RESOURCE-SENSITIVITY, BINDING AND ANAPHORA

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Chapter 8

BINDING ON THE FLY: CROSS-SENTENTIAL ANAPHORA IN VARIABLE-FREE SEMANTICS

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Combinatory logic (Curry and Feys, 1958) is a "variable-free" alternative to the lambda calculus. The two have the same expressive power but build their expressions differently. "Variable-free" semantics is, more precisely, "free of variable binding": it has no operation like abstraction that turns a free variable into a bound one; it uses combinators—operations on functions—instead. For the general linguistic motivation of this approach, see the works of Steedman, Szabolcsi, and Jacobson, among others.

The standard view in linguistics is that reflexive and personal pronouns are free variables that get bound by an antecedent through some coindexing mechanism. In variable-free semantics the same task is performed by some combinator that identifies two arguments of the function it operates on (a duplicator). This combinator may be built into the lexical semantics of the pronoun, into that of the antecedent, or it may be a free-floating operation applicable to predicates or larger chunks of texts, i.e. a type-shifter.

This note is concerned with the case of cross-sentential anaphora. It adopts Hepple's and Jacobson's interpretation of pronouns as identity maps and asks how this can be extended to the cross-sentential case, assuming the dynamic semantic view of anaphora. It first outlines the possibility of interpreting indefinites that antecede non-c-commanded pronouns as existential quantifiers enriched with a duplicator. Then it argues that it is preferable to use the duplicator as a type-shifter that applies "on the fly". The proposal has consequences for two central ingredients of the classical dynamic semantic treatment: it does away with abstraction over assignments and with treating indefinites as inherently existentially quantified. However, cross-sentential anaphora remains a matter of binding, and the idea of propositions as context change potentials is retained.

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1. The Duplicator as a Type-Shifter

Reflexives must, and pronouns can, be bound. Where should the binding device be localized? As a background, we start with a brief review of the sentence internal case.

Szabolcsi (1989, 1992) argues that the binding needs of reflexives and pronouns are to be encoded in their lexical meanings. This is the conceptually simplest way to ensure that the assembly of lexical items automatically yields a well-formed result and no filters need to be invoked to rule out reflexives that are unbound or pronouns that are bound from too close. The core of the semantics is **W**, the duplicator, as in (1). Anti-locality for pronoun binding is ensured by letting the dominating sentence inherit duplicatorhood, i.e. the more complex semantics attributed to *him* in (2) is simply a pied piper's semantics. The relevant parts of two sample derivations are as follows:[1]

(1) Everyone saw himself
himself: W= $\lambda f \lambda x[f(x)(x)]$
saw himself: $\lambda x[saw(x)(x)]$

(2) Everyone thought Mary saw him
him: C(B(BW)B)= $\lambda g \lambda f \lambda x[f(g(x))(x)]$
thought that Mary saw him: $\lambda x[thought(saw(x)(m))(x)]$

In extending the grammar to VP-ellipsis, Szabolcsi, 1992 deviates from this strategy. She notes that while it would be natural to interpret *do* essentially as W (which now duplicates VP-meanings), the equivalence of (3) and (4), as well as the derivation of strict readings with quantificational antecedents, cf. (5), necessitates that W or a version of it (BBW, i.e. $\lambda f \lambda h \lambda y[f(hy)(hy)]$) be employed as a type-shifter:

(3) John left before Mary did.
(4) John left before Mary.
(5) Everyone mentioned himself before Mary did.
$\forall x[before(mentioned(x)(m))(mentioned(x)(x))]$

[1]W, B, and C are some of the basic combinators in Curry and Feys, 1958. The combinator W, as mentioned in the text, is the duplicator, $\mathsf{W}fx = fxx$, or in lambda notation, W= $\lambda f \lambda x[f(x)(x)]$. The combinator B is the compositor, $\mathsf{B}fgx = f(gx)$ or in lambda notation, $\lambda f \lambda g \lambda x[f(gx)]$. The combinator C is the permutator, $\mathsf{C}fxy = fyx$, or $\lambda f \lambda x \lambda y[f(y)(x)]$.

Combinatory terms associate to the left, as the lambda paraphrases show. Notice that B applied to one argument is the Geach rule: it breaks up the first argument of the input function f, thereby turning f into $\lambda g \lambda x[f(gx)]$. All the other combinators used in this paper are definable in terms of W, B, and C. These definitions are sometimes interesting, because they reveal the relationship between two proposals or two techniques. In such cases they will be spelled out. In other cases they are entirely boring, and irrelevant to the main concerns of this short note. In these latter cases the definitions will be suppressed in favor of intentionally sloppy talk, such as "a family of Geach operations" or "Duplicate".

This implies that *do* itself is not making a semantic contribution. This claim could be made precise by interpreting *do* as an identity map.

Hepple, 1990 and Jacobson (in a series of papers 1992 through 1999, see the references in Jacobson, this volume) advocate an identity map treatment of reflexives and pronouns, respectively, implementing the duplicator as a type-shifter. Especially Jacobson develops a wide variety of empirical arguments supporting this position, including one that is similar to that pertaining to (4): in functional questions, duplication may arise although there is no pronoun present. On the combined strength of all these arguments I conclude that locating the duplicator in the syntax, as opposed to the lexicon, is correct. This is what I explore in this note, focusing solely on pronouns.

The essence of Jacobson's analysis, which I adopt, can be summarized as follows. *Him* is interpreted as $\lambda y.y$ and bears a syntactically inert functor category that I will write as $np \mid np$, which can only be applied to. The Geach rule (combinator B applied to one argument) enables *saw* and *Mary* to combine with it:

(6)

$$\dfrac{\dfrac{\dfrac{\text{Mary}}{s/(np\backslash s)}}{(s \mid np)/((np\backslash s) \mid np)}\,\mathit{Geach} \qquad \dfrac{\dfrac{\dfrac{\text{saw}}{(np\backslash s)/np}}{((np\backslash s) \mid np)/(np \mid np)}\,\mathit{Geach} \qquad \dfrac{\text{him}}{np \mid np}}{(np\backslash s) \mid np}}{s \mid np}$$

The resulting clause bears the category $s \mid np$ and is accordingly interpreted as a property, $\lambda y[saw(y)(m)]$. If *him* is to be bound by a c-commanding quantifier, the silent combinator Z does the job of duplication. Jacobson's Z is B(BW)B, essentially the same combinator that was used to interpret *him* in (2). The difference lies in what the first argument is: the clause-mate predicate that the pronoun is an argument of, on Szabolcsi's analysis, or the matrix verb, on Jacobson's:[2]

(7) Everyone thought Mary saw him
Z = B(BW)B = $\lambda f \lambda g \lambda x[f(g(x))(x)]$
Z-thought = $\lambda g \lambda x[\mathit{thought}(gx)(x)]$
Z-thought(Mary saw him) = $\lambda g \lambda x[\mathit{thought}(gx)(x)](\lambda y[\mathit{saw}(y)(m)])$ =
$\lambda x[\mathit{thought}(\mathit{saw}(x)(m))(x)]$
Everyone Z-thought Mary saw him = $\forall x[\mathit{thought}(\mathit{saw}(x)(m))(x)]$

[2]On both Szabolcsi's and Jacobson's analyses, a family of duplicators is needed to account for the fact that reflexives and pronouns need not be linked to the closest possible binders; likewise, we need a Geach-family. See Jacobson, 1999, (25) and (29).

A crucial feature of Jacobson's proposal is that the identity map interpretation is invariant: it supports both the bound variable and the deictic uses of the pronoun. In the latter case, it eliminates the traditional ambiguity between different free variables, arising from the fact that pronouns do not come equipped with indices. If *him* is deictic, the property $\lambda x[saw(x)(m)]$ is predicated of a contextually salient individual.

Now the question arises how this proposal extends to cross-sentential anaphora. This is what the present note is concerned with.

2. Cross-Sentential Anaphora in Dynamic Semantics

I will adopt the general assumptions of DMG (Groenendijk and Stokhof, 1989) as a point of departure. That is, I assume a compositional theory in which an indefinite is an existential quantifier with a continuation variable in its scope, conjunction is interpreted as composition, and pronominal anaphora is captured by interpreting the pronoun as a variable bound by the antecedent. In addition, DMG initially interprets pronouns as free variables (discourse markers); this is an assumption that I will obviously abandon, but it is useful to recap how it works:

(8) a. A man came in: $\lambda p \exists x[man(x) \,\&\, came(x) \,\&\, \{x \backslash d\}\, {}^{\vee}p]$

b. He whistled: $\lambda p[whistle(d) \,\&\, {}^{\vee}p]$

c. A man$_d$ came in. He$_d$ whistled:

$\lambda q[\lambda p \exists x[man(x) \,\&\, came(x) \,\&\, \{x \backslash d\}\, {}^{\vee}p]({}^{\wedge}\lambda p[whistle(d) \,\&\, {}^{\vee}p](q))]$

$= \lambda q[\exists x[man(x) \,\&\, came(x) \,\&\, \{x \backslash d\}[\, {}^{\vee}\, {}^{\wedge}\, whistle(d) \,\&\, {}^{\vee}q]]]$

$= \lambda q[\exists x[man(x) \,\&\, came(x) \,\&\, whistle(x) \,\&\, \{x \backslash d\}\, {}^{\vee}q]]$

Abstraction over assignments (^) allows us to bring the free variable pronoun into the scope of the quantifier. The indefinite's translation contains a state (=assignment) switcher $\{x \backslash d\}$. This effectively associates a free variable d with the indefinite, though unlike DRT, solely for binding purposes. When $\{x \backslash d\}$ is prefixed to a proposition p, it sets the discourse marker d in p to the value of x, the variable bound by the existential quantifier. The pronoun gets bound iff its discourse marker is d.

3. Identity Maps and Cross-Sentential Anaphora: A Fairly Static Semantics

The simplest way to extend Jacobson's theory to cross-sentential anaphora might be this. Retain the DMG treatment of *A man came in.* Assume that $\{x \backslash d\}$ makes d contextually salient. *He whistled* starts out as a property. Assimilate the anaphoric use to the deictic use and apply this property to d. From here on, proceed as in (8). This extension may be viable, but it is not particularly interesting; I will not pursue it here.

In developing alternative accounts, we first observe that abstraction over assignments will not be needed in the combinatory framework. Whether pronouns are interpreted as duplicators or as identity maps, they are not free variables. Therefore, bringing them within the scope of the intended binder is not an issue.[3]

Second, consider a rebracketing of (7), available due to the associativity of the categorial syntax:

(9) [Everyone thought] [Mary saw him]:
everyone **Z**-thought = $\lambda g \forall x[\mathit{thought}(gx)(x)]$
Everyone **Z**-thought Mary saw him =
$\lambda g \forall x[\mathit{thought}(gx)(x)](\lambda y[\mathit{saw}(y)(m)]) = \forall x[\mathit{thought}(\mathit{saw}(x)(m))(x)]$

Notice that *A man came in* in (8) and the *everyone* **Z**-*thought* segment in (9) are quite parallel: both contain (i) a quantifier, (ii) a slot within the quantifier's scope for an incoming clause, and (iii) a binding device that links a pronoun in the incoming clause to the quantifier. In (8), the binding device is the state switcher $\{x \backslash d\}$ (aided by $\hat{}\,/\,\check{}$); in (9), it is the combinator **Z**. The parallelism suggests that, with pronouns as identity maps, cross-sentential anaphora does not require any machinery beyond what is needed for sentence-internal binding. Namely, not only is $\hat{}\,/\,\check{}$ unnecessary, but also $\{x \backslash d\}$ can be eliminated in favor of **Z**.

In other words, the basic assumptions of combinatory grammar make it possible to treat significant aspects of non-c-command anaphora using a traditional, static semantics. In this respect, the present approach converges with the approach of Dekker (1994, 1999, 2000). It is less radical than Dekker's in that I crucially retain the feature of dynamic semantics that sentences are interpreted as sets of possible continuations and conjunction is interpreted as functional composition. Dekker argues both for a static notion of meaning and for dynamic conjunction to be analyzed as an ordinary form of conjunction, with the second conjunct interpreted strictly in the context of the first. To what extent these approaches can be unified is an important question that goes beyond the scope of this note.

§4 develops the basic proposal, to be labeled "binding built in", and shows that it is in principle viable, but the combinatorics is overly complicated. §5 therefore proposes a variant of it, one that does "binding on the fly". As a by-

[3]Chierchia, 1995 notes that on the pronouns as free variables view, the syntactic operation known as reconstruction raises the same logical problem as cross-sentential anaphora. He argues that the fact that DMG makes abstraction over assignments $\hat{}$ available constitutes an empirical argument in favor of dynamic semantics, as opposed to DRT. We see that the need for $\hat{}$ vanishes in the variable-free combinatory framework. Moreover, Szabolcsi, 1997a points out that reconstruction being a sentence-internal process is in fact easier in combinatory grammar than cross-sentential anaphora (does not require binding on the fly). Thus the choice between dynamic semantics and DRT should be based on considerations other than the use of abstraction over assignments.

product, a uniformly "disclosed" interpretation of indefinites emerges, which returns to some of the intuitions of Heim–Kamp style DRT in the variable-free setting. This is discussed in §6.

4. Cross-Sentential Anaphora with "Binding Built In"

Assume, with Jacobson, that pronouns are identity maps. Assume, with DMG, that sentences are associated with context change potentials. But, for the continuation, do not use a propositional variable p and a state switcher $\{x\backslash d\}$, as in (8). Instead, use a property variable with an argument bound by the indefinite's quantifier or the pronoun's lambda:[4]

(10)	A man came:	$\lambda f \exists x[\textit{man-came}(x) \,\&\, f(x)]$
(11)	A dog barked:	$\lambda f \exists z[\textit{dog-barked}(z) \,\&\, f(z)]$
(12)	He/She smiled:	$\lambda f \lambda y[\textit{smiled}(y) \,\&\, f(y)]$

Here, the combinator **Z** comes built into the interpretations of indefinites and pronouns. Its effect is different in the two cases, though. In (10)-(11), $f(x)$ and $f(z)$ let the indefinites bind pronouns; on the other hand, in (12), $f(y)$ passes on the binding ability of the pronoun's binder.

The interpretations given in (10)-(12) are invariant. Whether an indefinite actually binds an incoming pronoun does not depend on its or the pronoun's interpretation. It depends on how the two sentences are put together, specifically, on whether and how they are Geached before getting dynamically conjoined, i.e. composed ($\circ$); see the discussion below.[5]

(13) A man$_i$ came. He$_i$ smiled. **(10)∘(12)**
$\lambda f \exists x[\textit{man-came}(x) \,\&\, f(x)] \;\circ\; \lambda f \lambda y[\textit{smiled}(y) \,\&\, f(y)] =$
$\lambda g \exists x[\textit{man-came}(x) \,\&\, \textit{smiled}(x) \,\&\, g(x)]$

(14) A man$_i$ came. She$_j$ smiled. **GEACH(10)∘IN-GEACH(12)**
$\lambda r \lambda v \exists y[\textit{man-came}(y) \,\&\, r(v)(y)] \circ \lambda r \lambda z \lambda d[\textit{smiled}(z) \,\&\, r(z)(d)] =$
$\lambda k \lambda v \exists y[\textit{man-came}(y) \,\&\, \textit{smiled}(v) \,\&\, k(v)(y)]$

(15) A man$_i$ came. A dog$_j$ barked. **(10) ∘GEACH(11)**
$\lambda f \exists x[\textit{man-came}(x) \,\&\, f(x)] \;\circ\; \lambda r \lambda v \exists y[\textit{dog-barked}(y) \,\&\, r(v)(y)] =$
$\lambda r \exists x[\textit{man-came}(x) \,\&\, \exists y[\textit{dog-barked}(y) \,\&\, r(x)(y)]]$

Two problems might seem to threaten the viability of this proposal. First, it might seem that if the indefinite ever needs to bind more than one pronoun in one swoop, (10)-(11) do not suffice and $\lambda r \exists x[\textit{man-came}(x) \,\&\, r(x)(x)]$, etc.

[4] After the completion of Szabolcsi, 1997a, Paul Dekker (p.c.) kindly informed me that the core of "binding built in" is the same as a proposal in Zimmerman, 1991, which antedates Jacobson's theory.

[5] **GEACH** and **IN-GEACH** are members of the Geach-family and differ as to which argument slot of the input function is affected. The details are irrelevant to us, although the fact that such distinctions need to be kept track of is somewhat relevant, as will be pointed out below.

must be added. But this need actually does not arise. As Jacobson shows (Jacobson, 1999, 143), the pronouns can be "merged" first even in (16), where the two instances of *him* do not c-command each other.

(16) A man$_i$ came. The woman who saw him$_i$ greeted him$_i$.

The second problem stems from the fact that negation makes an indefinite in its scope inaccessible for subsequent anaphora, but it does not affect a pronoun's ability to pass binding on.

(17) A man$_i$ came. [I do] not [think that] a[ny] woman$_j$ saw him$_i$.

$$\left\{\begin{array}{l}\text{He}_i \text{ smiled.}\\ \text{She}_{*j} \text{ was busy.}\end{array}\right\}$$

This problem is solved by defining externally static operators that yield just the desired result. DMG-style negation, see (18), would simply wipe out the continuation variable within the scope of the existential by application to the tautological continuation $\top$, and place a new continuation variable outside the existential's scope. This may be replaced by (19a), for example, for the case where the sentence contains one indefinite and one pronoun:

(18) $\text{NOT}_{\text{DMG}} = \lambda h \lambda q[\neg(h(\top))\ \&\ q]$

(19) a. $\text{NOT} = \lambda h \lambda f \lambda z[\neg(h(\lambda x \lambda y.\top)(z))\ \&\ f(z)]$

b. not... a woman saw him =
$\text{NOT}(\lambda r \lambda x \exists y[\mathit{woman}(y)\ \&\ \mathit{saw}(x)(y)\ \&\ r(x)(y)])$
$= \lambda f \lambda z[\neg\exists y[\mathit{woman}(y)\ \&\ \mathit{saw}(z)(y)\ \&\ \top]\ \&\ f(z)]$

The present proposal is very attractive in that it handles cross-sentential anaphora without any new binding trick. But it is time to admit that its combinatorics are very costly. To see this, let us consider how the three patterns (13)-(15) come about.

No application of Geach is called for when the old text contains n independent *dramatis personae* (indefinites or free pronouns), and the incoming text contains just a matching number of pronouns in a matching order, each of them getting bound. (13) presents such an unusually happy situation, with $n = 1$. Deviations in either direction call for applications of Geach. When the incoming text contains k pronouns that are not getting bound right away, the old text needs to be Geached k times; witness (14). This is something we cannot help; we inherit this directly from sentence internal binding. What happens to the incoming text is less easy to put up with. When the old text contains n distinct players, its continuation variable is an n-place function. An incoming clause with the n + 1th new player (an indefinite or a pronoun that is not getting bound) must be Geached n times, to adjust its type, as in (14)-(15). In addition, the right subspecies of Geach needs to be used, to ensure that arguments match up correctly.

Imagine now the rather typical situation in which a sentence like *A dog barked* is added to a long story that already contains one hundred distinct players. No binding is involved. Nevertheless, the incoming sentence must undergo Geach one hundred times. This contradicts the intuition that, whatever the cost of binding might be, at least the addition of new players to a discourse should be effortless.

Of course, the above complexities carry over to binding whenever the match is not as lucky as in (13). All in all, the examples in (13)-(15) are deceptively simple, because they involve at most two distinct players.

In view of these problems, as well as the requisite redefinition of externally static operators, I will abandon the most straightforward application of the sentence-internal binding mechanism to the cross-sentential case.

5. Cross-Sentential Anaphora with "Binding on the Fly"

The problems in section 4 stemmed from the fact that the continuation variable was an n-place function, its arity encoding the number of players in the old text. To remedy this, we try to make do with a continuation variable of the plain sentential type. In this regard, the proposal resembles DMG, but it continues to be static: our p is not a variable over sets of assignments.

The simplest thing would be to start with (20)-(21), and let all binding happen in the course of dynamic conjunction, when the need arises:

(20) A man came: $\lambda p \exists x[\textit{man-came}(x) \,\&\, p]$
(21) He/she smiled: $\lambda p \lambda y[\textit{smiled}(y) \,\&\, p]$

In other words, what we want is for a duplicator to apply to *A man came* when a pronoun in the continuation is anaphoric to it. Unfortunately, since x is bound in (20), no duplicator can access it. Thus, replace (20) by (22).

(22) A man came: $\lambda p \lambda z \exists x[\textit{man-came}(x) \,\&\, x = z \,\&\, p]$

This move facilitates duplication, because we will now have two lambda-bound arguments. One is z in (22). The other will be introduced by the Geach rule that welcomes any incoming pronoun (see (24a)). The result can undergo duplication (24b), and composes with the clause containing the anaphoric pronoun, as usual (24c).

Thus, the motivation for (22) lies in the fact that the extra argument place allows the switch from "binding built in" to "binding on the fly". We cannot help noticing, however, that (22) is equivalent to (23).

(23) A man came: $\lambda p \lambda z[\textit{man-came}(z) \,\&\, p]$

This fact has some significance of its own, to be commented on in section 6. For the time being, we focus strictly on how anaphora works.[6]

[6] **DUPLICATE** is BW, a member of the duplicator family.

(24) A man$_i$ came. He$_i$ smiled. **DUPLICATE(GEACH(23)) ∘ he-smiled**

a. GEACH(23)
$\lambda g\lambda y[\lambda p\lambda z[\mathit{man\text{-}came}(z)\ \&\ p](gy)] =$
$\lambda g\lambda y\lambda z[\mathit{man\text{-}came}(z)\ \&\ g(y)]$

b. DUPLICATE(GEACH(23))
$\lambda f\lambda v[\lambda g\lambda y\lambda z[\mathit{man\text{-}came}(z)\ \&\ g(y)](f)(v)(v)] =$
$\lambda f\lambda v[\mathit{man\text{-}came}(v)\ \&\ f(v)]$

c. DUPLICATE(GEACH(23)) ∘ (21)
$\lambda q[\lambda f\lambda v[\mathit{man\text{-}came}(v)\ \&\ f(v)](\lambda p\lambda y[\mathit{smiled}(y)\ \&\ p](q))] =$
$\lambda q\lambda v[\mathit{man\text{-}came}(v)\ \&\ \mathit{smiled}(v)\ \&\ q]$

In contrast to "binding built in", on the present setup both the old text and the incoming clause are invariably of the form $\lambda p[\ldots\ \&\ p]$ and can be smoothly composed. All that is needed is a local type adjustment: one application of Geach for each incoming pronoun, whether anaphoric or not, as in Jacobson, and for each incoming indefinite, which are now of the same type. Alongside (24), we have (25) and (26).

(25) A man came. A dog barked. **GEACH(23) ∘ a-dog-barked**

$\lambda q[\lambda g\lambda y\lambda z[\mathit{man\text{-}came}(z)\ \&\ g(y)](\lambda p\lambda v[\mathit{dog\text{-}barked}(v)\ \&\ p](q))] =$
$\lambda q\lambda y\lambda z[\mathit{man\text{-}came}(z)\ \&\ \mathit{dog\text{-}barked}(y)\ \&\ q]$

(26) A man came. Everyone smiled. **(23) ∘ everyone-smiled**
$\lambda q[\lambda p\lambda z[\mathit{man\text{-}came}(z)\ \&\ p](\lambda p[\forall y[\mathit{smiled}(y)]\ \&\ p](q))] =$
$\lambda q\lambda z[\mathit{man\text{-}came}(z)\ \&\ \forall y[\mathit{smiled}(y)]\ \&\ q] =$

Turning to some details, I propose to compose Duplicate (here: BW) and Geach (B) into a single operation, rather than applying them sequentially, as in (24). This is necessary because, as things stand now, when Duplicate enters in (24b), it in fact has no way of knowing which of the lambda-bound arguments are old "binder arguments" and which are new "bindee arguments". On the other hand, the one-step operation B(BW)B knows which arguments have just been created for the sake of incoming pronouns. It is therefore also generalizable to more complex binding patterns, without identifying arguments incorrectly:

(27) A man$_i$ met a boy$_{j/*i}$. He$_{i/j}$ smiled.

It is natural to observe that the one-step operation B(BW)B is nothing but Z. In other words, we have come to a full circle: "binding on the fly" in (24) is performed by conjunction interpreted as BBZ.

(28) A man$_i$ came. He$_i$ smiled. **Z(23) ∘ (21) = BBZ(23)(21)**

Likewise, an operation replicating Kamp and Reyle's (1994) summation for split antecedents can be defined as a single combinator SUM applying to the old text before dynamic conjunction. As K&R suggest, the sum individual is created only if it is needed for anaphora.

(29) A man$_i$ met a boy$_j$. They$_{i+j}$ hugged.

a. A man met a boy: $\lambda p\lambda v\lambda u[man(u)\ \&\ boy(v)\ \&\ met(u,v)\ \&\ p]$

b. SUM: $\lambda f\lambda g\lambda x\lambda y[f(g(x+y))(x)(y)]$

c. They hugged: $\lambda p\lambda w[hug(w)\ \&\ p]$

d. SUM(28a) $\circ$ (28c) =
$\lambda q\lambda x\lambda y[man(y)\ \&\ boy(x)\ \&\ met(y,x)\ \&\ hug(x+y)\ \&\ q]$

6. Indefinites Disclosed

We have been led to interpret sentences with indefinites as in (30):

(30) A man came: $\lambda p\lambda z\exists x[man\text{-}came(x)\ \&\ x=z\ \&\ p] =$
$\lambda p\lambda z[man\text{-}came(z)\ \&\ p]$

Given the fact that the existential quantifier is now removed, and the manner in which it is removed, (30) might be aptly called "Existential Disclosure built in", cf. Dekker, 1993.

The resulting theory shares features with both Kamp–Heim style DRT and Dynamic Semantics. The fact that our indefinites are not existentially quantified makes it a variant of DRT. On the other hand, our indefinites are not (sentences with) free variables. This is an inescapable consequence of the variable-free combinatory setting. Therefore, non-c-command anaphora is not a matter of coreference, as in DRT; it remains a matter of binding, as in Dynamic Semantics.

These observations indicate what further ingredients need to be added. First, given that *A man came* and *He came* are of the same format, some measure must be taken to prevent the former from getting bound. This may be achieved by making a distinction between the two sorts of property (in the spirit of the novel/familiar variables of Heim, 1982) and setting up the grammar in such a way that **Z**-style combinators can only capture the latter sort.

Second, a text containing indefinites needs to undergo existential closure under the appropriate circumstances: (i) when they fall within the scope of externally static operators, such as negation, universals, propositional attitudes, and (ii) when the ultimate truth value of the text needs to be determined. In other words, the "downarrow" operation of DMG that turns context change potentials into truth values will have two versions, $\downarrow_{\exists}$ incorporating existential closure to capture the relevant indefinites. The "uparrow" operation that supplies a new continuation variable will, of course, not disclose those indefinites.

In this spirit, the context change potentials of the narrow and wide scope existential readings of *Everyone knew that a man came* will be derived, roughly, as follows.

(31) Everyone knew that a man came ($\forall > \exists$)

a. $(a\text{-}man\text{-}came) = \exists(\lambda p \lambda x[man\text{-}came(x)\ \&\ p](\top)) = \exists x[man\text{-}came(x)]$

b. knew that = $\lambda p \lambda y[knew\text{-}that(p)(y)]$

c. everyone knew that a man came = $\forall z[knew\text{-}that(\exists x[man\text{-}came(x)])(z)]$

d. $\uparrow$(everyone knew that a man came) =
$\lambda p[\forall z[knew\text{-}that(\exists x[man\text{-}came(x)])(z)]\ \&\ p]$

(32) Everyone knew that a man came ($\exists > \forall$)

a. GEACH(everyone)(GEACH(knew-that)($\downarrow$(a-man-came))) =
$\lambda y \forall z[knew\text{-}that(man\text{-}came(y))(z)]$

b. $\uparrow(\lambda y \forall z[knew\text{-}that(man\text{-}came(y))(z)]) =$
$\lambda p \lambda y[\forall z[knew\text{-}that(man\text{-}came(y))(z)]\ \&\ p]$

The extra-clausal application of existential closure threatens to produce inappropriately weak truth conditions in certain cases. Reinhart, 1997 proposes to use existential closure of choice function variables, as opposed to individual variables, to solve this problem. Szabolcsi, 1997b points out that the same problem can be handled without invoking choice functions. The variables corresponding to indefinites need to range over (singular or sum) individuals constructed from the minimal witness sets of the generalized quantifier denoted by the indefinite.[7] This move has independent motivation in the semantics of scope, laid out in Beghelli et al., 1997. This leads to our final modification of the treatment of indefinites:

(33) A man came: $\lambda p \lambda \mu[came(\mu)\ \&\ p]$
where μ ranges over individuals constructed from minimal witnesses of the generalized quantifier denoted by *a man*, namely, singleton sets of men.

This interpretation blends in smoothly with the combinatory machinery outlined above, because the binder and the bindee variables are of the same logical type: *e*. On the choice functional interpretation of indefinites, pronouns might be rethought as involving choice function variables; a move that may have independent advantages or disadvantages.

To summarize, the modifications forced upon us by the needs of "binding on the fly" lead to a semantically coherent treatment of indefinites.[8] It remains to be seen, though, whether all the ingredients that are programmatically outlined in this section can be implemented in a sufficiently simple way in the general case.

[7] A witness set of a generalized quantifier is an element of the generalized quantifier that is also a subset of the determiner's restriction (Barwise and Cooper, 1981).

[8] Following Zimmerman, 1991 and Dekker, 1993, this proposal might be extended to accommodate adverbs of quantification as "unselective binders" of indefinites. However, I subscribe to the view, argued in de Swart, 1991, that adverbs of quantification operate on sets of events, and the appearance that they bind indefinites emerges only as a special case when there happens to be a one-to-one correspondence between events and (tuples of) individuals. Therefore, such an extension would not be desirable.

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