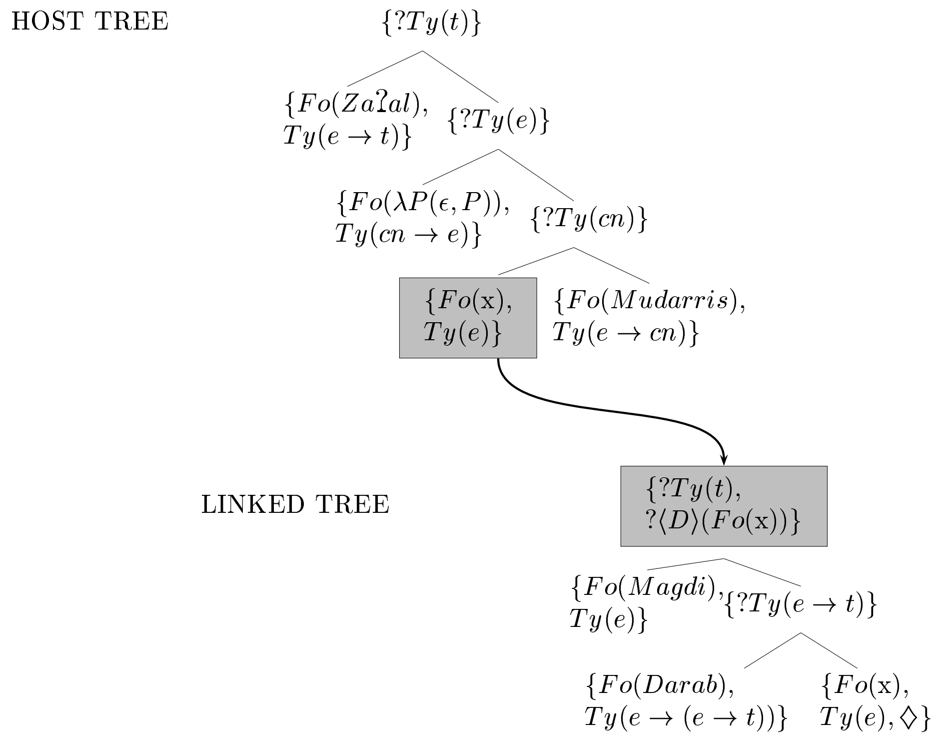


Figure 6: Projection of LINKed trees in Arabic with resumptive pronoun

copy of the formula annotating the head. Thus Arabic provides a case indicated earlier, in which the complementiser imposes a complex requirement on the topnode of a newly introduced tree which is met in virtue of some annotation to a node by a pronoun whose position in the string may be indefinitely far away from the complementiser. This obligatory occurrence of a resumptively construed pronominal needs no separate stipulation, and the substitution process updating the pronominal remains a purely pragmatic process. It is merely the interaction of this process with the modal form of requirement on the topnode of the LINKed tree which determines the result (see Kempson et al 2001 for analyses in detail, and all formal specifications of the framework).[12]

[12]Such phonologically weak pronouns are characteristically associated with a more liberal distribution than pronouns in languages in which there is no such reduced form, in that such clitic pronouns can occur freely in topicalisation structures. This requires a

From the different patterns displayed in English and Arabic, we can abstract the common pattern across all linked structures. All pairs of linked trees can be characterised as sharing a common element: and all transitions from one tree to the other involve the imposition of a requirement on the second for a copy of the selected formula in the first (in head-initial languages, the formula corresponding to the head). What varies is the mode of projection onto this structure – according to whether an unfixed node is or is not projected that carries the required copy; or as varying locality restrictions are or are not imposed upon where within such structures the copied term is required to occur. But the process over all is anaphoric, a copying from one structure to another.

1.3 Correlatives

We can see this anaphoric process, equally, in correlative structures. These occur in languages such as Hindi (Dayal 1996), but, arguably, occur also in English, as the so-called Extraposition from NP construction:

(6) One student has withdrawn from the course,
who Bill said was sick.

(7)

ve	*do*	*laRkiyaan*	*Lambii*	*naiN*	*jo*	*khaRii*	*haiN*
those	two	girls	tall	be-PR	who	standing	be-PR

'Those two girls who are standing are tall [Hindi]

modification of the lexical information projected by such pronouns, viz. the loss of the terminal-node restriction characteristic of full lexical items, a restriction retained by the strong form of pronoun. This is because the node projected in a topicalisation structure as initially unfixed, and merging with the node decorated by the pronoun with a meta-variable, may have arbitrarily complex internal structure.

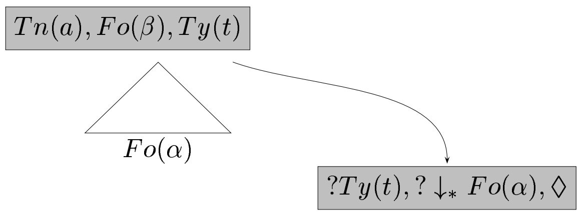
It is notable that in English resumptively construed pronouns may occur without having to posit loss of any such terminal node restriction. In English relative clauses, pronouns can occur with resumptive construal in relative clauses (as reported in Kempson and Kaplan forthcoming):
(i) They've bought a house, which it's called Pandemonium.
In such a structure, the formula associated with the head is copied over into the LINKed structure as the annotation by the relative pronoun of an initially unfixed node (without any accompanying structure reflecting the possible complex internal structure of that formula), a node whose fixed position can then be determined by merging with a node decorated by the subsequent pronoun without violating the restriction imposed by that pronoun that the node that it decorate be a terminal node in some semantic tree structure. Such resumptive use of pronouns, though restricted to informal conversation, is widespread in relative clauses. However, the same resumptive use of pronouns is strikingly absent from left-dislocation structures, as we would expect on an analysis in which the English pronoun has not lost its terminal-node restriction.

(8)

jo	*laRkiyaaN*	*khaRii*	*haiN*	*ve*	*do*	*lambii*	*haiN*
Which	girls	standing	be-PR	those	two	tall	be-PR

'Which girls are standing, those two are tall'

As with more familiar relative clause constructions, these structures essentially share a common term, but the LINK relation is constructed from one top node to a new top node. The LINK relation is built from the top node of the first tree, imposing the requirement for a copy of one of its subterms in the linked structure:



To make such a rule possible, we define a pair of rules: one to introduce such a set of paired structures, a second to evaluate them, once constructed: *LINK-Correlative Introduction*

$$\frac{\{\{Tn(a), Fo(\beta), Ty(t), ..\}, ...\{MOD(Tn(a)), Fo(\alpha), Ty(e)\}....\}}{\{\{Tn(a), Fo(\beta), Ty(t), ..\}, ...\{MOD(Tn(a)), Fo(\alpha), Ty(e)\}....\} \atop \{\langle L^{-1}\rangle Tn(a), ?Ty(t), ?\downarrow_* Fo(\alpha)\}}$$

$$MOD \in (\langle\uparrow_0\rangle, \langle\uparrow_1\rangle)*$$

LINKed Tree Evaluation:

$$\frac{\{\{X, ...Fo(\phi), Ty(t), \Diamond\}, \{\langle L^{-1}\rangle MOD(Tn(X)), ...Fo(\psi), Ty(t), \Diamond\}...\}}{\{\{X, ...Fo(\phi \wedge \psi), Ty(t)\}, \{\langle L^{-1}\rangle MOD(Tn(X)), ...Fo(\psi), Ty(t)\}...\}}$$

$$\text{where } MOD \in (\langle\downarrow_0\rangle, \langle\downarrow_1\rangle)*$$

Notice how the primary difference between this LINK evaluation rules and that defined for restrictive relatives lies in the point at which the process takes place, the one for compiling a complex restriction for a type *cn* node (see figure 5), the present rule for compiling a conjunction at a node of type *t*.

2 Quantifier Construal

Having set out an essentially anaphoric account of relative clause construal, the next step is to see the evidence for defining quantifier construal in similar terms, assuming relatively weak lexical specifications and concepts of tree growth, while nevertheless retaining the analyses so far set out. The first step, then, is to review the phenomenon of quantifier scope ambiguity.

In all discussions of quantifier scope variation in natural language, one assumption has remained constant. A reconstruction of scope construal between one scope-taking expression and another has to be defined at a propositional level to reflect their contribution to propositional operations, functions from (open) proposition to (possibly open) proposition. This very familiar assumption is illustrated by the fact that sentences containing more than one quantifier can be interpreted in a number of ways within a clause according as the one is taken to have scope over the other:[13]

(9) Every nurse interviewed a patient.

(10) A nurse interviewed every patient.

This phenomenon of scope ambiguity is standardly modelled along the pattern of predicate logic; and it has been assumed to be uncontroversial that the formal reconstruction of scope must be defined as a general process, whether syntactic or semantic.

Either way, there are a number of puzzles. First, not all pairs of quantifiers allow reversed scope interpretations. Though (11) allows an interpretation 'For every visiting dignitary at the station, there was a student meeting them', neither (12) nor (13) allow such a reversed scope interpretation:

(11) A student was meeting every visiting dignitary at the station.

(12) Most anarchists tolerate few politicians.

(13) Almost no student has read every book by Chomsky.

Secondly, of those quantifiers which allow reversed scope interpretations, only indefinites freely allow interpretations in which they are interpreted as taking scope wider than the clause in which they are contained. Thus (14) can have the interpretation in which *most particularly good scripts* is

[13] English speakers report a preference for an interpretation of (10) reflecting linear order, with (10) accordingly describing that one nurse interviewed the full set of patients, but also allow as possible an interpretation in which not all patients are interviewed by the same nurse.

interpreted as taking wide scope with respect to *two examiners*, but it cannot be interpreted as meaning that for some large proportion of scripts it is the case that for each such script everyone agreed that two examiners had marked it:

(14) Everyone agreed that two examiners marked most particularly good scripts.

(15) to the contrary has just such an interpretation, allowing the interpretation in which for each of two particularly good scripts everyone agrees that most examiners marked that script:

(15) Everyone agreed that most examiners marked two particularly good scripts.

In the ongoing controversy about the analysis of scope choice for indefinites, a number of authors (Reyle 1993, Alshawi 1996, Kempson et al 2001) have argued for an analysis in terms of underspecification of the NP-projected content,[14] some partial logical form then being said to be resolved through a subsequent algorithm enriching the constructed logical forms. One property that has gone almost unnoticed in these discussions is the parallelism between choice of interpretation for an anaphoric expression and choice of interpretation for indefinites, and the cross-linguistic variation that this gives rise to, with many informants in other languages robustly denying the variation which most English informants allow for (10) and (11):[15]

(16)	*mei*	*ge*	*ren*	*mai*	*le*	*yi*	*ben*	*shu*
	every	CL	man	buy	ASP	one	CL	book

Every man read one book [ambiguous]

(17)	*yi*	*ge*	*ren*	*mai*	*le*	*mei*	*ben*	*shu*
	one	CL	man	buy	ASP	every	CL	book

One man read every book [unambiguous]

In particular in Chinese, though (16) is reported to be ambiguous, as indeed an ambiguity analysis of indefinites would allow, (17) is said to have only a single interpretation, with no interpretation of the indefinite as taking narrower scope than the following universal *mei*. For such speakers, then,

[14] Contra analyses which stipulate lexical ambiguity of every indefinite, as in Fodor and Sag 1982, Scabolzci 1997, Reinhart 1997.

[15] There is variation between English speakers also over the degree of sensitivity to linear order with which they evaluate interpretations.

inverted scope interpretations are possible with indefinites FOLLOWING some other quantifier, but not in the reverse order, a phenomenon which the ambiguity account of indefinites does not provide a means of addressing.

This property goes hand in hand with quantifier construal restrictions. Whatever role linearity considerations play in a language in determining how a pronoun is understood will also determine relative scope of indefinites in that language. Chinese, for example, is a language in which pronominal construal is strictly determined by linear order. It is an exceptional language in allowing relative clauses both to follow and to precede the modified noun head, and these options display different potentiala for construal of pronouns contained within the relative clause. If the relative clause precedes the head, as in (18)-(20), the pronoun *ta* cannot be understood as dependent on the following quantified expressions:

(18)

xiang-xin	*mary*	*chong-bai*	*ta*	*de*	*mei-yi-ge*	*ren*	*dou*
believe	Mary	admires	him_i	REL	every	man_j	all
cuo-le							[Chinese]
mistaken	[unambiguous]						

' Everyone_j who believes Mary admires him_i is mistaken'

(19)

hushi	*ta*	*muqin*	*de*	*mei*	*ge*	*ren*	*dou*	*mei*
ignored	he_i	mother	REL	every	CLASSIFIER	man_j	all	not
kao	*jige.*							
test	pass							

'Everyone_j who ignored his_i mother failed the test.'

(20)

xiang-xin	*Mary*	*chong-bai*	*ta*	*de*	*mei-yi-ge*	*ren*	*dou*
believe	Mary	admires	him_i	REL	every	man_j	all
cuo-le							
mistaken							

'Everyone_j who believes Mary admires him_i is mistaken.'

However, with reversed order of head and restrictive relative, there is an interpretation in which the pronominal is interpreted as bound by the quantifier:

(21)

mei	*ge*	*hushi*	*ta*	*juqin*	*de*	*ren*	*dou*	*meikao*
every	classifier	ignored	he	mother	REL	man	all	not
jige								
test	pass							

'Everyone_i who ignored his_i/j mother failed the text.'

(22) *mei-yi-ge* *xiang-xin* *Mary* *chong-bai* *ta* *de* *ren* *dou*
everyone blieve Mary admires him REL man all
cuo-le
mistaken
'Everyone$_i$ who believes Mary admires him$_i$/j is mistaken.'

These facts go together with (16)-(17). In (17), choice of dependency of the indefinite cannot be made relative to some quantified expression succeeding it, but if the quantified expression precedes as in (16), then the indefinite may be interpreted as being dependent on that quantifier. [16] [17]

The parallelism between anaphora and indefinites is sustained even in languages where the correlation between word order and scope is not deterministic. For example, German is a language in which linearity effects in quantifier construal have been observed, but these effects are not tight enough to warrant encoding in the grammatical system. The phenomenon arises in German subordinate clauses, where all noun phrases precede the verb.[18] In subordinate structures, an indefinite expression preceding some quantifying adverbial is generally not interpreted as within the scope of the following adverbial, whereas indefinites that follow the adverbial are freely interpretable as taking either narrow or wide scope with respect to that adverbial:[19]

(23) *weil* *ein* *Assistentsarzt* *zweimal* *einen* *Patienten* *von*
because a doctor twice a patient from
einer *gefährlichen* *Krankheit* *geheilt* *hat.* [German]
a dangerous disease cured
'because one doctor twice cured a patient of a dangerous disease'

(24) *weil* *zweimal* *ein* *Assistentsarzt* *einen* *Patienten* *von*
because twice a doctor a patient from
einer *gefährlichen* *Krankheit* *geheilt* *hat.*
a dangerous disease cured

[16] Not quite all our informants reported the asymmetry between (19) and (20), but, commensurate with the assertion of parallelism between indefinites and pronominal construal, The one Taiwanese informant who reported that (17) allowed a reversed scope interpretation, also reported that (19) and (18) allowed interpretations in which the pronoun is construed as a bound variable, as is consistent with this analysis.

[17] This restriction on the interpretation of indefinites as ambiguous only if they follow some other quantified term is very widespread, though it is not often expressed in the terms suggested here (see Hoji 1986 for a report of similar data in Japanese).

[18] In main clauses, where the V-2 effect ensures that at least one expression is isolated as preceding the verb, the effects of linearity are less clearcut.

[19] These data are, we believe, due to Hans Kamp.

'because twice a doctor cured a patient of a dangerous disease'

(25)

weil	*von*	*einer*	*gefährlichen*	*Krankheit*	*zweimal*	*ein*
because	from	one	dangerous	disease	twice	a

Assistentsarzt	*einen*	*Patienten*	*geheilt hat.*
doctor	a	patient	cured

'because from a dangerous disease one doctor twice cured a patient'

So in (23) *ein Assistentsarzt* is interpreted as taking wide scope with respect to *zweimal*, whereas both *einen Patienten* and *einer gefährlichen Krankheit* freely allow interpretations with wide or narrow scope with respect to *zweimal*. In (24) all three indefinites can be interpreted in both ways, and in (25) it is *einer gefährlichen Krankheit* that is restricted to take wide scope with respect to the adverbial. However, the restriction does not appear to be structurally definable, because if TWO indefinites precede the adverbial in such constructions, the second may take narrow scope with respect to the adverbial which immediately follows, as in (26), which allows an interpretation in which one doctor twice cured a patient of some dangerous disease (different patient and different disease on each occasion):

(26)

weil	*ein*	*Assistentsarzt*	*einen*	*Patienten*	*zweimal*	*von*
because	a	doctor	a	patient	twice	from

einer	*gefährlichen*	*Krankheit*	*geheilt*	*hat.*
a	dangerous	disease	cured	

In the same circumstances, anaphora resolution also allows an interpretation of the pronominal *ihren* in (27) as bound by the quantified expression that follows:

(27)

weil	*ein*	*Assistentsarzt*	*ihren*	*Krankheitsverlauf*	*zwei*
because	one	doctor	their	disease-progress	two

Patienten	*zeigte*
patients	showed

'because one doctor showed two patients their hospital record'

Reflecting this parallelism, given the analysis of pronoun construal in terms of a choice mechanism determining what term provides the antecedent for fixing its interpretation, one might seek to model indefinites also in terms of some underspecified lexical input and a choice mechanism to determine what other term the indefinite should be dependent on.

2.1 Quantifier Construal and Scope choice

The task is to define quantifier construal in terms that reflect the incremental process of building up interpretation, which brings out the parallelism between indefinite and pronoun forms of construal in contradistinction to the rigidity of the scope mechanism for other quantifying NPs.

The first problem, given the commitment to a left-right processing perspective, is that we have to incorporate the information supplied by quantified noun phrases into the tree before their scope relations to other quantified terms and to modalities can be determined. We therefore want to be able to collect any restrictions on scope between quantified terms as they become available in the course of a parse through the string. To reflect this, our analysis of quantification falls into three parts. First, we analyse quantified NPs as projecting structured objects of type e. Secondly, we assign *scope relations* to these structured objects.[20] Finally, we define an algorithm determining the evaluation of the pair of a sequence of scope relations and a propositional formula.

Quantified NPs, like proper names, are taken to project values of the *Formula* predicate of type e. The representations they project are partial specifications of *variable binding term-operators*. For instance, the phrase *a man* will be represented by an incomplete epsilon term:

$$(\epsilon, x, Man(x))$$

Such incomplete terms can be completely described by fixing four parameters:

1. The **Binder** which indicates the mode of quantification (e.g. existential): it is projected by the determiner, or, failing any such determiner, the noun.

2. The **Variable** to be bound by the binder: it is projected by the noun.

3. The **Restrictor** indicating a constraint on the binding domain of the variable, also projected by the noun.

Finally, to characterise the interpretation of such terms as projected from a sentence:

[20] The assumption that relative scope statements are collected in the construction of a fully annotated tree is similar to that defined in Minimal Recursion Semantics (see Copestake, Flickinger, and Sag 1999), though in their analysis, the concept of 'outscope' (expressed by '< ' extends to all terms, e.g. *every* outscopes *dog*, and the progressive collection of such scope statements is exclusively on a bottom-up basis, with no intended correspondence to a left–right process of interpretation.

4. A scope statement is required. These **Scope** statements take the form

$$x < y$$

where x and y are arbitrary variables of type e stating, in this case, that the quantifier binding x has scope over the quantifier binding y.

Each of these features needs to be fixed, by whatever encoded or pragmatic means, so that the semantic, i.e. truth-functional, interpretation of a clause projection will be fully determined. With a given *Formula* value ψ of type t,

$$\psi = \phi((\nu_1, x_1, \psi_1) \ldots (\nu_n, x_n, \psi_n))$$

where the (ν_i, x_i, ψ_i) displayed are the projections of quantified NPs occurring in a clause, each with a unique variable x_i, we can associate a strict partial order:

$$\mathcal{B} = \langle B, <_{\mathcal{B}} \rangle$$

where $B \subseteq \{x_1, \ldots, x_n\}$ and $<_{\mathcal{B}} \subseteq B \times B$ is an irreflexive, transitive relation on B. Such an ordering reflects a choice of scope constraints on the terms occurring in ψ. Once we have such an order, the interpretation of the string can be algorithmically determined, as we shall shortly see.

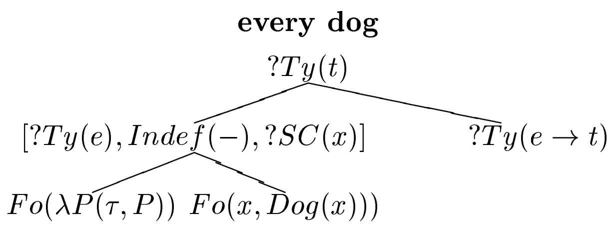
2.2 The Dynamics of Building up Interpretations

The task of incrementally building up such interpretations is induced from the lexicon. Scope statements are collected incrementally at the closest proposition-requiring node, with determiners and nouns introducing the requisite sub-terms of type e, their associated structure, and the accompanying scope statement. Such packages of information projected by a determiner-noun combination yield an incomplete variable-binding term operator with assorted actions for updating the tree. These include introducing new variables, restrictor predicates, scope statements, and imposing any additional idiosyncratic constraints on interpretation. For example, indefinites are assigned a constraint on scope determining that they must have NARROW scope with respect to something. This takes the form of a scope statement whose first argument is a metavariable, the flexibility of interpretations for indefinites arising from the fact that the value of this metavariable is restricted only by the additional filter that the selection be made out of other terms in the construction process.[21] All other quantifiers are assigned a scope statement that restricts the scope of the quantifier to being fixed relative to the most recently constructed (nonindefinite) term.[22]

For example, consider the incremental parsing of (28)

(28) Every dog ate a biscuit.

The determiner introduces the binder and a feature classifying the term under construction as not indefinite. The noun introduces the variable to be bound, as well as the nominal, together with a requirement on the higher type e node of the form $?SC(\mathbf{x})$ for the introduced variable $\mathbf{x}$, which is a requirement that the term constructed stand in a scope statement to at least one other term:

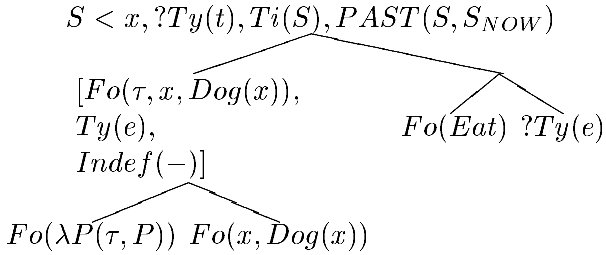


Every propositional formula is assumed to have a variable representing its index of evaluation, and the tense-marking on the verb projects this variable, a formula of the form $Ti(S)$ that sortally classifies this variable as a temporal variable, and a temporal relation, here the relation 'past' to the time of utterance, indicated by S_{NOW}. With this addition, a scope statement for the first quantifying expression can also be added:

[21] Given that under certain circumstances, anaphoric processes in English can be construed cataphorically, we expect that indefinite scope choice might also be cataphoric, in this way providing an explanation for reversed scope interpretations for examples such as (i) without invoking any quantifier raising process for the nonindefinite in such cases:
(i) A nurse intervewed every patient.

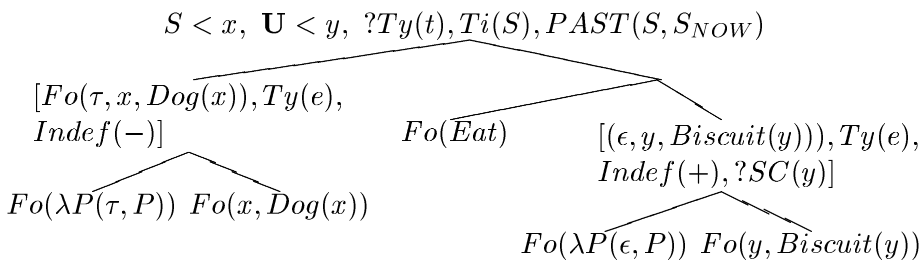
[22] This is achieved by defining two predicates $DOM(\phi)$ and $DOM^{+}(\phi)$. $DOM(\phi)$ holds at some $Ty(t)$ node of the index of evaluation and of all terms of type e at nodes the node dominates. $DOM^{+}(\phi)$ holds at the topnode of some tree of the index of evaluation and all nonindefinites whose formulae decorate nodes within the tree in question. The restrictions then make reference to these two predicates. Any idiosyncratic exceptions to the rule for nonindefinites, such as *each* which is commonly said to license wide scope construals with respect to other expressions in its containing clause, would, like the indefinite, have to be specifically defined.

every dog ate



Indefinites are analysed in the manner of other quantifiers, with the noun introducing the variable and the associated specification of restrictor, with the indefinite determiner itself imposing a promissory note for an epsilon term, together with the constraint that this term take narrow scope with respect to some OTHER term introduced in the construction process:

every dog ate a biscuit



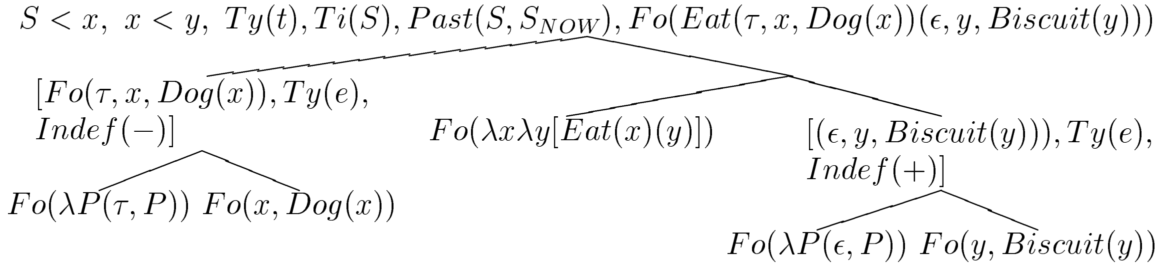
The scope action defined for indefinites is:

IF	$\{Indef(+), ?SC(\mathbf{x}), ?Ty(e)\}$
THEN	**go-to-first** $?Ty(t)$, **put(** $\mathbf{U} < \mathbf{x}$,
	$?\exists\mathbf{y}(DOM(\mathbf{y})\ \wedge \mathbf{y} < \mathbf{x} \wedge$
	$\forall\mathbf{z}(\mathbf{y} < \mathbf{z} \rightarrow (\mathbf{x} < \mathbf{z}))))$
ELSE	ABORT

Note the restriction on the scope statement for $\mathbf{x}$, the variable associated with the indefinite, that it take narrow scope with respect to some term $\mathbf{y}$ under construction (of which $DOM(\mathbf{y})$ holds) and that for whatever choice of $\mathbf{y}$, $\mathbf{x}$ takes wider scope than all other terms contained with the scope of $\mathbf{y}$.

This choice of first argument for the indefinite's scope statement ranges over all variables used in the construction process, including those expressing temporal (or modal) relations. One such choice can be, as here, that the indefinite is construed relative to the variable projected by the subject, and so we can obtain a propositional formula and complete scope statement.

every dog ate a biscuit



Other choices available include terms introduced later in the construction process, such a choice leading to the reversed scope interpretations of (10) and (11). Interpretations in which the indefinite apparently takes widest scope – the so-called specific uses of indefinites – are said to take narrower scope than the time of utterance. All the available types of interpretation are thus characterised from a unitary lexical specification which under-determines the interpretation selected in context, thereby avoiding the disjunctive characterisation of ambiguity-based analyses.[23]

2.3 Term-Operator Evaluation Rules

Once a pair of a propositional formula and an associated scope statement has been compiled, the Evaluation Rule determines how the terms are to be completed. The algorithm defining these processes follows the equivalences:

$$\frac{\exists \mathbf{x} \phi(\mathbf{x})}{\phi(\epsilon, \mathbf{x}, \phi(\mathbf{x}))}$$

Formulae of the form:

$$\phi(\nu_1, x_1, \psi_1), \ldots, (\nu_n, x_n, \psi_n)$$

[23] To flesh this analysis out in detail would require a specification of the index of evaluation in detail for temporal and modal statements, which we leave on one side pending a proper account of tense and mood. Though this renders these results provisional, it will not affect the analysis of the dynamics of the construction process, which is our main concern.

are evaluated relative to a scope statement:

$$\frac{\langle \ldots, S < x_1 < \ldots < x_n, \ldots, t\rangle : \phi[\nu, x_n, \psi_n/x_n]}{\langle \ldots, S < x_1 < \ldots < x_{n-1}, \ldots, t\rangle : f_{\nu_n, x_n, \psi_n}(\phi),}$$

where for x occurring free in ϕ and S a (temporal) index, the values $f_{\nu x \psi}(\phi)$, for $\nu \in \{\epsilon, \tau, Q\}$, and $f_S(\phi)$ are defined by:

- $f_{\tau x \psi}(\phi) = \psi[a/x] \rightarrow \phi[a/x]$

  where $a = \tau x(\psi \rightarrow \phi)$
- $f_{\epsilon x \psi}(\phi) = \psi[b/x] \wedge \phi[b/x]$

  where $b = \epsilon x(\psi \wedge \phi)$
- $f_{Q x \psi}(\phi) = (\psi[c/x])(\phi[c/x])$

  where $c = \nu_Q x((\psi)(\phi))$.
- $f_S(\phi) = (S : \phi)$

Evaluation is from the narrowest scope outwards. Notice how each such statement is a function on the restrictor of the term under development and the propositional formula to yield a compound formula with appropriate connective '$\wedge$' for existential, '$\rightarrow$' for universal quantification. The effect of all such binding statements is to replace any open variable with the corresponding closed term, itself containing the full specification of the propositional formula with all occurrences of the variable bound within it by the appropriate term operator. The result of evaluating a complete set of scope statements is a propositional formula whose arguments are all closed terms. To take the simplest example, consider:

(29) A man is leaving.

Parsing (29) induces a tree with rootnode formula:

$$S \ < \ x : \ Fo(Leave(\epsilon, x, Man(x)))$$

This can be represented by

$$S : \ Man(a) \wedge Leave(a)$$

where $a = (\epsilon, x, Man(x) \ \wedge \ Leave(x)))$
This pattern of term building is sustained in more complex examples also: each resulting term is closed, whether or not it contains narrow or wide scope with respect to its companion terms. The representation of the interpretation of (30)illustrates this. The two terms constructed are given schematically as b and a (with subscripts on a to indicate the dependency):

(30) Every child peeled an apple.

$$(S < x < y) \quad Fo(Peel((\tau, x, Child(x)), (\epsilon, y, Apple(y)))), Ty(t).$$

$$Fo(S : Child(b) \rightarrow (Apple(a_b) \wedge Peel(b, a_b))), Ty(t)$$

where

$$a_b = (\epsilon, y, (Apple(y) \wedge Peel(b, y)))$$

$$b = (\tau, x, Child(x) \rightarrow (Apple(a_x) \wedge Peel(x, a_x)))$$

$$a_x = (\epsilon, y, (Apple(y) \wedge Peel(x, y))).$$

b occurs as a subterm of the narrower scoped term a, and b itself contains a further occurrence of a, this time with x as a subterm. But x is bound by the τ operator, hence the entire term a is fully closed.

3 Linked Structures and quantifier construal

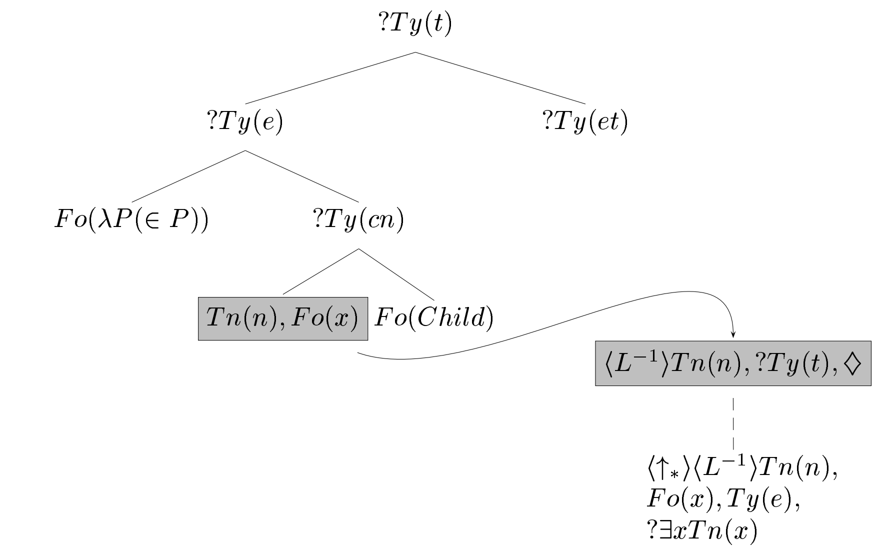
With this sketch of the quantifier construal rules as background, we now investigate their interaction with the construction of linked structures. We assume that, aside from the idiosyncracies of indefinites, all quantifier constraints are implemented as locally as possible within a propositional structure whose subterms the quantifying expressions project, and following the linear ordering.[24] There are systematic exceptions, however, in which expressions have to remain unevaluated within a given structure, and for these cases, as we shall see, some accompanying scope statement, though initially entered at the local $?Ty(t)$ node, is lifted up to a higher node for later evaluation.

Consider first a case in which the choice selected is for the indefinite to be interpreted relative to the structure within which the term is taken to decorate a node:

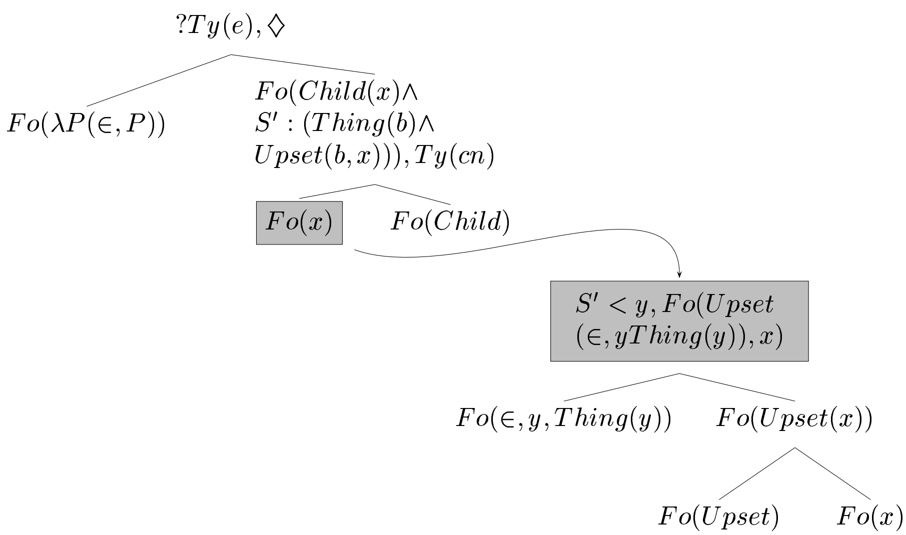
(31) A child who something had upset cried.

Following the LINK transition, we assume that the relative pronoun copies the variable projected by the noun at an unfixed node within the newly induced LINKed structure.

[24] Note the lack of reversed scope readings of (12)-(13).



Given a choice of the indefinite *something* in *child who something had upset* as dependent for its construal on the local index of evaluation S', the result of evaluating the scope statement of the form $S' < y$ in conjunction with the resulting propositional formula $Fo(Upset(\epsilon, y, Thing(y)), x)$ yields an open propositional formula with one variable remaining free:



Interpretation of relative: $S' < y, Fo(Upset(\epsilon, y, Thing(y)), x)$
$= Fo(S' : Thing(b) \wedge Upset(b, x))$

$b = \epsilon, y, Thing(y) \wedge Upset(y, x)$

The variable x associated with *a child* is evaluatable only in the initially introduced tree. When the construction and decoration of this tree is complete, the resulting form is the pair:

$$S < x, \quad Fo(Cried(\epsilon, x, (Child(x) \wedge S' : (Thing(b) \wedge Upset(b, x)))))$$

By evaluation of the pair of scope statement and the propositional formula, the resulting interpretation is:

$$S : Child(a) \wedge S' : (Thing(b) \wedge Upset(b, a) \wedge Cried(a))$$

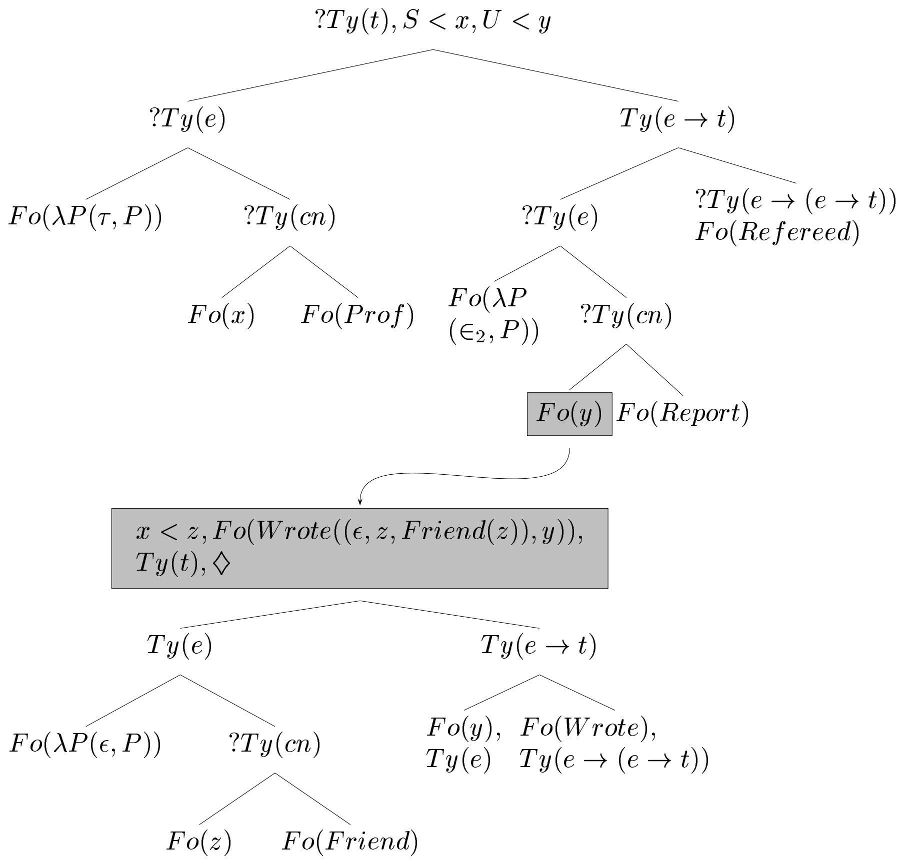
where

$$a = \epsilon x.Child(x) \wedge S' : (Thing(b) \wedge Upset(b, x) \wedge Cried(x))$$

Things are of course not always this simple. In particular, should the scope choice for the indefinite not be part of the subtree into which the variable has been introduced, the corresponding scope statement will not be evaluable in that LINKed structure, as, relative to such choice, there will be no occurrence of the first argument of the scope statement in the propositional formula under evaluation at the topnode of that LINKed structure. Consequent upon an anaphoric-like choice of this sort, the associated scope statement will have to be lifted up in the tree to a node at which it can be evaluated. This process is displayed in the following example on the assumption that *a friend of his* is construed as taking wide scope with respect to *two reports* but narrow scope with respect to *every professor*.[25]

(32) Every professor refereed two reports that a friend of his wrote

[25] It has been argued Kratzer 1998 that such interpretations occur only in the presence of a pronoun identified as bound by the wider scope quantifier. However this isn't so, as demonstrated by Reinhart 1997, Winter 1997. We retain a Kratzer-style example simply to secure the salience of the relevant reading.



Possible Resulting Interpretation:
$S < x < z < y$
$Fo(Refereed(\tau, x, Prof(x)), (\epsilon_2, y(Report(y) \wedge S' : Wrote((\epsilon, zFriend), y)))))$

The scope statement for the indefinite, $x < z$, is first entered at its local type t-requiring node; but it had to be lifted up from there to the topnode of the structure into which the variable x (associated with *every professor*) was introduced, in order that it be evaluated as part of the scope statements for the sentence as a whole. The quantifier binding the variable y, on the other hand, associated with *two reports that a friend of his wrote*, projects a scope statement determining that it takes narrow scope with respect to some term to be chosen; and on the assumption that this is the variable x associated with the subject, consistency with the constraint imposed by the indefinite that it also take narrow scope with respect to the subject determines the final result.[26] The upwards passing of scope statements is defined as follows:[27]

U-Scope-Passing

$$\frac{\{\{Tn(X), ?Ty(t), ..\}, \{\{MOD(Tn(X)), Ty(t), ..\Diamond\}, \{...x_i < y_j, ..\}\}...\}}{\{\{\{Tn(X), ?Ty(t), ..\}, \{...\{...x_i < y_j, ..\}...\}\}, \{MOD(Tn(X)), Ty(t), \Diamond\}...\}}$$

$MOD \in \{(\uparrow_0) * (\uparrow_1) *\}^*$

3.1 Nonrestrictive relatives

Turning back to the nonrestrictive form of construal which formed the point of departure for this account of relatives, recall that these were analysed as copying the formula decorating the higher of the two type e nodes - the local top node projected by a noun phrase expression. In section 1.2, this was illustrated with a simple name; but in quantified cases, this will have the consequence that incomplete terms may be copied from one structure over to a LINKed structure, as these constitute the intermediate form of interpretation assigned to quantified expressions. What we now see is that this type of transition covers a number of different types of case, giving a more fine-grained analysis than the orthodox binary division between restrictive and nonrestrictive forms.

First, recall that LINKed structures are projected as a conjunctive propo-

[26] There are many details here which need to be established, in particular the interaction between temporal and modal variables and the evaluation of the containing formulae.

[27] Such upward-passing processes are not restricted to the wide scope effects associated with indefinites. See also (i), in which with *each* licensing a scope construal for its associated term that is wider than other terms introduced in its containing structure, there is an available wide scope interpretation, which requires application of *U-Scope-Passing* for successful evaluation of any such scope statement:
(i) Most questions that each student answered were too hard for him.

sitional formula. The rule is defined to apply both to structures constructed by a LINK relation to some node contained within that tree, and to structures LINKed to the topnode of the first tree (repeated here):[28]

LINKed Tree Evaluation:

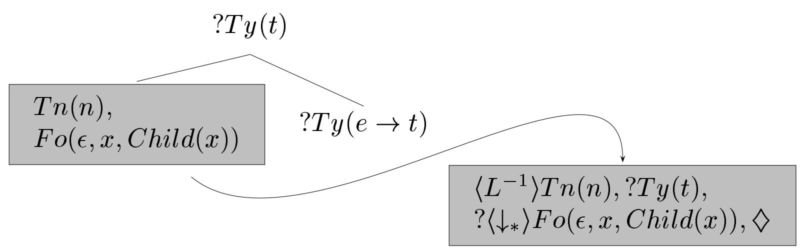
$$\frac{\{\{X, ...Fo(\phi), Ty(t), \diamondsuit\}, \{\langle L^{-1}\rangle MOD(Tn(X)), ...Fo(\psi), Ty(t), \diamondsuit\}...\}}{\{\{X, ...Fo(\phi \wedge \psi), Ty(t)\}, \{\langle L^{-1}\rangle MOD(Tn(X)), ...Fo(\psi), Ty(t)\}...\}}$$

$$\text{where } MOD \in (\langle\downarrow_0\rangle, \langle\downarrow_1\rangle)*$$

With this rule in mind consider the nonrestrictive construal of (33), in which what is asserted is that John had upset a child, and that that child cried, with *cried* as the primary predicate:

(33) A child, who John had upset, cried.

The analysis we propose is that incomplete terms may be copied over as a requirement on the introduced LINKed structure:



Resulting form:

$S < x, \quad Fo(Cried(\epsilon, x, Child(x)) \wedge S' : Upset(John, (\epsilon, x, Child(x)))$

The LINK transition in (33) induces a requirement for a copy of the incomplete term, $(\epsilon, x, Child(x))$ as a constraint on building up the LINKed structure. This open formula is taken to be the second conjunct of a compound formula:

[28] The rule is defined with the pointer at the node of the primary structure. Notice that unless the evaluation of the accompanying scope statement has already applied to this structure, which it will not if what is copied over is an incomplete term, a return of the pointer to this node is essential to achieve an evaluated coordinate proposition.

$Fo(Cried(\epsilon, x, Child(x)) \ \wedge Upset(John, (\epsilon, x, Child(x))))$

The evaluation rule then applies to this compound formula and its associated scope statement $S < x$ binding occurrences of x free in either conjunct to yield a compound existential assertion:

$$S : (Child(a) \wedge Cried(a) \wedge S'(Upset(John, a))))$$

where

$$a \ = \ (\epsilon, x, Child(x) \wedge (Cried(x) \wedge S' : (Upset(John, x))))$$

Notice how in (33) there is no possibility of evaluating the copied term in the LINKed structure, as its presence in that structure is solely due to the copy process.

It is notable that the constructed terms provide a record of successive steps in the evaluation process, thus retaining a concept of which is primary predicate, *Cried*, and which is its argument, here the incomplete term $(\epsilon, x, Child(x))$. This is in contradistinction to the restrictor both for the corresponding restrictive relative, and for the corresponding cross-sentential anaphoric form. The restrictive interpretation has the full formula projected from the LINKed structure contained within the restrictor for the contained *cn* node:

$S < x \ \ Cried(\epsilon, x, Child(x) \wedge Upset(J, x)))$

On the other hand, the process of cross-sentential anaphora resolution identifies the value of the metavariable projected by the pronoun as the epsilon term resulting from the completed evaluation of the first sentence, so the restrictor of the copied epsilon term containing the predicates contributed by both the subject and predicate in that antecedent sentence:

(34) A child cried. John had upset her.

$S < x \ Cried(\epsilon, x, Child(x)) \quad S' < x \ Upset(J, (\epsilon, x, Child(x) \wedge Cried(x)))$

This differentiation of denotationally identical structures through the process of building up interpretation is a notable advantage over alternative analyses (Chierchia and McConnell-Ginet 1986, Potts 2001). It has been noted by these authors that, while the nonrestrictive construal of the relative is in some sense to be captured not the primary part of the assertion made, its projected content does not constitute a proposition of the whole (see Hoshi 1995), for, if so, it should constitute a necessary condition on the context, relative to which the asserted content is evaluated. But, contrary to such an analysis, it is possible to use relative clauses, nonrestrictively construed, to present "new" information, transparently not part of some already established context:

(35) I saw a man, who ignored me.

(36) I saw a man, who because he ignored me, I hit him.

(37) I saw a man, who I hit, because I was upset.

An alternative analysis of nonrestrictive construals (suggested by Chierchia and McConnell-Ginet and developed in detail by Potts) is that they constitute a conventional implicature, being merely a filter on the projection of content for the associated main clause, and not part of the descriptive content overall. But this analysis does little more than label the problem. And in so far as it does anything more than identifying the problem of how to distinguish the content of the nonrestrictive from that of the main clause, it provides an analysis in which all of (35)-(37) and indefinitely many further variants of such structure all project identical denotational content. But this renders problematic any account of subsequent anaphoric expressions which are taken to refer to some antecedent introduced in such relatives, since the content of nonrestrictives, according to the conventional-implicature analysis, is just a filter on content, and not itself part of that content. Accordingly, the content of the nonrestrictive will not contribute to the context-update established by the denotational content expressed by the sentence, in which the relative is contained. But anaphoric expressions are quite generally assumed to be interpreted as a constant update-function on the context relative to which they are evaluated,[29] an analysis which would lead one wrongly to expect that anaphoric expressions should not be able to establish their intepretation from an antecedent expression in such relatives:

(38) I saw a man, who ignored a friend of mine. When she hit him, he continued to ignore her.

The advantage of the present analysis is that it reflects an asymmetry between the projected interpretation of nonrestrictive relatives and that of the sentence within which they are contained, without any such problematic consequence.

[29] Such an analysis is the model-theoretic analogue of the substitutional account developed here. See Milward 1995, Scabolsci 1996, and many others.

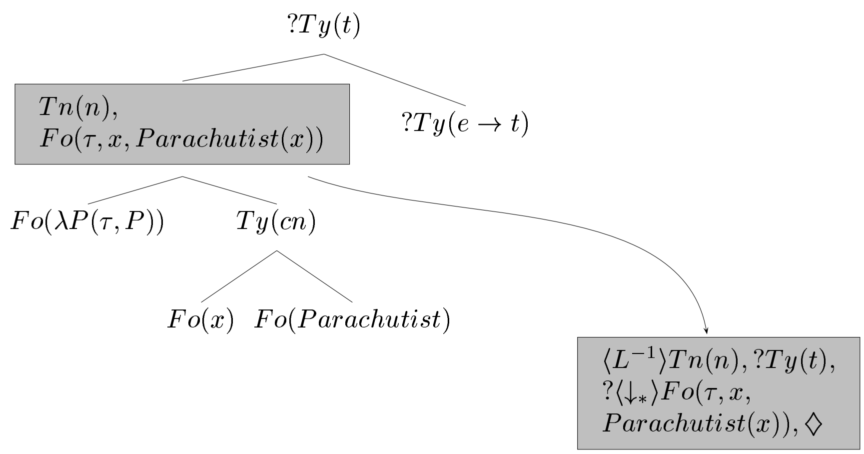
It further leads us to expect that nonrestrictive relative modification is freely available to all noun phrases, not merely indefinites or names (as widely reported):[30]

(39) Every referee, who I had personally selected, turned down my research application.

(40) Every parachutist, who was instructed by the pilot, was warned not to open his parachute too early.

In these cases, it is the tau term that is copied over into the LINKed structure; and the combination of the LINK evaluation rule, which yields a conjunction, and a subsequent single process of scope evaluation, ensures that the construal of the LINKed structure forms a conjunction in the consequence of the conditional associated with the evaluation of the tau term:

Processing the subject in (40): [31]



Resulting Interpretation:

$S < x: \quad (Warned(\tau, x, Parachutist(x)) \wedge (Instructed(\tau, x, Parachutist(x))$

Fully evaluated form:

[30] This is contrary to Fabb (1990) who observes that nonrestrictive relatives may not modify quantified noun phrases, and Demirdache's stronger report (1991) that there is no interaction at all between nonrestrictive modification and quantified noun phrases, contra the observation of Safir 1986. The Safir analysis does not however provide an account of this phenomenon.

[31] For simplicity, the interpretation of the verb-phrase sequences *warned not to open his parachute* and *was instructed by the pilot* are presented as a single predicates. Nothing turns on this.

$Parachutist(a) \rightarrow (Warned(a) \wedge Instructed(a))$

$a =$

$\tau, x, Parachutist(x) \rightarrow (Warned(x) \wedge Instructed(x))$

There are a number of further consequences. First, since the head of the relative is associated with a scope statement in the structure projected from the clause in which it is contained, we allow nonrestrictive relative construals to modify a term which has narrower scope than some other term in the main clause:

(41) A referee, who I admired, turned down every project application.

Possible resulting interpretation:

$S < y < x$

$Fo(Turndown((\tau, y, Application(y)), (\epsilon, x, Referee(x)))$

$\wedge\ S' : Admire(I, (\epsilon, x, Referee(x))))$

With the incomplete term $(epsilon, x, Referee(x))$ carried over as the basis of constructing the LINKed structure, this will be used to provide the second conjunct of a compound formula. But with the scope statement of an indefinite allowing free choice of scope dependency out of the terms under construction, nothing prevents a construal in which the indefinite, albeit with a nonrestrictive modifier, is interpreted as taking narrow scope with respect to *every project application* (a construal of an indefinite with respect to a subsequently introduced term which is directly analogous to the reversed scope interpretation of (10)). This is a form of interaction between quantification and relative clause construal that is debarred by the Fabb and Demirdache analyses.

Secondly, we expect the syntactic restriction that nonrestrictively construed relatives follow restrictively construed relatives:

(42) A man who I met in Prague who you disliked is coming to dinner

		?that I met in Prague
(43)	A man, who you dislike,	*I met in Prague
		who I met in Prague

In (43), given a nonrestrictive construal of 'who you dislike' as adding information about the entity in question without this predicate constituting an additional restrictor on what is quantified over, the relatives 'who I met in Prague' and 'that I met in Prague' have to be interpreted equally as not serving to restrict the domain over the quantifier is taken to range (the variant with *that* being of dubious acceptability since use of *that* tends to preclude nonrestrictive construals), and the null variant which requires a restrictive construal is illformed.[32] These results follow from the restrictiveness of pointer movement. A nonrestrictive involving a LINKed structure induced from the higher $Ty(e)$ node, once this has been complete, of necessity follows subsequent in the construal process to the building up of the type *cn* node, hence also subsequent to any lexical input associated with the building of any LINKed structure on some variable introduced by the nominal. The pointer never returns to some daughter of the *Ty(cn)* node from the top $Ty(e)$ node, so the order of nonrestrictive-restrictive clause construals is precluded. This restriction, as we would expect, applies equally to all noun phrases, indefinite and non-indefinite alike:

(44) Every interviewer you disliked, who I was on good terms with, liked our cv's.

(45) *Every interviewer, who I was on good terms with, you disliked, liked our cv's.

Thirdly, we expect that both epsilon and tau terms will provide antecedents for anaphoric expressions occurring in nonrestrictive relative clauses modifying other heads, since the incomplete terms remain available as putative antecedents throughout the construction process, and are subject to evaluation as the final step of the interpretation process:[33]

(46) A man was rude to John, who forgave him.

(47) I saw a man assault John, who sued him.

(48) Every sinner prays to God, who forgives him.

(49) Every exam script was checked by John, who had to make a record of its number as the candidate handed it in.

(50) Every parachutist was instructed by the pilot, who warned him not to open his parachute for 20 seconds.

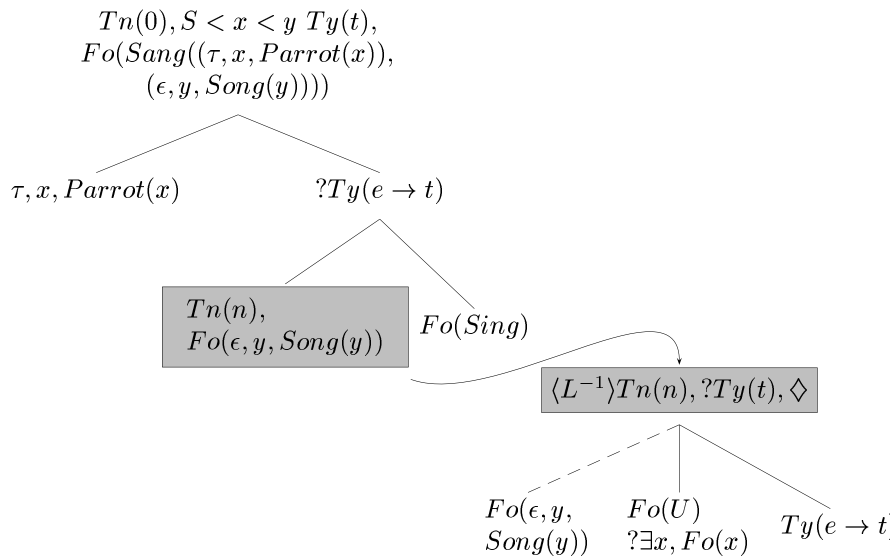
[32] Relative clauses formed with *that* have an intermediate status. They are often reported to license restrictive construal only, but (i) is not unacceptable:
(i) Every interviewer, who I was on good terms, that you disliked, liked our cv's.
However, as we would expect, if the first relative is interpreted nonrestrictively, then the second, despite the presence of *that*, must also be interpreted nonrestrictively.

[33] Example (48) is from Safir 1986).

(51) Every nurse alerted the sister, who congratulated her on her prompt reaction.

(52) Every parrot sang a song, which it ruined.

The display of the process of interpreting (52) brings out the conjunctive form of analysis and the availability of all terms of type e as antecedents for anaphora resolution:



Final logical form for (48):

$$S < x < y \quad Sing(\tau, x, Parrot(x)), (\epsilon, y, Song(y)) \wedge$$
$$Ruined(\tau, x, Parrot(x)), (\epsilon, y, Song(y))$$

Final evaluation

$$Parrot(a) \to (Song(b) \wedge Sang(a, b) \wedge Ruined(a, b))$$

Notice how all the information projected by the LINKed structure, given the single set of scope statements for the resulting conjunction, is in the consequent of the conditional (this being the major connective associated with the widest scoping term). This is a result that in other frameworks (notably DRT: Roberts 1990) requires an itemised rule of accommodation to license the binding across the conjunction – here a bonus of the analysis without special stipulation.

As we might also expect, there is an additional method for licensing such nonrestrictive relatives, using the correlative process of construction. This will apply to provide an interpretation for the familiar extraposition from NP cases in which a complete logical form is constructed prior to the introduction of a LINK relation onto a new node requiring $?Ty(t)$, with this newly introduced node having a requirement for a copy within that structure of a term of type e constructed as a subterm of the formula decorating that preceding tree:[34]

(53) A woman left, who had been badgering everyone for money.

This gives rise to two possible strategies for processing relative clause sequences nonrestrictively, which come together when the relative sequence immediately following the head occurs sentence-finally:

(54) I met a man, who smoked.

Either the LINK transition is defined from the term projected from the noun phrase sequence, or it is defined from the topnode of the propositional structure just constructed. In the former case, the nonrestrictive will be interpreted as a transition from the type e node constructed from the lexical processing of the determiner-noun sequence, as in the processing of (54). On this strategy, the incomplete term $\epsilon, x, man(x)$ is copied over into the LINKed structure, the LINKed structure is duly decorated with $Smoked(\epsilon, x, man(x))$, and the pair of trees is compiled into a compound formula, leading to the resulting scope statement-formula pair:

$$S < x \;\; Smoked(\epsilon, x, man(x)) \wedge Met(I, (\epsilon, x, Man(x)))$$

This yields the resulting completed form:

$$Fo(S : Man(b) \wedge Met(I, b) \wedge smoked(b))$$

where

$$b \;=\; \epsilon(x, Man(x) \wedge Met(I, x) \wedge Smoked(x))$$

On the latter strategy, with the propositional structure projected from the main clause being complete, the relative sequence is interpreted as a correlative, and the full term $\epsilon x, man(x) \wedge met(I, x)$ resulting from the algorithmic

[34] It also includes nonfinite clausal adjuncts:

(i) John left, tired.
(ii) Everyone left, tired.

With no associated scope statement, such structures will depend on the process of LINK-evaluation defined, since the copy of the incomplete term must be evaluated in the primary structure at which the head is introduced.

evaluation of the first conjunct may be carried over as input to the processing of the LINKed structure. This term, in virtue of the fact that indefinites project epsilon terms, can be applied to the predicate *Smoked*, yielding the formula:

$$S < x \ \ Smoked(\epsilon, x, Man(x) \wedge Met(I, x))$$

which is in turn evaluated as:

$$Fo(S : Man(b) \wedge Met(I, b) \wedge smoked(b))$$

where

$$b \ = \ \epsilon(x, Man(x) \wedge Met(I, x) \wedge Smoked(x))$$

The result is demonstrably identical to that of the previous strategy.

This step turns on the inference:

$$\exists x \phi(x) \wedge \psi(\epsilon, x, \phi(x)) \quad \models \quad \exists x(\phi(x) \wedge \psi(x))$$

In the case of universal quantification however, the second of these interpretation strategies is only available prior to any such final step of evaluation. This is because there is no binding of a closed tau term across the conjunction, it being closed in the step of evaluation: the step of inference available to epsilon terms is not available for τ terms. This notably provides us with a means of explaining the observations of Fabb 1990 and Demirdache 1991, noting the questionable acceptability of (55-(56):

(55) ??John ignored every student, who disliked him.

(56) ??Every Christian forgave John, who warned him.

Such sentences will be judged as unacceptable if the interpretation of the main clause is taken to be fully evaluated and the quantifying terms closed off prior to the construction of the relative clause sequence.[35] It is notable that where the quantified term is taken as antecedent to a pronoun in such a relative, the sentences become fully acceptable if a plural pronoun is used:

(57) Every Christian forgave John, who warned them.

[35] Examples such as (i) indicate that the correlative LINK transition is itself unrestricted, with tau terms being copied from one structure to another as long as the process of scope evaluation is delayed until after the compilation of the LINKed structure:
(i) I passed each customer to Jo, who she dealt with promptly.

We thus capture a broad range of nonrestrictive relative clause data, some of it novel, with the minimum of stipulation. The results emerge from the interaction of assumptions – that quantified noun phrases project terms of type e, that relative clause construal involves an encoded anaphoric process across paired propositional structures, and that these are construed as conjoined. Overall, the assumption that quantifying expressions project incomplete terms of type e has led to an integrated account of head-initial relative clause construal. This account, moreover, provides a richer characterisation of the interaction between relative clause and quantifier construal than is made available by the postulated binary distinction between restrictive and nonrestrictive relative clause construal. In all cases, the variations depend on what stage of the interpretation process the LINK relation is constructed, and what type e formula is accordingly available.[36]

3.2 Type III LINKed tree precedes head – Verb-final Languages

We now have a means of characterising quantifier and relative clause construal in combination, which we apply to head-final relatives. Despite the emphasis on the step by step update of the construction process, it should be borne in mind in what follows that there is no reflection of linear order on the tree itself: the variation in mode of interpretation has come solely from the different processes where by such trees are set up. In particular, there is nothing to preclude the projection of a LINKed tree prior to the projection of the head, with copy processes from the antecedent structure onto the subsequent term; and languages in which the relative clause precedes the nominal acting as head come as no surprise. The details of the structures licensed in such languages are furthermore of considerable interest.

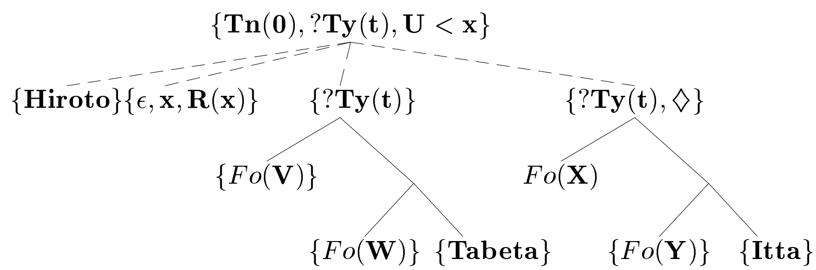
Verb-final languages are the primary form of language in which relative clause sequences precede their head.[37] They are also invariably full pro-

[36] We do not give a full account here of so-called functional relatives (see footnote 27). Similarly, we do not give an account of reconstruction phenomena in relative clauses, said to provide evidence of the need for processes that pass information down into a relative-clause structure, though we believe there is evidence that these involve progressive compilation of information at the type cn node with delay in identification of anaphorically projected meta-variables rather than any such downward passing of information:
(i) The picture of his that each boy submitted to the competition was on display at the exhibition.
(ii) The picture that he had painted that each boy had selected for the competition was on display at the exhibition.

[37] Given that all languages allow LINK relations to be constructed to independent struc-

drop languages, to use the GB terminology, the verb being able freely to stand as the single member of a clausal string with all arguments construed contextually. To reflect this, we model the process of construal for sentence sequences as involving a flat sequence of unfixed nodes, the verb projecting a full propositional structure, with argument nodes filled with meta-variables, subject to Merge. Even the structure projected by the verb has to be seen as unfixed, since some following verb may be interpreted as taking the preceding sequence of items as projecting a complement propositional structure:

(58) *Hiroto-ga* *ringo-o* *tabeta-to* *itta*
Hiroto$_{NOM}$ apple$_{ACC}$ ate$_{COMP}$ said
'Hiroto said he ate an apple.'



These arguments are decorated with metavariables, and may merge with the attendant nodes of $Ty(e)$. In fact there is rampant ambiguity as any one of the verb's accompanying argument nodes may be interpreted relative to some entity independently introduced in the larger discourse context, so that (58) is ambiguous as to whether Hiroto is or is not subject of the subordinate verb *tabeta* ('ate'), and is or is not subject of the main verb *itta* ('said').

Given that all nodes are introduced as unfixed, and no type e node corresponding to a major constituent receives a fixed position until after some verb is processed, scope statements will be collected at the root and may necessitate a process passing down scope statements for evaluation at some dominated node:

(59) *dono-kyoujyu-mo,* *[futari-no* *sikenkan-ga* *kaku-touan-o*
every professor, two-GEN examiners-NOM each script-ACC
saiten-sita]-to *houkoku-sita.*
marked-did]-COMP reported
'Every professor reported that 2 examiners marked each script'

tures of type e, in root clauses, noun phrases can follow the verb, but these invariably have a reminder or after-thought effect, as we would expect, given this analysis.

Every Prof < Two examiners < Each script
Two examiners < Each script < Every Prof

There is a strong preference for identifying scope relativity following linear order, though in the case of indefinites this is a choice, hence the ambiguity of (59).

The downwards passing scope rule, we define as:

D-Scope Passing

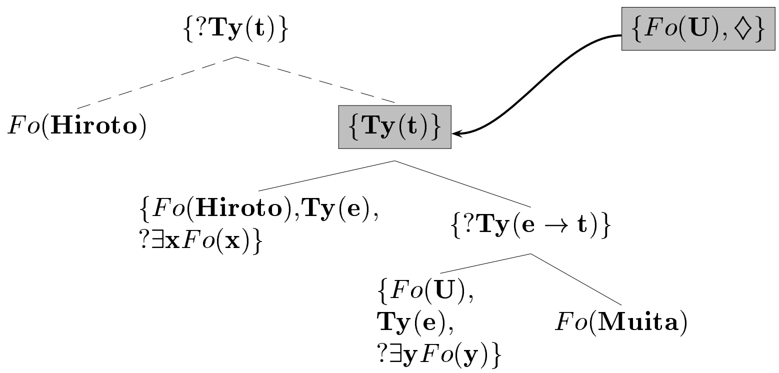
$$\frac{\{\{Tn(X), ?Ty(t), ...x_i < y_j, ...\}...\}, \{\{MOD(Tn(X)), Ty(t), ..., \Diamond\}...\}}{\{\{Tn(X), ?Ty(t), ...\}...\}, \{\{MOD(Tn(X)), ?Ty(t)...x_i < y_j, ...\Diamond\}...\}}$$

$MOD \in \{\langle\downarrow_0\rangle, \langle\downarrow_1\rangle, \langle L\rangle\}^*$

3.3 Type III Head-final relatives – Japanese

With this mode of projection of scope construal, we turn to relative clauses in Japanese. In Japanese, like all other verb-final languages, relative clauses precede any lexical head which they modify: indeed one of the few context-INdependent certainties in parsing a Japanese sentence is given by the sequence of V + NP, for this sequence determines that what precedes the noun must be interpreted as a relative. Accordingly, we define a LINK transition which, given some completed propositional structure containing an unsubstituted meta-variable, licenses the construction of a LINK relation in which the variable identified is copied over as the metavariable with which to introduce and decorate the head, this being the starting point for building the structure to which the structure just compiled is LINKed. Bearing in mind the anaphoric nature of building up LINKed structures, the process is taken to be one of copying a decoration, albeit in this case merely a metavariable. Not being a fixed term, this variable cannot participate in scope statements:

(60) *Hiroto-wa* *muita* *ringo-o* *tabeta*
Hiroto$_{TOP}$ peeled apple$_{ACC}$ ate
Hiroto ate an apple he peeled

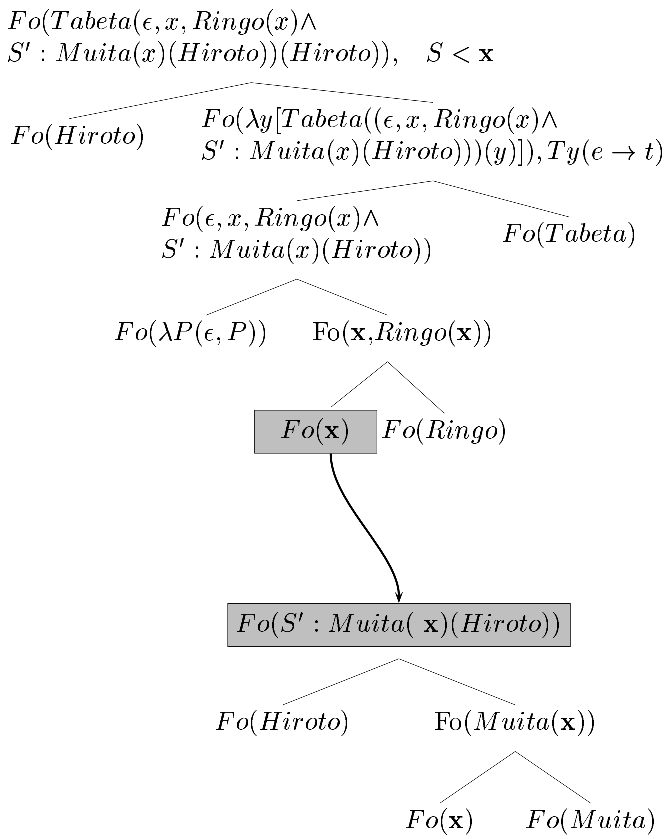


LINK-Introduction (Japanese):

$$\frac{\{...\{X, Ty(t), \ldots \Diamond\} \ldots \{MOD(Tn(X)), Fo(\mathbf{U}), Ty(e), ?\exists \mathbf{x} Fo(\mathbf{x}) \ldots\}\}}{\begin{array}{c}\{...\{X, Ty(t), \ldots\} \ldots \{MOD(Tn(X)), Fo(\mathbf{U}), Ty(e), \ldots\}\}, \\ \{\langle L \rangle X, Fo(\mathbf{U}), ?\exists \mathbf{x} Fo(\mathbf{x}), Ty(e), \Diamond\}\end{array}}$$

$$MOD \in (\langle \uparrow_1 \rangle, \langle \uparrow_0 \rangle)*$$

Once the transition has been effected, the subsequent structure for the term to constitute the head is built up from the following nominal, with whatever scope statements in that other structure that the nominal or associated determiners may initiate. The final result is a structure exactly as that of the head-initial languages:



The result of processing (60) prior to scope evaluation

As this rule of LINK-Introduction for Japanese would lead us to expect, defined as it is for any node of type e decorated with a metavariable, head-final relative-clause sequences are ambiguous in Japanese, allowing both nonrestrictive and restrictive construal. One difference from English that Hoshi 1995 reports is that such relatives freely allow binding of an argument contained within such structures by some other quantifying head, unlike their English congener:

(61) *doono* *Kurisutyan-mo$_i$* *keikokusituzukeru* *John-o*
every Christian him keep on warning John$_{ACC}$
yurusiteiru
forgive
'Every Christian$_i$ forgives John, who warns him$_i$.

This difference is as we would expect. Given the obligatory positioning of the relative clause sequence before the head, and before the verb, the process of interpretation is manifestly not complete. All that could be copied into the LINKed structure is therefore the incomplete τ term, which then leads subsequently to a construal in which that argument is construed as bound by the term projected by the quantifying expression. The tension that arises in the English data simply doesn't arise.[38]

3.4 Head-Internal Relatives

We now turn to the puzzle of head-internal relatives, a notorious problem for every other framework. These are clauses in which the head of the contained structure is internal to the relative and projects an E-type effect as the resulting interpretation. Such structures are at best contrary to expectation, since the lexical head is contained within a relative which is c-commanded by some empty co-indexed head, rather than the expected reverse relation. The DS framework, to the contrary, might have been defined to match these data, for explanations are expressed in terms of the dynamics of how structural updates are made available on a left to right basis.

As a first step to seeing this, note that the rule of *LINK Introduction (Japanese)* as provided is the mirror image of head-initial relatives: instead of the head providing a value for the LINKed structure, the LINKed structure provides an interim value for the head. Viewing relative clause construal as a substitution process, the replacement of this provisional value by a metavariable to be subsequently replaced by the variable provided by the head is not the most natural, going against the dictates of linear order as it does. We would, rather, expect structures in which the copy process

[38] Hoshi 1995 notes these data as problematic, without explanation. He also notes that sequences in which a numeral occurs before the relative clause sequence are invariably interpreted restrictively, whereas those in which the numeral occurs following the relative clause sequence but before the noun head are interpreted nonrestrictively:

(i) John-wa sanko-no Mary-ga muitekureta ringo-o tabeta
John-topic three-GEN Mary-subject peeled apple-ACC ate
John ate three apples that Mary peeled (restrictive)
(ii) John-wa Mary-ga muitekureta sanko-no ringo-o tabeta
John-topic Mary-NOM peeled three-GEN apple-ACC ateJohn ate
three apples, which Mary peeled (nonrestrictive)

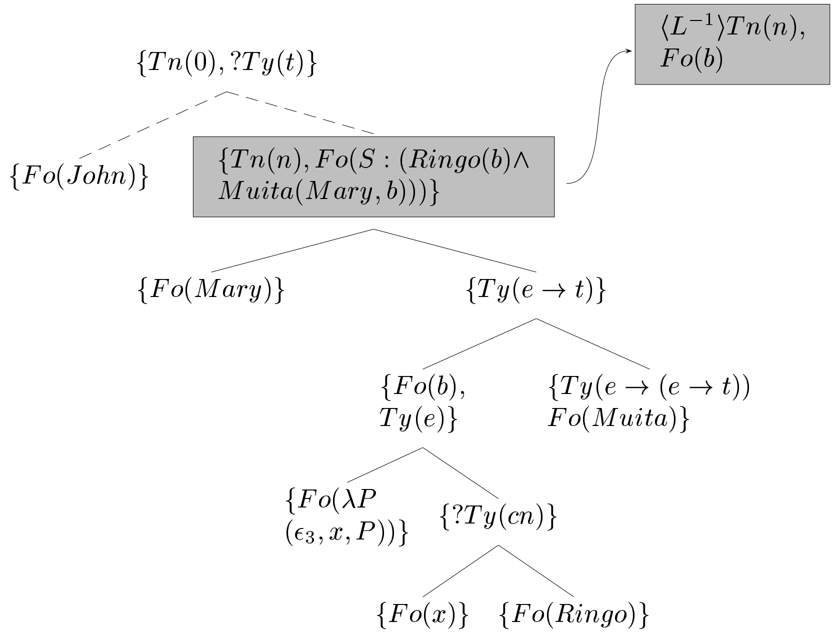
A definitive analysis of these remains to be established. We simply note that the building of a LINKed structure in (i) will involve a transition subsequent to the completion of the tree onto a node from which the noun can be parsed, hence arguably onto the node for the variable which that noun will introduce, whereas in (ii) the transition from the completed LINKed structure will be onto a node from which the numeral can be parsed, hence arguably the top type e node for an NP; and that this provides an appropriate basis for their distinct interpretations.

follows the regular dynamics of the left-right process with some full term being provided first and its value copied to some subsequent incomplete term as indicated. From this perspective, we expect, that is, to find head-internal relatives. And indeed head-internal relatives occur in all verb-final languages. These are clausal sequences in which the head is contained internally to the structure. What adds to the puzzles induced by these data for other frameworks is the interpretation imposed on such sequences. These head-internal relatives are not interpreted as equivalent to relatives in which the nominal follows the relative. To the contrary, they are interpreted as having an E-type form of construal, much like the more complex form of nonrestrictive relative construal in English. The only analysis that is remotely close to bringing together head-external and head-internal relatives is a Kayne-style analysis with multiple movements, hence multiple copies with choice as to which is deleted in the different variants of relative clause binding (see Kayne 1994). However, even with this richness of processes available in an unrestricted Copy and Delete style of analysis, the E-type form of interpretation is unexpected.

(62)	*John wa*	*[Mary ga*	*sanko no*	*ringo o*	*muita-no] o*	*tabeta*
	John_{TOP}	Mary_{NOM}	three_{GEN}	apple_{OBJ}	$\text{peeled}_{REL-OBJ}$	ate
	'John ate three apples Mary peeled.'					

On the proposed analysis to the contrary, both the structure and the resulting interpretation are as expected. Scope is evaluated as locally as possible, and in (62) the sequence of NPs plus verb provides all the information necessary to complete and evaluate such a propositional structure. Accordingly a propositional form is constructed, and its scope statements evaluated to yield a fully determined propositional formual and associated completed epsilon terms. The resulting interpretation is just as we would expect – it is one of these completed terms which is copied over through the anaphoric device of *no*. Figure 7 displays the tree structure representing the partial stage in processing (62) immediately after processing the particle $-no$:[39]

[39] I leave the tense suffix *-ta* unanalysed in the predicate.



Interpretation of relative clause:
$S < x \quad Muita(Mary, (\epsilon_3, x, Ringo(x))$
$= S : Ringo(b) \wedge Muita(Mary, b)$
where
$b \;=\; (\epsilon_3, x, (Ringo(x) \wedge Muita(Mary, x))$

"Mary peeled three apples."

Resulting interpretation of (62):
$S' < x \;\; Tabeta(J, (\epsilon_3, x, S : (Ringo(x) \wedge Muita(M, x))))$
$=$
$S' : Tabeta(J, a') \wedge Ringo(a') \wedge Muita(M, a')$
$a' = (\epsilon_3, x, Tabeta(J, x) \wedge S : (Ringo(x) \wedge Muita(M, x))$

"John ate the three apples that Mary peeled." The relative clause sequence, from which a complete, and completely evaluated, propositional formula can be constructed, is interpreted as:[40]

[40] We approximate the representation of plural quantification.

$S < x \quad Muita(Mary, (\epsilon_3, x, Ringo(x))$

$= S : Ringo(b) \wedge Muita(Mary, b)$

where

$b \;=\; (\epsilon_3, x, (Ringo(x) \wedge Muita(Mary, x))$

The final specification of the object node is accordingly:

$(\epsilon_3, x, (Apple(x) \wedge Peel(Mary, x))$

It is this term which is copied over as the value of the head: hence the E-type interpretation.[41]

On this analysis, $-no$ is the counterpart to the English relative pronoun. It is a fixed anaphoric device that takes some provided value and ensures the presence of a copy across a LINK relation:

no

IF	$\mathbf{Ty(t)}$	
THEN	**IF**	$\langle\downarrow_*\rangle\mathbf{Fo(x)}, \mathbf{Ty(e)}$
	THEN	$\mathbf{make}(\langle \mathbf{L^{-1}}\rangle)$;
		$\mathbf{go}(\langle \mathbf{L^{-1}}\rangle)$;
		$\mathbf{put}(\mathbf{Fo(x)}, \mathbf{Ty(e)})$
	ELSE	**ABORT**
ELSE	ABORT	

Notice how the account turns on the analysis of quantifying expressions as projecting terms of type e, and furthermore ones which, upon full interpretation, denote a witness of the containing propositional formula. It is striking that an account of quantification whose motivation might seem to be primarily semantic turns out to have direct syntactic consequences.

4 Relatives: Towards a Typology

The significance of this analysis is not restricted to Japanese. The explanation turned on the dynamics of building linked trees, with one structure – whichever is the first – providing the context for the building up of the second, with anaphoric processes of copying from one structure to another, all variants involving the progressive and monotonic growth of partial logical forms. It turned also on analysing quantifying expressions in natural language as incomplete expressions of type e whose construal involves both the

[41] It is arguable that this result can also be effected by copying the epsilon term prior to evaluation, upon the assumption that there is a single scope statement for the resulting conjoined structure, as in the English data. This would have the advantage of not needing to assume any process of scope lowering. We leave this as an open possibility, pending a more detailed characterisation of scope phenomena in Japanese.

projection of scope constraints and a projection at some proposition-bearing node of the overall formula in the light of such incrementally collected constraints, The separation of the evaluation of terms from the projection of the final logical form was essential to the projection process, since the types of copy process from one structure to another turned on whether or not the evaluation of the quantificational terms has taken place. And the variation in relative clause construals emerged from the different stages in the process of building up the quantified logical forms, while retaining an integrated characterisation of linked structures and the process of introducing them across a LINK relation.

Taking a step back from the details of individual languages, we can now sketch the outlines of a typology of relative clauses, in terms of the type of process whereby a pair of linked trees is projected. There is the transition from the head to the LINKed structure, in which the required copy is induced either by some fixed algorithmic device or by interaction with a general pragmatic device as controlled by imposed constraints on development. This gives the distinction between relative clauses in which a relative pronoun projects the required copy at an unfixed node, with a subsequent pronominal not being required to achieve the resulting completed propositional structure, and those relative pronouns in which there is no relative pronoun, and a subsequent pronominal is essential to the construction process. There is also the distinction between forms that are copied at different stages of development, whether variable, incomplete or completed term. Then there is the reverse process, in which the projection of a LINKed structure precedes the projection of the head, with a copy device either morphologically realised or a consequence of defined computational actions. These then differ according as the full term follows the LINKed structure as the mirror-image to head-initial languages would lead us to expect, or is contained within the LINKed structure, as driven by the dynamics of processing.

An additional parameter for variation is whether the copy process is subect to locality constraints, as expressible through different types of modal requirement (see Kempson et al 2001 for a discussion of Arabic, Hebrew and Romanian in these terms). But the general direction and extent of the variation is clear. The extent of the variation is determined by the form of interpretation together with the dynamics of incrementally building it up. Given the assumptions of the framework, these are indeed the only bases for structural variation across languages, for there is only one level of articulated structure. Yet notwithstanding the limit on possible variation which this perspective imposes, the range of cross-linguistic data that can be expressed in these terms confirms that this dynamic perspective provides a surprisingly rich basis for characterising both the extent of the variation and the particular subvariants within the limits provided.

5 Coda

Centring on long-distance dependency as this family of effects does, this array of data is uncontentiously central to the computational device for natural language. Indeed, in the 70's long-distance dependency provided the primary argument that syntactic phenomena in natural language were not reducible to semantics hence providing justification for an autonomous concept of syntax. Yet according to the present perspective, a typology of long-distance-dependency effects in relative clause construal has been defined solely in terms of variant processes in the building up of logical forms alaong a primarily left-right dimension. With such phenomena characterised in terms of the process of building up logical forms, the long-held argument for an autonomous syntax that long-distance dependency effects are taken to provide is now undermined. the vehicle for syntactic explanation is no more than the dynamics of monotonically developing semantically transparent structure. Further, the success of this explanation of relative clause construal in terms of different anaphoric processes, and how they interact, strongly buttresses the assumption that general and system-internal substitution processes are, equally, an integral part of the computational device. A particularly important part of this account was the construction of partial variable-binding term operators subsequently completed, since these were essential to the characterisation of nonrestrictive relatives cross-linguistically available, and also the characterisation of head-internal relatives. We thus reach the conclusion that the dynamic and left to right process of building logical forms representing interpretation in context provides a basis for syntax.

Such a conclusion turns the representationalism issue in semantics on its head. The debate about the status of representations in semantic explanations has generally taken the form of demonstrations that we do/do not need a level of semantic representation over and above that posited for syntactic explanation. this is the heart of the dispute between DPL and DRT (see Kamp and Reyle 1994, Groenendijk and Stokhof 1991, Kamp 1996, Dekker 2001, among others). Rather than following this line of argument and reducing a representationalist semantic account to one in terms of denotational content at some appropriate level of abstraction, we have, to the contrary, reduced the syntax of natural languages to the characterisation of structures representing denotational content taken in conjunction with the dynamics of mapping sequences of words following a left-right dimension onto such representations of content. So the question is transformed from that of "Do we need a level of semantic representation in a grammar formalism to express semantic phenomena displayed by natural languages", into the very different question: "Do we need any level other than that of semantic representation in a grammar formalism to express syntactic phenomena displayed by natural languages?"

This new perspective suggests a shift in the concept of language itself. The explanation of structural properties of a natural language expression (whether simple or complex) is replaced by an account of the dynamics of processing it. Knowledge of language ("knowing that") is recast as "knowing how" to use it in language processing. Language processing is thus, by claim, basic, and language production has to be analysed in terms that make reference to the parsing task. The repercussions of the asymmetry between processing and production, as is the avoidance of any use-neutral concept of knowledge, are considerable; and I offer to philosophers the challenge of helping us think through the problems that these pose. It is not uninteresting in this connection that Brandom (1994) has developed a dynamic normative concept of reasoning taken as basic, in terms of which he proposes that static concepts such as truth and reference should be defined; and that in this perspective the concept of substitution underpinning both anaphora and quantification is taken as central. The corresponding centrality of substitution in developing the concept of linked trees, on which the articulation of the relative clause typology turns, is suggestive, though the strong cognitivist underpinnings of DS are at variance with the normative and social perspective argued for by Brandom. One way of pursuing the philosophical dimensions of exploring the "knowing how" perspective on linguistic knowledge proposed by the Dynamic Syntax framework is to investigate the extent and significance of the overlap in the two perspectives. But this further task, we leave for another time.

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