

Or and Anaphora¹

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0. Introduction

Since Montague (1973), semantic theories have received precise implementations as algorithms that translate linguistic expressions compositionally into a logical language. Particularly troublesome for this strategy have been DONKEY sentences:

- (1). If a man owns a donkey, he beats it.

The meanings of donkey sentences cannot be captured using a procedure which, like Montague's, uses the existential quantifiers of classical logic to translate indefinites and the variables to translate pronouns. The treatment of these examples requires meanings which depend on the context in which sentences appear, and thus necessitates a logic which models this context to some extent. If context is represented as the information conveyed in discourse, and the meanings of pronouns are enriched to depend on this information, the result is the E-Type approach (ETA) adapted by Heim (1990) from proposals in Evans (1980) and Cooper (1979). If the context is represented as a list of potential referents, and the meanings of indefinites are enriched to introduce new referents into this list, the result is a compositional formulation like Groenendijk and Stokhof's (1990) of the discourse representation theory (DRT) of Kamp (1981) and Heim (1982). Either tack suffices to capture the way in which the referents of *he* and *it* systematically correspond to the alternative possibilities described by the antecedent.

Disjunction offers a parallel way of introducing alternatives in the antecedent of a conditional, as shown in (2).

- (2). If Mary sees John or Bill, she waves to him.

It is natural to expect that because they exploit the same insight in accounting for (1) ETA and DRT would generalize equally well to an account for (2). This is not the case. The ETA encoding of context and pronoun meaning straightforwardly predicts the anaphora in disjunctive conditionals, once the obvious meaning for *or* is provided. In contrast, DRT can only explain (2) by adopting the operations on objects native to ETA. This distinction between the two approaches is a fundamental consequence of the difference in the mechanics and representations of the two systems, so the ability of ETA to generalize to disjunction constitutes a strong argument in its favor.

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1. Heim's ETA

I initiate the argumentation that establishes this with a sketch of ETA and DRT that highlights the properties of the representation and use of context important later on. (A comprehensive exposition of the two systems is beyond the scope of this presentation, but the interested reader is referred to Heim 1990 or Chierchia 1992.) I turn first to ETA.

Heim's ETA encodes context as information using an important innovation in the model structure of logic: a set of indices called SITUATIONS. A situation is a representation of part of a world, or of a partial collection of facts about the world, which serves as a background against which to evaluate the truth of a formula. As with the indices of modal logics, the interpretation of predicates and relations can vary across situations, but because situations are partial, the values of predicates and relations may be undefined for some objects, rather than true or false. As information grows, propositions whose truth-value is undefined are resolved to true or false. So, like possible worlds, situations are linked by accessibility, but now accessibility encodes growth of information rather than alternative possibility. That is, the situation j is accessible from i when the information contained in j is an augmentation of the information contained in i . This structure among indices allows finer distinctions to be made than are made in classical logic. In fact, when Barwise and Perry (1981, 1983) first introduced situations to solve linguistic problems, it was to use this added structure to correctly distinguish propositions which receive identical interpretations in classical logic.

The precise logic of situations depends on several choices about indices and the relations between them, for which alternative positions give rise to distinct but consistent formulations. For example, different proposals have been made for the way in which the falsehood of a proposition in a situation is to be determined. Likewise, variations in ideas about indices distinguish several models of information growth. Heim has in mind the system in Kratzer (1988). Here situations do not contain negative facts; falsehood is established when the truth of a fact is ruled out in every extension of an information state. Meanwhile, each situation can extend only to a single total information state, that of its world.

These stands are vital in understanding the specifics of Heim's proposal, but the predictions of ETA carry over when alternative positions are taken. Despite their differences, each variant reflects a common intuitive understanding of situations which alone is vital to the success of Heim's ETA. It rests on two ideas. First, whether they are bunches of facts or pieces of worlds, situations are abstract structures finely discriminated (Kratzer 1988:612-614). In particular, situations can specify facts about an individual at a particular place and time without necessarily specifying other facts about that individual or about what else may be happening then and there. Second, despite their partiality, a situation specifies simple facts such as a world does, and no others. Complex propositions, such as those generated by disjunction, quantification, and modal operators, are not separately and explicitly

encoded into a situation: as in classical logic, their truth in a situation is determined by the truth of simple facts there and the ways in which that situation is related to others. Hence, complex patterns are represented only implicitly (Landman 1986).

With this model structure, the meaning of a sentential formula remains a function from indices to truth values, as it is in modal logics. However, situations have been adopted in part because they allow the identification of them meaning of a proposition with a simpler set: the MINIMAL situations which verify it. Here is why. Information grows consistently, so once a formula is known to hold in a situation, it must hold in all situations accessible to it by the growth of information. This fact is known as the persistence of propositions. Consider the set of pieces of information i which have the property that p is true in i without being true given any proper subset of the information in i . It follows from persistence that every supersituation of an element in this set verifies p . Moreover, only such situations do, because whenever a situation verifies p , removal of information ultimately yields an element of this set. Thus, there is a one to one correspondence between propositions and these sets, their minimal situations. Simple facts will have only a single minimal situation in each world; but as explained in more detail below, facts derived from logical operations such as existential quantification will require many minimal situations. For a contradiction, the set of minimal situations which verify it is empty. I'll denote the minimal situations of a proposition p as $\mu(p)$.

With this architecture of situations, the information communicated in a discourse can be treated simply as the conjunction of the propositions which make it up. Such a context, κ , always identifies a unique set of minimal situations, $\mu(\kappa)$. This equivalence permits a natural realization of the relativized salient descriptions that Heim's ETA is to assign pronouns. The meaning of a pronoun is a function which maps each of the minimal situations of the context to an individual. Such a function is salient, an appropriate interpretation for the context in which it appears, just when its values are determined in a way that reflects the information structure of its domain. Every proposition containing such a function must now be evaluated with respect to a context which is to provide these minimal situations; its meaning must indicate not only whether it is true or false, but also how the context which results from incorporating it is to be constructed.

Let's examine exactly how Heim's proposal works, using this simplified variant of the perennial example:

- (3). A man owns a donkey. He beats it.

Assume that this discourse appears in isolation. The context for the first sentence of (3) is therefore the set of situations that contain no contingent facts—one such situation for each world—and the minimal situations for the first sentence serve as the context for the second. As always, the first sentence, the erstwhile antecedent, receives the translation in (4).

- (4). $\exists x \exists y [\text{MAN}'(x) \wedge \text{DONKEY}'(y) \wedge \text{OWN}'(x, y)]$

Now note that each of the minimal situations at which (4) is true contains some particular individual x_0 who is a man, and similarly some donkey y_0 . For, in this situational logic, the verification of the complex propositions occasioned by existential quantifiers must proceed on the basis of the simple facts—such as x_0 is a man or y_0 is a donkey—of which situations are constituted. Moreover, x_0 is the ONLY man in that minimal situation, and y_0 the only donkey. Given the precise delineation of situations, the extra information about any superfluous individuals could be stripped away yielding a smaller situation which continued to verify (4). The existence of x_0 , y_0 , and their correlates renders well-defined and salient a function f_m which associates with each minimal situation of (4) the unique man there, and a function f_d that associates with each the donkey there.

The second sentence will pick up these functions respectively as the interpretation of *he* and *it*, as it contributes its information to the context. At each contextual situation, $i \in \mu(\kappa)$, the second sentence will determine a proposition

$$(5). \quad p(i) = \text{BEAT}'(f_m(i), f_d(i))$$

true at those extensions of i at which the man beats the donkey. Since the context going in to the second sentence consists of the union of the i 's, the context going out should consist of the union of the $\mu(p(i))$'s. The set of situations which results is just the set of minimal situations where a man owns and beats some donkey, as is correct.

This logic shows how ETA can in fact assign the correct truth-conditions to (3), but it is equally important to verify that these rules do not countenance any incorrect interpretations. Many functions can be imagined which map the minimal situations of (4) onto individuals. Not all of them can serve as the interpretation of a pronoun in the consequent. For each function, ETA must explain precisely why it is or is not possible. To do this, Heim herself looks to a mechanism that licenses an E-type function by establishing a formal, syntactic link to between it and its antecedent. However, the following argument suggests that salience can be given a precise semantic characterization that constrains the functions with which pronouns are interpreted to those that actually can occur.

The necessary characterization depends only on two intuitively plausible manifestations of respect for context. The first is that a salient function must always pick out an individual in a situation that the situation gives information about. The functions f_m and f_d do meet this requirement, since each of the situations in their domain contain unique facts about individuals being men or donkeys, but many conceivable functions do not. One such example is the function f_Q , which gives some arbitrary but fixed individual, Dan Quayle perhaps, from each of the minimal situations of (4). f_Q does not respect the information in any situation in which Dan Quayle is neither man nor donkey. Since the situation gives no fact on the basis of which to determine who Dan Quayle is, it is not the information in it that goes into designating Dan Quayle there. (This argument only holds, of course, as long as (3)

is not itself evaluated in a context from which Dan Quayle can be determined. This is to be expected: in such a case f_Q would in fact be a perfectly good interpretation of the pronoun in it.)

The second relevant dimension of respect for information ensures that a salient function take corresponding arguments to corresponding results. All of the minimal situations for (4) can be thought of as little copies of each other, since they all contain variants of the same three facts. By picking out an individual from each that is described by the same properties, f_m and f_d respect this relationship, but again, not all functions do this. f_h , for instance, picks out the donkey in half of the minimal situations and the man in the other half. Because each of the situations looks more or less the same, there is no criterion which distinguishes the situations in which f_h picks out a donkey on the basis of the information they contain. With f_A as with f_Q it is not the information in a situation that determines its value there.

The first principle, and the reasoning which applies it to f_Q , ensures that a function into individuals salient in the minimal situations of (4) picks out either the man or the donkey there. The second, and the reasoning which applies it to f_h , ensures that a salient function, if it picks out the donkey or the man in any particular situation, must do so in all of them. In short, the only salient functions in this example are the ones that actually serve as the interpretations of its pronouns.

The role that salience plays in restricting possibilities for anaphora informs the choice of working with MINIMAL situations. If pronouns applied to EVERY situation at which the first were true, even the two correct functions would no longer meet the above requirements: salience does not work if applied to constructs that contain too much information. For instance, in a situation which contains the same information about the two donkeys in it, no function that picks out a donkey is salient. Minimal situations don't have this problem: their partiality gives them the requisite tight, uniform structure. So minimal situations really are the crucial resource that makes ETA sensible.

For this treatment to extend to (1), all these observations must apply to conditionals. In particular, because pronoun meanings are constructed based on the minimal situations of the context, the definition of *if* must have the antecedent provide the context for the consequent. Heim's definition, (6), does this.

- (6). $\varphi \rightarrow \psi$ (if φ , ψ) is true just in case every minimal situation in which φ is true extends to a situation in which ψ is true.

For, indeed, just the minimal situations at which the antecedent is true will be considered when evaluating the consequent. In all, the E-type theory assigns to (1) truth conditions that can be paraphrased with—(1) is true if and only if every minimal situation i at which some man owns some donkey extends to a situation in which the man at i beats the donkey at i .

This fixes the aspects of ETA crucial for the upcoming discussion. In ETA, the context is established as a set of minimal situations; pronouns are functions that

look into the information contained in the context to choose, in a constrained way, an individual from each alternative that the context sets up. Two aspects of this system will prove distinctive: first, that minimal situations constitute a purely semantic representation of the meaning of some proposition, traditionally constructed; and second, that contextual complexity lies in the pronoun.

2. Dynamic DRT

In DRT, as in ETA, a context is constructed to represent alternative realizations of a discourse and is then used to determine reference. In DRT, however, the context directly encodes possibilities for anaphora instead of ETA's more general information. DRT describes each alternative in a context in terms of special variables called discourse markers which are used as the translations of pronouns. Whether a sentence that contains a pronoun is true or false depends on the object that is assigned to the corresponding discourse marker. Accordingly, sentences are always evaluated with respect to functions called discourse models that associate some entity of the world with each active discourse marker. The context for a series of sentences consists of all the discourse models in which it is true, and hence the effect of incorporating a sentence into the context is to restrict the context to those alternatives in which that sentence also is true. Conjunction, denoted Δ in this language, generates the function that updates the context first with the argument on its left and then with the one on its right.

A new meaning for indefinites in dynamic DRT takes advantage of these contexts. As formulated by Groenendijk and Stokhof (1990, 1991) and Chierchia (1992), indefinites are translated using an unusual kind of existential quantifier, \exists . Instead of quantifying over alternative variable assignments as usual, \exists quantifies over alternative discourse models to those in the context. \exists thereby expands and enriches the context so that all possibilities are considered for embedding the new variable which follows it. Because its role is to change the context, \exists does not really have a scope; it can bind the variable it introduces as long as that variable remains available.

Operations called tests, on the other hand, close off the availability of variables introduced within their scope. Included in this category are \supset and $\supset\supset$. Incorporating $\supset\varphi$ into a context does not alter any elements of the context (as \exists does); it merely removes those discourse models which are compatible with φ . For example, $\exists x \text{ MAN}'(x)$ introduces the variable x to each contextual alternative, then accepts only the new alternatives in which x is assigned a man. $\supset[\exists x \text{ MAN}'(x)]$ thus lets pass only those alternatives for which no discourse models in which x is a man can be found. Subsequent reference to x is impossible. Meanwhile, $\varphi \supset\supset \psi$ tests that each way of extending a discourse model so that φ is true extends in turn to a discourse model in which ψ is true. Alternatives in which this is not the case are rejected by the test.

It is also possible to introduce λ -abstraction and intensional operators into this

logic. This ensures that meanings can be provided for each word that specifies its contribution to sentence meaning. As expected, $\lambda\tau\varphi$ is a function that takes an object of the same type as τ and returns the interpretation of φ when that object is assigned to τ . If φ is a formula denoting a function to update the context, then $\hat{\varphi}$ denotes the function from contexts to contexts associated with the meaning of φ . These two operations interact in a slightly surprising way. If x is a discourse marker, the equivalence in (7) shows that an apparently free variable can be bound in an operation of λ -conversion.

$$(7). \quad \lambda p[\exists x P(x) \Delta \hat{p}](\hat{Q}(x)) \equiv \exists x P(x) \Delta Q(x)$$

Because the $\hat{\quad}$ operator abstracts over discourse models, the interpretation of x is 'frozen' (to use Chierchia's term) exactly like the world used as the current one is 'frozen' in the expression of intensional logic below:

$$(8). \quad \lambda p[\Diamond(\hat{q} \wedge \hat{p})](\hat{\varphi}) \equiv \Diamond(\hat{q} \wedge \hat{\varphi})$$

These definitions suffice to illustrate how dynamic DRT accounts for (1).

- (1). If a man owns a donkey, he beats it.

The translations of *a man* and *owns a donkey* look very much like their translations in static Montague grammar. The translation of *a man* might be represented as in (9), if x_1 is a discourse marker that has not previously been introduced.

$$(9). \quad \lambda P[\exists x_1 \text{MAN}'(x_1) \Delta \hat{P}(x_1)]$$

Similarly, *owns a donkey* would be translated as (10) when rendered in terms of the discourse marker x_2 .

$$(10). \quad \lambda x[\exists x_2 \text{DONKEY}'(x_2) \Delta \text{OWN}'(x, x_2)]$$

However, because of the dynamic logic's added treatment of context, the similarity of these translations with Montague's is rather superficial. Thus, in (9), P is a DYNAMIC property, whose denotation is a function which, when provided its argument, returns not a truth-value but a function for updating the context. The meaning provided for *owns a donkey* is such a dynamic property. The first, when applied to the meaning of the second, results in (11).

$$(11). \quad \exists x_1 \text{MAN}'(x_1) \Delta \exists x_2 \text{DONKEY}'(x_2) \Delta \text{OWN}'(x_1, x_2)$$

This represents a function for updating a context which could be expressed in words as follows: Take the context and extend each discourse model there to x_1 and x_2 in any way so long as the object assigned to x_1 is a man, and the object assigned to x_2 is a donkey.

The translation of the consequent is comparatively easy. Pragmatics determine that *he* is to be translated as x_1 and *it* is to be translated as x_2 . This decided, *he*

beats it is rendered just as $BEAT'(x_1, x_2)$, a test that accepts contextual alternatives where the individual assigned to x_1 beats the one assigned to x_2 . (11) and this are assembled using the dynamic definition of *if* described earlier, to yield the correct meaning. Symbolically, the result is (12).

$$(12). \quad [\exists x_1 MAN'(x_1) \Delta \exists x_2 DONKEY'(x_2) \Delta OWN'(x_1, x_2)] \Rightarrow BEAT'(x_1, x_2)$$

The meaning of this is a function that builds a new context by considering in turn each of the alternative models of the old one. If every way of extending a given discourse model so that there is a man, x_1 , that owns a donkey, x_2 , results in a discourse model where x_1 beats x_2 , the model is accepted. Otherwise it is rejected. Thus, this function narrows the context to the set of discourse models where, in fact, all men who own any donkeys beat them.

With this idea of how DRT accounts for examples like (1), we can more accurately assess its differences from Heim's ETA. By introducing new referents, indefinites play the principal role in ensuring that the correct possibilities for anaphora are constructed. Pronouns are translated simply as variables as they are in Montague's work. This contrasts with ETA, where indefinites receive the familiar, simple translation and complexity resides in the meanings assigned to pronouns. This might be described as a difference in DIRECTIONALITY: in DRT, sophisticated operations look FORWARD, setting up referents in advance; whereas in ETA they look BACKWARD, determining referents when needed. A related difference is that in representation. DRT relies on its relatively straightforward, relatively syntactic mechanism of an indexed list to keep track of possible referents, where ETA uses a relatively abstract, relatively semantic mechanism to keep track of information in general. The two issues of directionality and representation are the key ingredients in arguments about the treatment of disjunction in the two systems.

3. Disjunction

Sections 1 and 2 explored theoretical accounts the use of indefinite noun phrases in establishing connections between antecedents and consequents in conditionals. Here, I address the formulation of a more general theory of the way in which such correspondences are introduced. The data for this investigation is provided by conditionals in which the interpretation of the consequent parallels alternatives in the antecedent expressed using disjunction.

Sentences as simple as (2), repeated below, motivate the simultaneous consideration of correspondence anaphora and disjunction.

(2). If Mary sees John or Bill, she waves to him.

Here, as in (1), the pronoun *him* varies according to the individual chosen to realize the circumstances described in the antecedent. (2) asserts that when Mary sees John, she waves at John, and when Mary sees Bill, she waves at Bill. As always,

the expectation is that such similar phenomena as the correspondences set up by indefinites and disjunctions should derive from a common underlying origin.

To extend earlier explanations to disjunctive cases, we will make the assumption that the meaning of a sentence like (2) derives from the relatively simple meaning of *if* that we've already seen, when combined with some straightforward meaning for *or*. In static treatments of the grammar, *or* is accounted for using the simple and elegant analysis seen, among other places, in Partee and Rooth (1982). The idea is to provide *or* with a polymorphic interpretation, denoted by the infix operator \sqcup , that can form the disjunction of two constituents of almost any type. When combining truth values, \sqcup acts exactly like the connective \vee ; for two functions of the same type, \sqcup is defined as in (13).

$$(13). \quad f \sqcup g \equiv \lambda u [f(u) \sqcup g(u)]$$

From the recursive step, it is clear that a function can be used in this definition only if it yields a truth value after taking all its arguments. Yet, expressions like names that usually denote individuals can combine using *or* as well. The simplest course in accounting for the disjunction there is to use Montague's translations of names like *John* and *Bill*: $\lambda P[P(j)]$ and $\lambda P[P(b)]$. These CAN be conjoined using \sqcup , to yield the appropriate $\lambda P[P(j) \vee P(b)]$. For Partee and Rooth, verbs and other constituents shift to slightly more complex translations when these more sophisticated arguments are supplied to them.

Amazingly, this polymorphic definition suffices to explain sentences like (2) in ETA. The meaning of *or* and the interpretations of *John* and *Bill* explained above determine the propositional formula obtained for its antecedent. It is simply:

$$(14). \quad \text{SEE}'(m, j) \vee \text{SEE}'(m, b)$$

Now, the logic of situations treats disjunction much like the existential quantification that we saw earlier: a disjunctive formula can only be satisfied in a situation in virtue of the truth of one of its disjuncts there. Hence, given their disjunctive specification, the minimal situations at which (14) is true fall into two classes. Any situation in one set contains Mary seeing Bill, and no other individuals or events; any in the other contains instead Mary seeing John, and no other individuals or events. Recall that an appropriate function must use the information in each of these situations to pick out an individual: the same concerns that dictated that we must choose the man or the donkey out of the situations in (1) dictate that we must choose either Mary or the person she sees out of these situations. This second function must pick out Bill in the first set of situations described and must pick out John in the second sort. Sure enough, this precisely captures the reference of *him* in (2). The truth-conditions, correct, come out as:

- (15). Every minimal situation in which Mary sees Bill or John extends to a situation in which Mary waves at the man she sees.

This simple solution is possible in ETA because of the directionality and representation of the system. ETA straightforwardly encodes the information associated with disjunction and lets the impact of disjunction on pronoun interpretation fall out from constraints placed elsewhere. Because the architecture allows pronouns to select their referents, there is no need to explicitly address the tricky question of the action of *or* in introducing new potential referents. The effect of *or* on anaphora cannot be finessed this way in DRT.

Standard dynamic DRT offers two possibilities for disjunction, neither of which accounts for the anaphora in (2). To see why they are inapplicable, bear in mind that the translation of *him*, like the DRT translation of every pronoun, must be some individual variable, say x_1 . For this variable to refer either to Bill or to John, whichever is appropriate, it must be introduced in the antecedent of (2). Now, most frequently, *or* is modeled as a test, denoted as \vee . This connective lets pass any discourse model in the context that could be truthfully continued with one of its arguments, but does not introduce any new models into the context. Because of this, no discourse markers introduced in either disjunct are available subsequently; nor are any new variables introduced to link referents between disjuncts. Since there is no way to obtain the needed x_1 , \vee is of no help in accounting for (2).

The second interpretation of *or* in dynamic DRT is program disjunction, denoted \cup . The context that results from $\varphi \cup \psi$ consists of all of the discourse models which can be obtained by applying φ or ψ to the current context. Thus, if φ and ψ introduce the same discourse marker with two different constraints, the effect of program disjunction is to generate a new constraint on its interpretation equivalent to the disjunction of those in φ and ψ . Because it involves introducing the same marker in two places, program disjunction may lead to technical problems, but a more basic reason prevents its use here: standard formulations of dynamic DRT would not introduce any individual variables in interpreting either of the disjuncts in (2). If Bill and John have already been referred to in discourse, they will be interpreted using old markers, perhaps b and j . No opportunity for program disjunction to generate the needed x_1 will arise in this case, because program disjunction can only identify newly introduced markers.

To determine how best to resolve this difficulty, let us follow the argumentation of Rooth and Partee (1982).² Rooth and Partee note the need for the disjunction itself to introduce a new variable in the antecedent of (2). They argue that such an introduction is well-motivated, because the logic of such disjunctions of individuals renders it equivalent to existential quantification over an explicitly specified domain. If the mechanism by which language realizes existential quantification is through dynamic variable introduction, the same method should apply in these disjunctions. They suggest a rule for disjunction of individuals parallel to the rule for indefinites:

²Their paper presents ideas rather than explicit formulations, in part because DRT at that time did not incorporate the architecture necessary to implement them; the details in what follows therefore constitute in part my own interpretation.

just as *a donkey* introduces a variable, with the constraint that its value be some donkey, *A or B* introduces a variable, with the constraint that its value be either that of *A* or that of *B*. In the notation of dynamic logic, *A* and *B* are dynamic montagovian property sets. We abstract over the variable each introduces using an equality property, and then indefinitely quantify over this abstraction. In symbols, the result of this disjunction rule with variable x_1 is as follows:

$$(16). \quad \lambda P[\exists x_1[A(\lambda x[x = x_1]) \vee B(\lambda x[x = x_1])] \Delta \sim P(x_1)]$$

In (2), this disjunction applies to the dynamic properties of Bill and the dynamic properties of John to establish the properties of Bill or John, and a way to talk about Bill or John. This is exactly what we need to interpret (2). In all, we get the correct translation for it that is written out in (17).

$$(17). \quad [\exists x_1(j = x_1 \vee b = x_1) \Delta \text{SEE}'(m, x_1)] = \text{WAVE}'(m, x_1)$$

Rooth and Partee's treatment makes correct predictions for (2). However, more complicated examples exist which, although easy to explain in ETA, are accommodated within DRT only with much more complicated manipulation of variables than Rooth and Partee's. The added difficulty posed by these sentences reflects the fact that the disjunctions which they contain combine expressions of one category, but impact later anaphora for other types of constituents. Consider for instance (18):

(18). If Mary catches a fish or John traps a rabbit, Bill cooks it.

Here, too, the pronoun *it* is used to express two correspondences: when appropriate *it* refers to the fish, but when appropriate *it* refers to the rabbit.

For ETA, the explanation that we use for (18) is exactly the same as the explanation of (2). We translate the antecedent of (18) using existential quantifiers and the static meaning of disjunction, to yield this result:

$$(19). \quad \exists x [\text{CATCH}'(m, x) \wedge \text{FISH}'(x)] \vee \exists y [\text{TRAP}'(j, y) \wedge \text{RABBIT}'(y)]$$

As before, this is satisfied in minimal situations of two different kinds: each i of the first type contains Mary and some unique fish $f_f(i)$, while each i of the second contains John and some unique rabbit $f_r(i)$. If we are to choose a function that picks an individual other than Mary or John from each of these situations, it must select $f_f(i)$ or $f_r(i)$, whichever is appropriate at i . But this is exactly what the pronoun in the consequent does refer to: the rabbit or the fish, whichever it turns out to be.

Rooth and Partee's rules, on the other hand, will not account for the anaphora if applied to (18). As always, if *it* is to receive a correct interpretation as x_1 in the consequent of (18), the variable x_1 must be introduced in the antecedent in such a way as to potentially pick out either a rabbit or a fish. The rules considered earlier would work if the two NP's *a rabbit* and *a fish* were combined. However, the

sentence does not contain the explicit disjunction the two noun phrases for which we must introduce a variable: it joins full sentences instead.

For sentence (18) to be correctly interpreted, then, some principle must apply which relates the discourse entities introduced INSIDE one disjunct to those introduced in the other. This is exactly what program disjunction does, and in fact, program disjunction will give the correct result in this case. Suppose the indefinites in the two disjuncts translate in terms of the same variable x_1 , and the union of the contexts generated by the disjuncts is the context for the consequent. The rule for *if* then tests every assignment in which x_1 is a fish that Mary catches and every assignment in which x_1 is a rabbit that John traps, to make sure that Bill cooks x_1 . x_1 is the fish or the rabbit, whichever appropriate, and the correspondence is established.

Unfortunately for program disjunction, examples analogous to (2) show that linking between disjuncts must take place when objects are referred to, as well as introduced:

(20). If Mary hasn't seen John lately, or Ann misses Bill, she calls him.

(20) violates the prediction of program disjunction that as many new variables are available after a disjunction as are introduced in each disjunct. The disjuncts introduce no variables, yet two new variables are available subsequently.

A more dramatic example of the failure of this prediction is found in the discourse below.

(21). It's interesting what happens if a man calls a woman or a woman calls a man. Sure, they're nervous about making the call, and they're surprised to get it. But even today, she waits for him to ask her out.

With only a small amount of awkwardness, (21) manages to use pronouns corresponding to all four combinations of the individuals set up in the scenario, even though each disjunct sets up only two discourse referents. Again, for (21) to be interpreted in DRT, discourse variables must be introduced at the disjunction itself. Indeed, (21) shows that it is not enough for the interpretation rule for *or* to introduce a discourse variable not corresponding to SOME pairing of variables introduced or referred to in each disjunct. Needed are new variables corresponding to EVERY such pairing. The involved procedure of establishing all these linkings represents a combination of the mechanisms of program disjunction and variable introduction we've seen earlier, plus an extension of both.

Meanwhile, ETA as it has been already outlined captures the meanings of all four pronouns in (21). Recall that the two constraints used earlier to describe salience were that a salient function always picks out an individual described in a situation and always designates corresponding individuals in corresponding situations. Their application to the context set up in (21) determines first that a salient function must return the woman or the man in each situation, and second that its value on the

two kinds of situation in the context—those where the man calls the woman, and those where the woman calls the man—must be uniform. However, no constraint is placed on how the individual chosen in one kind of situation is related to the individual chosen in the other. This is correct. Choosing the man in the first set and the woman in the second gives the interpretation of the first *they*; choosing the woman in the first and the man in the second gives that of the second *they*; always choosing the woman gives the interpretation of *she* and *her*; always choosing the man gives the interpretation of *him*. Each of these functions is salient according to the simple definition above.

Thus we find that ETA generalizes easily from existential quantification to disjunction. DRT, however, requires the implementation of an involved rule for disjunction that encodes through the introduction and pairing of variables the effect of *or* on later anaphora. It is worthwhile to examine the reasons why the rule for DRT seems so much more involved: I claim it is because DRT, to accommodate *or* must incorporate the machinery of ETA without importing the representation and directionality that makes that machinery sensible.

Recall that the initial versions of DRT and ETA outlined earlier made essentially identical predictions. This was because their operation was for the most part isomorphic. The difference is minimal between a set of discourse models and a set of situations paired with a set of functions from situations to individuals. To verify this, think of a variable, when dynamically bound by an existential quantifier of dynamic DRT, as a function that picks out the appropriate individual in the appropriate contextual alternative. Now, what we have discovered here is that the second notion, that of a function, generalizes easily when we must consider the effect of taking the union of two sets of situations. In contrast, to maintain variables, we were required to pair up variables and introduce new ones in their place. We motivated the pairing operation by examining data, but it can be motivated theoretically in terms of the conception of variable as function mentioned above. The functions available in the union of two contexts *A* and *B* ought, intuitively, to consist of any and all of those functions whose restrictions to *A* and *B* are functions available in those domains. This is how and why ETA makes the predictions it does. When variables approximate those functions, as in DRT, the equivalent move is pair up variables in each component context in all possible ways, to derive the new variables that may be used subsequently. This perspective reveals how DRT, extended to incorporate a rule to this effect, must be regarded as a recreation of the E-type theory without the semantic representation that informs it.

The DRT perspective is not only derivative. Measured by the standard of computational complexity, the strategy of DRT must also be regarded as the more costly one. Here complexity analysis is only a convenient and objective mathematical measurement to use in applying Occam's razor. Examples like (21) suggest that to find the appropriate interpretation for a pronoun after a disjunctive antecedent, one must select one out of a set of possibilities whose cardinality grows exponentially as

the number of disjuncts increases. In the ETA, salient functions can remain implicit until the occurrence of an anaphor requires one, so one can imagine consistently making a good guess about the appropriate function to use in such a way that the exponential number of possibilities was never a problem. Not so in DRT as described above: Each possibility must be explicitly represented in advance as a variable in a discourse model whose size no smart choices in interpretation can reduce. This is why ETA's directionality seems better suited to the problem.

4. Extensions and Prospects

So far, we have considered the effect of disjunction on possibilities for pronominal anaphora. But, as illustrated in this example, from Rooth and Partee (1982), the alternatives introduced by *or* can affect anaphora of other constituents as well.

(22). If Mary swims or dances, then Sue does.

On one reading, the sentence uses VP-ellipsis to claim that Sue swims or dances when Mary swims or dances, but on the other, the sentence asserts that when Mary swims and when Mary dances Sue performs the same activity Mary does. This latter reading suggests that context plays the same role in licensing VP-ellipsis as it plays in establishing the possibilities for pronominal anaphora. Investigating this hypothesis reinforces the arguments presented above in favor of ETA.

In both theories, the method of constructing this parallel is clear. In ETA, recall that the key step is the assumption that pronouns are interpreted as salient functions from situations to individuals. Analogous here is the postulate that *does* has a null-complement which is interpreted as a salient function from situations to properties. It is more difficult to specify criteria governing the salience of properties in situations than those developed for the salience of individuals. However, some straightforward principles about the identification of a property *P* offer a good characterization. First, any property *P* makes the same claim about all individuals; this reflects, for example, the fact that *John saw Mary* ascribes to John what *Ann saw Mary* ascribes to Ann. The logical behavior of *P* can therefore be reconstructed from the behavior of the fact $P(a)$ for any individual *a*. Second, the fact $P(a)$ may be realized in many ways. For instance, the property of seeing someone is shown true of John with the fact that John saw Mary, that John saw Bill, etc. This suggests that a property is fully described in a context when (but only when) a complete catalog of the ways in which it can be shown true of an individual is provided by the context. Only such fully described properties should be salient; what's more, the property chosen at a situation *i* should reflect what is happening at that particular index. In the examples presented here, this can be collapsed to the constraint that the property chosen at *i* must in fact be true of some individual at *i*.

These constraints identify the correct two properties for (22). The antecedent is translated as in (23).

(23). $\text{SWIM}'(m) \vee \text{DANCE}'(m)$

Again we have two kinds of minimal situation, and again we must pick out a salient object from each. This time we will be choosing a property from each as outlined above. Since the minimal situations for the property of swimming and the property of dancing are describable from the minimal situations of (23), any combination of those properties can be reconstructed. However, the property selected must hold of Mary in virtue of her swimming in the first kind of situation and her dancing in the second: for the property must be true of someone. This leaves salient the two functions which are actually appropriate: the function that picks out the property *swims or dances* at each index, and the function that picks out at each index the property *swims* or the property *dances*, whichever takes place there. When the complete interpretation is constructed using this second function, the meaning of the correspondence reading results:

(24). Every minimal situation in which Mary swims or dances can be extended to a larger situation either in which Sue swims or in which she dances, whichever Mary does in the minimal situation.

Extending DRT to an account of these correspondence phenomena requires a significantly more involved extension, the beginnings of which are also to be found in Rooth and Partee's 1982 paper. They propose the following analogy between the mechanics of VP ellipsis and those of pronominal anaphora. Each time a verb phrase appears, it introduces a new property variable into the discourse model corresponding to it, just as each indefinite contributes a new individual variable. *Does* receives one of these property variables as its null complement. Rooth and Partee round out the parallel with a variant of the principle they used for individual disjunction to account for property disjunction: disjunction of verb phrases is just interpreted as existential quantification over a two-element set of properties.

For example, we now translate *swims* and *dances* so that appropriate variables are introduced. This gives (25a) and (25b) respectively.

(25). a. $\lambda x[\exists P_1 P_1 = \text{'SWIM}' \Delta \sim P_1(x)]$
 b. $\lambda z[\exists P_2 P_2 = \text{'DANCE}' \Delta \sim P_2(x)].$

The general rule to build a new property out of two such dynamic property meanings looks a lot like (16). The rule starts with the property *A*, in which variable P_1 is introduced, and the property *B*, in which P_2 is, and gives (26).

(26). $\lambda z[\exists P_3(A(z) \Delta P_1 = P_3) \vee (B(z) \Delta P_2 = P_3)]$

When this expression is incorporated into the meaning of a sentence, some new variable P_4 is introduced which corresponds to this property in its entirety.

Application of this procedure leaves the variables P_3 and P_4 available. This gives the correct predictions for (22). In the translation of the antecedent, we

recreate the schema in (26) with *A* as in (25a) and *B* as in (25b). Hence, P_3 contains the property *swims* or the property *dances*, whichever takes place; P_4 contains the property *swims or dances*. Since these two variables are available in the interpretation of the consequent, this analysis reproduces the ambiguity explained earlier using ETA.

Rooth and Partee's proposal has the conceptual fault that the context maintained to determine the possibilities for VP ellipsis is unrelated to the context maintained for pronominal anaphora. This account does hypothesize parallel operations for its two kinds of variables, but the two contexts remain distinct. In contrast, ETA, whose parallel operations for different kinds of anaphora are performed on the SAME representation, is clearly more theoretically parsimonious.

Compounding the theoretical deficiency of DRT is an empirical difficulty with the proposal as it stands. Like Rooth and Partee's rule for NP disjunction, this procedure expects the disjuncts it combines to have the same type as the potential anaphors they introduce. However, disjunction has the same effect on verb phrase anaphora no matter what constituents are involved. (27) is a simple example that illustrates the ease with which this fact falls out under ETA and the problems it causes for DRT.

(27). If Mary waves at John or Bill, so does Sue.

This sentence offers two readings analogous to those present in (22). In the first, Sue waves at John or Bill when Mary waves at one of them; in the second, Sue waves at the same person that Mary does.

ETA does not distinguish between (22) and (27), because of its completely semantic representation. Substitute waving at John for swimming, waving at Bill for dancing, and the argument described for (22) applies at once to (27).

No DRT rule so far considered explains the correspondence reading in this sentence. Its antecedent appears to introduce a VP only once, when *waves at John or Bill* is incorporated into the derivation, yet two property variables appear to be available in the context that follows. Additional property variables offer one method for resolving this difficulty. For example, *John or Bill*, interpreted as in (28), would leave the variable P_1 needed to explain the correspondence ellipsis, as well as the variable x_1 needed for the interpretation of pronouns, available for reference after the antecedent.

(28). $\lambda P[\exists x_1 \exists P_1 (x_1 = j \vee x_1 = b) \Delta P_1 = P \Delta \sim P_1(x_1)]$

No principles inform the effect of predicates on context in DRT which might militate against this strategy: data was always the principal motivation for the introduction of property variables. As such, this constitutes another example of a technical solution in DRT best understood in light of the representations and predictions of ETA.

A second approach in DRT to the ambiguity of (27) appeals to the notion of scope. A property variable with value $WAVE'(x_1)$ can be introduced by quantifying in *John or Bill* for some variable x_1 in the antecedent after the VP contributes its variable to the context. Thus, the correspondence reading is obtained when wide scope is assigned to the disjunction.

The correlation with scope that this predicts is in fact observed. For example, in (29), the use of *he* in the consequent forces the interpretation of the antecedent in which *or* has wide scope over *all*.

(29). If every donkey chases John or Bill, he runs away.

However, though a full treatment of the impact of scope on this problem cannot be presented here, the analysis below suggests that it may be more perspicuous to treat this consequence of scope semantically in ETA than syntactically in DRT. DRT's explanation is couched in terms of the formal operations chosen to model the effect of words on later referents. For dynamic DRT, *every donkey* creates a test which closes off the variables introduced in its scope. If it is given wide scope in (29), it eliminates the individual variable introduced at the disjunction needed to interpret the later pronoun. In contrast, ETA appeals to the meaning of *every* in its account to show directly that when *every* is given wide scope, the meaning needed to interpret the pronoun in the consequent is impossible to obtain. When *every donkey* has wide scope, the information required to verify the truth of the antecedent consists of an identification of all of the donkeys and a demonstration for each donkey either that it chases John or that it chases Bill. Any such piece of information yields a minimal situation for the antecedent on this reading, but these pieces of information do not specify any distinctive information about Bill or John. One way to see this is through the arguments presented earlier that rule out salient functions on representations which contain too much information, which apply again here. Some minimal situation in some possible world contains, say, eight equivalent donkeys of which four chase John and four chase Bill, giving the exact same information about the two men. A function that respects the information in this situation must pick out both or neither. Hence the ungrammaticality.

Thus, verb phrase ellipsis offers a case parallel to pronominal anaphora in which a backward-looking semantic architecture like that of the E-Type analysis provides a more natural framework to describe the effect on context initiated by disjunction. The reconciliation between multiple kinds of anaphora ETA suggests makes it particularly attractive.

I close with a word about where the argumentation presented here in favor of ETA might fit in. This paper instantiates a general argument used by many researchers in advocating purely semantic or combinatorial accounts of phenomena usually explained using variables. Outside DRT, variables and rules to coindex them typically account for problems of binding, control and agreement. For each of these functions there is an alternative. Szabolcsi (1987) shows how binding

of reflexives might be achieved using syntactic and semantic operations on the functions that the ontology of standard model-theories already provide. Dowty (1985) considers the replacement of theories of control based on variable binding by alternatives which exploit the resources of axiomatized constraints on acceptable semantic models. Jacobson (1991) examines the use of bound pronouns in general, and argues that their behavior can be modeled without indexing provided that the meanings are assigned to pronouns and the way those meanings are combined proceeds appropriately. Dowty and Jacobson (1989) and Pollard and Sag (1988) both emphasize the semantic rather than syntactic contribution to agreement.

As a rule, these proposals are claimed to be superior because of their more successful generalization: to treat unusual cases they cover naturally (cases that typically include conjunction and disjunction), syntactic accounts are forced to import or recreate the apparatus of the semantic account—the very occurrence we have just found here. The arguments above to prefer the E-type analysis over DRT constitute a particularly complementary addition to this literature because of the unusual status of the variables of DRT. Unlike other variables, it is argued that the discourse markers of DRT are fundamental to semantics: so much so that the meanings of sentences are to be modeled principally as functions describing the assignment of values to these variables. Finding, specifying, and arguing for an alternative to these strange entities is therefore a key step in constructing a grammar of language free from essential variables and variable binding operations.

References

- Barwise, Jon, and John Perry. 1981. Situations and attitudes. *Journal of Philosophy* 7.11.
- Barwise, Jon, and John Perry. 1983. *Situations and attitudes*. Cambridge, Mass: Bradford Books.
- Chierchia, Gennaro. 1992. Anaphora and dynamic binding. *Linguistics and Philosophy* 15.111-183.
- Cooper, Robin. 1979. The interpretation of pronouns. *Syntax and Semantics* 10, ed. by Frank Heny and Helmut Schnelle. New York: Academic Press.
- Dowty, David. 1985. On recent analyses of the semantics of control. *Linguistics and Philosophy* 8.291-331.
- Dowty, David and Pauline Jacobson. 1989. Agreement as a semantic phenomenon. *ESCOL 88 Proceedings*, 95-108. Columbus: Ohio State University.
- Evans, Gareth. 1980. Pronouns. *Linguistic Inquiry* 11.337-362.
- Groenendijk, Jeroen and Martin Stokhof. 1990. Dynamic Montague Grammar. *Papers from the Second Symposium on Logic and Language*, ed. by L. Kalman and L. Polos. Budapest: Akademiai Kiado.
- Groenendijk, Jeroen and Martin Stokhof. 1991. Dynamic Predicate Logic. *Linguistics and Philosophy* 14.39-100.
- Heim, Irene. 1982. *The semantics of definite and indefinite noun phrases*. Ph.D.

- dissertation, University of Massachusetts, Amherst. Published 1987, New York: Garland Press.
- Heim, Irene. 1990. E-Type pronouns and donkey anaphora. *Linguistics and Philosophy* 13.137-177.
- Jacobson, Pauline. 1991. Paycheck pronouns, functional gaps, and variable binding. Paper given at 1991 ASL/LSA Conference on Logic and Linguistics.
- Kamp, Hans. 1981. A theory of truth and semantic representation. *Truth, interpretation and information* ed. by Jeroen Groenendijk et al. Dordrecht: Foris.
- Kratzer, Angelika. 1989. An investigation of the lumps of thought. *Linguistics and Philosophy* 12.607-653.
- Landman, Fred. 1986. Data semantics: an epistemic theory of partial objects. *Towards a theory of information: The status of partial objects in semantics* by Fred Landman, 1-96. (GRASS 6) Dordrecht: Foris.
- Montague, Richard. 1973. The proper treatment of quantification in ordinary English. *Approaches to Natural Language* ed. by Jaakko Hintikka, et al. Dordrecht: Reidel. Reprinted in *Formal philosophy: selected papers of Richard Montague* ed. by Richmond Thomason. New Haven: Yale University Press.
- Partee, Barbara and Mats Rooth. 1982. Generalized conjunction and type ambiguity. *Meaning, Use, and Interpretation* ed. by Rainer Bäuerle et al, 361-383. New York: de Gruyter.
- Pollard, Carl and Ivan Sag. 1988. An information-based theory of agreement. *CLS Parasession on Agreement*. Chicago Linguistic Society, Chicago.
- Rooth, Mats and Barbara Partee. 1982. Conjunction, type ambiguity, and wide scope 'or'. *Proceedings of the First West Coast Conference on Formal Linguistics* ed. by D. Flickinger et. al. Stanford: Linguistics Department, Stanford University.
- Szabolcsi, Anna. 1989. Bound variables in syntax: are there any?. *Semantics and contextual expression* ed. by Renate Bartsch et al. 295-318. Dordrecht: Foris.

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