EMMON BACH

THE ALGEBRA OF EVENTS

0. Introduction

A number of writers have commented on the close parallels between the mass-count distinction in nominal systems and the aspectual classification of verbal expressions (Allen, 1966; Taylor, 1977; Mourelatos, 1978; L. Carlson, 1981; Hoepelman and Rohrer, 1980) that has been the subject of much attention in recent years in linguistics and philosophy. To take just one class of examples for now, there is a parallel between the two sets of distinctions in their cooccurrence patterns with expressions denoting numbers or amounts, as in Examples (1a)–(4b):

(1)(a) Much mud was in evidence.
(b)(*)Much dog was in evidence.

(2)(a) John slept a lot last night.
(b)(*)John found a unicorn a lot last night.

(3)(a) Many dogs were in the yard.
(b)(*)Many muds were on the floor.

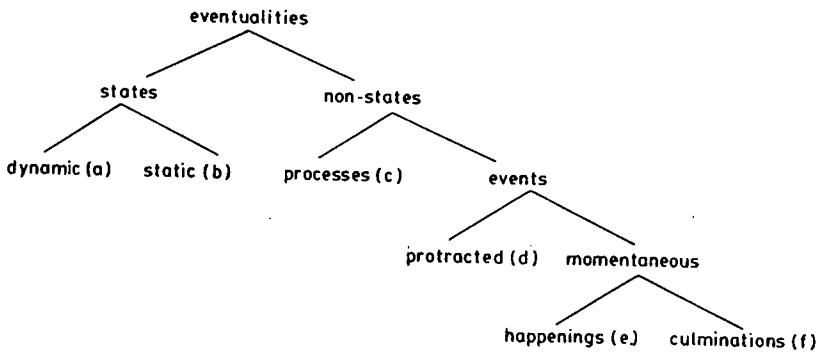
(4)(a) John fell asleep three times during the night.
(b)(*)John slept three times last night.

(By the use of "(*)" I intend to indicate two things: that we have to do a certain amount of work to impose a special interpretation on the sentence and that the interpretation is shaped by the presence of the number or quantity expression.)

The basic aim of this paper is to try to elucidate this proportion: events: processes:: things: stuff. The account draws heavily on a recent paper by Godehard Link on the count-mass-plural domain (Link, 1983) as well as on the work of a number of writers who have contributed a great deal to our understanding of "verb-classification".[1] In Section 1, I review briefly the classification and in Section 2 Link's analysis for the nominal domain. In Section 3, I set forth our proposals about events and processes and in Section 4 take up a number of problems, some with, some without, solutions.

1. Events, processes, states

Here's a scheme of the kinds of distinctions we want to deal with (based on L. Carlson, 1981, but using our terminology in part):



Typical examples are:

(a) sit, stand, lie + LOC
(b) be drunk, be in New York, own x, love x, resemble x
(c) walk, push a cart, be mean (Agentive)
(d) build x, walk to Boston
(e) recognize, notice, flash once
(f) die, reach the top

I will take it as given that it is necessary to have at least this much of a classification if we are to deal adequately with the syntax and semantics of English. A great deal of evidence for this point has been given in the last several years, for example in connection with attempts to understand the English progressive and similar constructions in other languages.[2] Most recently, Hans Kamp (1981) and E. Hinrichs (1981) have shown the necessity for these distinctions for interpreting narrative structures.

2. Mass, count, and plural in the nominal system

In the work alluded to above, G. Link (1983) argues for the adoption of a somewhat more richly structured model than those made available, for example, in Montague's work.[3] In this section, I will briefly sketch the outlines of Link's system.

The main idea in Link's semantics is to give more structure to the domain of individuals. Along with ordinary individuals like John and Mary as in standard interpretations of the predicate calculus or in

Montague's work we are to have plural individuals like those denoted by *the children* or *John and Mary* as well as quantities of "stuff" or matter that corresponds to individuals of both kinds, such as the gold in Terry's ring or the stuff that makes up the plural individual John and Mary.[4] Moreover, certain relations among these various subdomains and the elements making them up are proposed. I present the essentials in an informal way (for precise details the reader is referred to Link, 1983).

Start with a set A_i of individuals of the more familiar sort, for example, John, Mary, this table, Terry's ring. We extend this domain by means of a join operation to define a superset E as follows:

(i) $A_i \subseteq E_i$

(ii) If $\alpha, \beta \in E_i$ then the i-join (individual join: $\alpha \sqcup_i \beta$) of α and $\beta \in E$.

So the i-join of John and Mary is in E_i if each of John and Mary is. We establish a partial ordering on the members of E_i ($\leq_i$) by saying that α is "less than or equal to" (or "is an individual part (i-part) of") β just in case the i-join of α and β is just β itself. Thus the individual John is an i-part of the plural individuals John and Mary or Terry's ring and John. The individuals from which we started are atoms in the big structure that we are building.

Among the elements of A_i (and hence E_i) there is a subset which forms a special subsystem of its own. These are the portions of matter or stuff, for example, the gold of which Terry's ring is composed. This subsystem has its own join and partial ordering (m-join: $\sqcup_m$; m-part: $\leq_m$). Call this set D_i. Finally, we need to specify the relationship between the system of D_i and the rest of the domain. We do this by assuming a mapping h_i from individuals (atomic and plural) to the stuff out of which they are composed. This mapping should satisfy the requirement that the ordering $\leq_i$ among the individuals be preserved in the ordering $\leq_m$ among the quantities of matter making them up (it is a homomorphism). Moreover, $h_i(x) = x$ just in case $x \in D_i$. For example, if John is an i-part of the plural individual Terry's ring and John, then the stuff making up John had better be an m-part of the stuff making up Terry's ring and John. Note that we have two different part-whole relations. John is an i-part of the individual John and Mary, but John's arm is not an individual part of John, both are atoms. On the other hand, the stuff making up John's arm is an m-part of the stuff making up John. Note further that the same quantity of stuff can correspond to many different individuals. For example, there may be an individual falling into

the extension of the singular count noun *man*, say John, but there is also a plural individual falling under the extension of the plural noun *cells* such that the values for h_i given the two arguments are identical. The two individuals are members of the equivalence class induced by the relation of material identity. Link calls a system of this sort a "Boolean model structure with homogeneous kernel" (*boosk*).

Some consequences of Link's construction that I find interesting and apposite for the present context are these (I haven't given enough details to show that these consequences follow):

(5) Suppose Hengsta is a horse and Hengist is a horse. Then the plural individual Hengsta and Hengist is not a horse, but is in the extension of *horses* (contrast mass terms).

(6) Suppose the plural individual A and B is in the extension of *horses* and likewise C and D. Then the plural individual A, B, C, and D is also in the extension of *horses* (cf. mass terms).

(7) Even if the individual that is the quantity of gold composing Terry's ring is old, Terry's ring need not be.

(8) The two meanings of sentences like *John and Mary lifted the box* (each vs. together) can be nicely represented in Link's semantics by adding the interpretation provided for the plural individual to the interpretation provided, say, in Montague's PTQ.

3. The Algebra of Events and Processes

We now want to try out Link's ideas in the domain of eventualities, that is, to characterize the structure of the model when we extend it to the domain of events and processes, which for the moment I will consider just as new kinds of elements in the (sorted) domain. I will start by considering events to be analogous to the singular and plural individuals and bounded processes ('bits of process') analogous to the portions of matter that make up the 'material extensions' of those individuals.

Our new system will then include the following:

(1) E_e: the set of events with join operations $\sqcup_e$ and partial ordering $\leq_e$ (a complete atomic Boolean algebra);

(2) $A_e \subseteq A_e$: atomic events;

(3) $D_e \subseteq A_e$: bits of process with join $\sqcup_p$ and partial ordering $\leq_p$ (a complete join semilattice);

(4) In addition, we will need two temporal relations on $E_e \times E_e$:
$\propto$: "strictly precedes" (tr., irr., asymm.),
$^\circ$: "overlaps" (nontr., refl., symm.) (cf. Bach, 1981; Kamp, 1980);

(5) a homomorphism h_e from $\langle E_e, \cup_e, \leq_e, \propto, ^\circ \rangle$ to $\langle D_e, \cup_p, \leq_p, \propto, ^\circ \rangle$ such that
(i) $h_e(\alpha) = \alpha$ iff $\alpha \in D_e$,
(ii) $h_e(\alpha \cup_e \beta) = h_e(\alpha) \cup_p h_e(\beta)$, and
(iii) $\alpha R \beta \Rightarrow h_e(\alpha) R' h_e(\beta)$ for $R = \leq_e, \propto, ^\circ$ and $R' = \leq_p, \propto, ^\circ$, respectively.

For purposes of illustration, I will assume that tenseless clauses of English are to be interpreted as denoting sets of eventualities, i.e. members of the domain E_e (for some discussion of the general kind of model structure I assume, see Bach, forthcoming). So here are some examples of the kinds of eventualities that correspond to the above distinctions:

(9) John kiss Mary: atomic event

(10) Mary stumble and Mary twist her ankle: plural event

(11) Mary stumble: atomic event

(12) People discover the hidden cove: plural event

(13) Sally build a cabin: atomic event

(14) Sally pound in a nail: atomic event

(15) Jones poison the populace: atomic event

(16) Jones pour poison into the water main: atomic event

Our homomorphism h (henceforth I will drop subscripts on all symbols where it is clear from context which domain we are considering) will deliver up for us the bounded bits of process corresponding to instances of each of these event types. Just as in the case of the nominal domain it is exceedingly difficult to find English expressions which correspond to these 'pure processes' (cf. our remarks on "(*)" after our first examples). Some intuitions I want to capture with regard to the above examples are these:

Ad (10) and (11): a plural event of type (10) has (necessarily) a singular event of type (11) as an *i*-part, and the processes associated by h with the latter is a *p*-part of the process associated with the former.

Ad (13) and (14): an event of type (14) might very well be such that its process is a *p*-part of the process associated with an event of type (13)

Ad (15) and (16): Events of these two types might be materially (processually) equivalent while the events themselves are different. Thus, Jones might very well intentionally pour poison into the water main (in order to rid waterbeds of bedfish) and not intentionally poison the populace (cf. Davidson, 1980, *passim*).

Just as in the nominal domain (Link, 1983), I will assume that our interpretation assigns various predicates to different classes according as they fall under the sort of classification outlined above. (HOW we decide or do this will not be my concern in this paper.) So Dying names an atomic kind of event, Running doesn't, and so on. Familiar properties of these various kinds of eventualities will follow, such as indivisibility and additivity (cf. L. Carlson, 1981; Bach, 1981): no proper *p*-part of a dying is a dying; the fusion of two runnings is a running, but no two dyings are a dying. I will return below to some interesting problems connected with such facts.

4. Some Parallels and Puzzles

We have found it quite instructive to think about parallels and differences obtaining between the two domains. In a number of places questions and observations about one of the domains has led us to consider problems in the other domain in a new light.

4.1. *Packaging and Grinding*

It has frequently been observed that practically any count noun or name[5] can be used as a mass term: *There was dog splattered all over the road*; *Much missionary was eaten at the festival* (David Lewis's Universal Grinder, cf. Pelletier, 1979). Moreover, the opposite switch occurs as well: *muds* = 'kinds of mud', *ice-cream* = 'portions of ice-cream' (Universal Packager). In each case, we have a change of meaning with no overt marking in the form of the word.

In the verbal domain, we find the same sort of phenomenon. Dowty (1972) observed that practically any process verb can be used 'eventually', given the right context.

One of his examples was the process verb *look for*. One of the characteristics of process verbs is that they don't occur comfortably in the context *NP finished Ving*: *?I finished looking for a unicorn*. Yet in the context of a library with a well-defined search procedure, a sentence like *I finished looking for a book* seems perfectly ordinary.

In English, the way of switching back and forth between count and mass, event and process typically involves no change in the forms involved. The difference is rather induced by the context. In other languages, overt morphological processes or relationships are available or obligatory, for example, in the perfective-imperfective contrasts in Slavic languages. This raises important questions of principle for the analysis of English. Do we want to invoke formation rules with zero-morphology (identity operations in the syntax of words), as in Link's rule for forming the mass-term counterpart to a count noun like *apple*? Or do we want to somehow give meanings for words that are unspecified along this dimension?

It seems to me that there is an asymmetry in these relations between count and non-count meanings that runs in the same direction in the two domains. That is, if we start with a count meaning and derive the non-count meaning (as in Link's rule) there seems to be a regular and predictable meaning. The mass-term *apple* seems to mean the stuff such that there is at least one apple such that that stuff stands in the constitution-relation to the apple (but see below, Section 4.3 for some remaining problems with this account). On the other hand, going in the other direction, the connection seems much less systematic, as already noted. A beer may be a serving of beer or a kind of beer. Similarly, in the verbal domain, when we put a process expression into a count context, we must come up with some kind of corresponding event, but just what it is is relatively free, perhaps the beginning of the process in question, or some bounded portion of it. This asymmetry is predicted by our formal set-up: there is a function (homomorphism) from the count elements to the non-count ones, but it is a many-to-one mapping so that we can't in general expect a unique answer when we ask what count element this portion of non-count stuff might correspond to.

Count elements come as already bounded and discrete items. Therefore we can count them. Non-count elements don't and therefore need some additional specification in order to be used as countable expressions with plurals or numbers. Further, expressions which carve out measures or quantities of stuff,– pounds of, portions of, etc. – cannot go with pure count-items in the singular, but demand interpretation of the count-item as mass-term or process counterpart. Moreover, for plurals size and measure are relevant to determining naturalness and usefulness of the particular expressions; *two tons of horses* is odd for practical reasons in a way that *two tons of beans* or *fifty tons of horses* are not (cf. L. Carlson, 1981, on these and many other details). There are interesting puzzles about counting that we will return to below (Section 4.4).

4.2. *The Partitive Puzzle*

Dowty (1978) and others have discussed the socalled 'imperfective paradox' (I prefer to call it a puzzle). Briefly, the puzzle is this: how can we characterize the meaning of a progressive sentences like (17) on the basis of the meaning of a simple sentence like (18) when (17) can be true of a history without (18) ever being true?

(17) John was crossing the street.

(18) John crossed the street.

(See Vlach, 1981; Dowty, 1979.)

Naturally, we want to use the apparatus we have set up to provide an account of the English progressive, perhaps along the lines of Vlach (1981). Thinking about how to do this has led us to see that there is a perfectly parallel problem in the nominal domain, which we call the 'partitive puzzle'.

Consider Link's account of the following sentence:

(19) There is apple in the salad.

Link's interpretation amounts to this: there are some apples, such that some of the stuff making them up is present in the salid. Note the existential quantification over apples; the sentence could not be true of a history which never had any apples in it. This seems reasonable enough for this sentence, but consider the following:

(20) This is part of a paper on natural language metaphysics.

(21) We found part of a Roman aqueduct.

It seems as if (20) could be true even though (alas!) the paper in question never reached fulfilment, and (21) true when there no longer is an aqueduct or even if progress on the construction was interrupted forever by hordes of barbarians from the north.

Let us look more closely at Link's account. The denotation of the mass term correspondent m_p of a predicate P is given as this (p. 309):

$$[\![m_p]\!] := \{x \in D \mid x \leq \sup[h[\![P]\!]]\}.$$

(Here, *sup* stands for *supremum*.) That is, the denotation of *apple* (used as a predicative mass term) is the set of quantities of matter that are m-parts of the value of h applied to the set of apples in the world. Thus, no apples, no apple. But there could surely be a world in which it was possible to artificially manufacture apple without there being any apples, or for less farfetched examples, consider again Examples (4) and (5).

Such examples show that we need to allow for a more indirect relation between the denotation of a mass predicative mass term and the corresponding count predicate. Basically, we need to be able to say when certain stuff is of the right kind to qualify as falling under the extension of the mass term, or better we need to *assume* that we can say when this is the case. To actually give criteria is no part of linguistics (cf. Putnam, *passim*).

Further, although we have assumed that the two domains of things and stuff are separate, it seems to me to be reasonable to assume that our knowledge of what qualifies as a quantity of apple or mud or gold is based on our understanding of what is meant by the term phrases *apples*, *mud*, or *gold*, understood as names for kinds (G. Carlson, 1977) or properties (Chierchia, 1982). Both Carlson and Chierchia argue that such terms are more intensional than the properties of Montague, which are functions from world-time pairs to individuals. We may say that a property or kind determines such a function, which then may be used to get the denotations of the corresponding predicatives *apple*, *gold* and *mud*. So to say that there is apple in the salad is to say that there is some stuff in the salad of the right sort as to qualify as apple and the latter involves appealing to our knowledge of the kind of apples or the property of being an apple. It should then fall out of our theory that particular apples are made of apple and so on.

4.3. *How Old Is the Gold?*

Link provides a nice analysis of the puzzle presented by a sentence like this:

(21) The gold making up Terry's ring is old but the ring itself is new (not old).

Puzzles like this one are among the best evidence for not identifying things with their material counterparts. But there is still a problem.

The interpretation of (22) is this: The x such that x makes up Terry's ring and is gold is old but Terry's ring is not old. No contradiction, since x and Terry's ring are not the same thing, x is just the value of h with Terry's ring as argument. But now consider a sentence like (23):

(23) The snow making up this snowman is quite new but the H_2O making it up is very old (and the H and O even older!).

The interpretation of this sentence comes out like this: The x such that x

constitutes the snowman and x is snow is new but the y such that y constitutes the snowman and y is water is very old (not new). This *is* contradictory according to Link's account since x and y must be identical (since h is a function). If we follow Link's sage advice – "our guide in ontological matters has to be language itself" (Link, 1983, pp. 303f.) – then it seems to me that we have to set things up in such a way that we can refer to individuals under a description, somehow. This puzzle is closely connected to the next one.

If we follow Link's advice, then we must acknowledge that two things with contradictory properties cannot be identical. Thus the snow making up the snowman and the H_2O making it up must be different, and neither can be equated with the undifferentiated quantity of matter given by Link's homomorphism. What to do?

The first possibility is to acknowledge that our language allows us to talk about chains of composition, so to speak. The snow in the snowman is itself made up of the water in the snowman (plus air) and so on. What the example shows, then, is that we cannot use the constitution relation directly in an interpretation of a phrase like *the snow making up the snowman*. Our interpretation of such phrases must be such that it does not hold that if x makes up a and y makes up a then $x = y$. We can essentially keep all of Link's apparatus including the homomorphism and the equivalence classes generated by it but merely amend the way in which English words like *make up*, *constitute* or phrases like *the gold in the ring* are interpreted.

A second way would be to remove altogether the entities in D from the domain of individuals. I explore one way of doing this based on Cresswell's (1973) metaphysics of possible worlds and individuals in Bach, forthcoming. This would amount to saying something like this: *Stoff an sich* (just like the *Ding an sich*) can have no properties, at least as far as our language is concerned.

4.4. *How Many Things Are There in the Room?*

In both domains many writers have pointed to characteristic properties like additivity, subdivisibility, antiadditivity and antisubdivisibility which play clear roles in giving an account of entailment relations among sentences: Hengist's ear can't be a horse, mud plus mud is mud, a horse plus a horse isn't a horse, and so on. But in both domains there are clear and ordinary examples of count items that don't follow these restrictions. These are words like *thing*, *event*, *happen*, and so on. Suppose it is true that something happened, then in the normal case there are smaller

subevents that make up the big thing that happened that are also happenings. Similarly for things. In both domains we are at something of a loss to try to answer questions like these:

(24) How many things are there in the room?

(25) How many events took place in the last hour?

Gupta (1980) has stressed the importance of criteria of reidentification and individuation in the logic of common nouns. Our discussion here shows that principles of individuation are crucial for expressions and concepts in the verbal domain as well. We follow Link in *not* requiring that the subdomains D_i and D_e be atomic Boolean algebras. This is as it should be. It is not part of linguistics to decide whether all matter is atomic or all happenings are reducible to little granules of process. Indeed, if contemporary physical theories are to be believed, such ultimate questions are basically incoherent. Events and processes are disjoint, and this seems to be more an artifact of our language or conceptualizations of the world than something about the world itself, so that probably here too our strictly semantic theories should remain silent.

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Notes

[1] Besides the writers mentioned in the first paragraph, see for example, the excellent survey in Dowty (1979) and the references cited there. The classic modern works dealing with verb-classification are Kenny (1963), and Vendler (1957). To my knowledge, Verkuyl (1972) was the first extensive work which recognized the importance of these distinctions for linguistic theory.

[2] Dowty (1977), Vlach (1981), for example.

[4] It is important to notice that Link's proposals differ crucially from previous attempts to deal with plurals which constructed interpretations for plurals in purely set-theoretic ways, as for example in Bennett's (1974) classic treatment.

[4] Strictly speaking, we will have the corresponding NP denotations, that is, property sets for the individuals mentioned. I ignore this complication throughout the paper.

[5] Link does not deal with the use of names in mass contexts: *They put five pounds of Porky into the stew*.

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TENSE AND DISCOURSE LOCATION IN SITUATION SEMANTICS

0. INTRODUCTION

In Section 1 of this paper I will outline some aspects of situation semantics more or less as it has been presented in Barwise and Perry (1981) though with a few modifications in the direction of Barwise and Perry (1983) and some slight differences of presentation which are due to me. I will also add some comments of my own in this section. The remaining three sections present some explorations of my own of how some notions of situation semantics might be exploited for the treatment of tense and discourse. Barwise and Perry's introduction of space-time locations and in particular of a discourse location will be important throughout. Section 2 will discuss the analysis of the reportive or "sport's reporter" sense of the simple present tense in English and suggest that this might be a case where we can exploit the fact that the semantics uses *space*-time locations (as opposed to just time-locations, such as points or intervals of time). The main idea will be that the reportive sense of the present tense not only requires that things be happening now but also here, namely at the discourse location. We will see that this analysis makes different predictions about the strangeness or acceptability of sentences containing verbs from different Vendler classes. Section 3 will offer some suggestions of how extra-grammatical factors such as perception and rhetoric might be used to determine what the discourse location is and thereby give us a way of assimilating various problematic cases to the straightforward analysis of the simple present that we present. Finally, in Section 4, I will make some suggestions for a way in which Barwise and Perry's idea of connecting space-time locations to tensed verbs allows us to view the progression of time in discourse.

1. TOOLS

We shall take as our basic notion a kind of structure which we will call a *fact*. (This term is not actually used by Barwise and Perry (1981, 1983), though the structure exists in their theory. See Barwise et al., in preparation, for a slightly different formulation of facts than that given here.) A fact is an ordered pair of the kind given in (1).