TENSE AND TIME[1]

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I. INTRODUCTION

The semantics of tense has received a great deal of attention in the contemporary linguistics, philosophy, and logic literatures. This is probably due partly to a renewed appreciation for the fact that issues involving tense touch on certain issues of philosophical importance (viz., determinism, causality, and the nature of events, of time and of change). It may also be due

partly to neglect. Tense was noticeably omitted from the theories of meaning advanced in previous generations. In the writings of both Russell and Frege there is the suggestion that tense would be absent altogether from an ideal or scientifically adequate language. Finally, in recent years there has been a greater recognition of the important role that all of the so-called indexical expressions must play in an explanation of mental states and human behavior. Tense is no exception. Knowing that one's friend *died* is cause for mourning, knowing that he *dies* is just another confirmation of a familiar syllogism.

This article will survey some attempts to make explicit the truth conditions of English tenses, with occasional discussion of other languages. We begin in Section II by discussing the most influential early scholarship on the semantics of tense, that of Jespersen, Reichenbach, and Montague. In Section III we outline the issues that have been central to the more linguistically-oriented work since Montague's time. Finally, in Section IV we discuss recent developments in the area of tense logic, attempting to clarify their significance for the study of the truth-conditional semantics of tense in natural language.

II. EARLY WORK

1. *Jespersen.* The earliest comprehensive treatment of tense and aspect with direct influence on contemporary writings is that of Otto Jespersen. Jespersen's *A Modern English Grammar on Historical Principles* was published in seven volumes from 1909 to 1949. Jespersen's grammar includes much of what we would call semantics and (since he seems to accept some kind of

identification between meaning and use) a good deal of pragmatics as well. The aims and methods of Jespersen's semantic investigations, however, are not quite the same as ours.[2]

First, Jespersen is more interested than we are in cataloging and systematizing the various uses of particular English constructions and less interested in trying to characterize their meanings in a precise way. This leads him to discuss seriously uses we would consider too obscure or idiomatic to bother with. For example, Jespersen notes in the *Grammar* that the expressions of the form *I have got A* and *I had got A* are different than other present perfect and past perfect sentences. *I have got a body*, for example, is true even though there was no past time at which an already existent me received a body. Jespersen suggests *I have in my possession* and *I had in my possession* as readings for *I have got* and *I had got*. And this discussion is considered important enough to be included in his *Essentials of English Grammar*, a one volume summary of the *Grammar*.

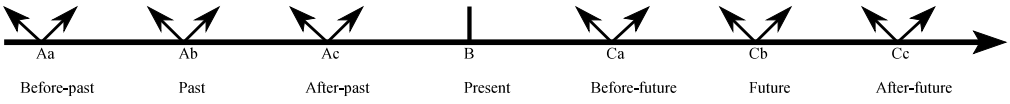
Jespersen however does *not* see his task as being merely to collect and classify rare flora. He criticizes Henry Sweet, for example, for a survey of English verb forms that includes such paradigms as *I have been being seen* and *I shall be being seen* on the grounds that they are so extremely rare that it is better to leave them out of account altogether. Nevertheless there is an *emphasis* on cataloging, and this emphasis is probably what leads Jespersen to adhere to a methodological principle that we would ignore; viz., that example sentences should be drawn from published literature wherever possible rather than manufactured by the grammarian. Contemporary linguists and philosophers of language see themselves as investigating fundamental intuitions shared by all members of a linguistic community. For this reason it is quite legitimate for them to produce a sentence and assert without evidence that it is well-formed

or ill-formed, ambiguous or univocal, meaningful or unmeaningful. This practice has obvious dangers. Jespersen's methodological scruples, however, provide no real safety. On the one hand, if one limits one's examples to a small group of masters of the language one will leave out a great deal of commonly accepted usage. On the other hand, one can't accept *anything* as a legitimate part of the language just because it has appeared in print. Jespersen himself criticizes a contemporary by saying of his examples that "these three passages are the only ones adduced from the entire English literature during nearly one thousand years."

A final respect in which Jespersen differs from the other authors discussed here is his concern with the recent history of the language. Although the *Grammar* aims to be a compendium of contemporary idiom, the history of a construction is recited whenever Jespersen feels that such a discussion might be illuminating about present usage. A good proportion of the discussion of the progressive form, for example, is devoted to Jespersen's thesis that *I am reading* is a relatively recent corruption of *I am a-reading* or *I am on reading*, a construction that survives today in expressions like *I am asleep* and *I am ashore*. This observation, Jespersen feels, has enabled him to understand the meaning of the progressive better than his contemporaries.[3] In discussing Jespersen's treatment of tense and aspect, no attempt will be made to separate what is original with Jespersen from what is borrowed from other authors. Jespersen's grammar obviously extends a long tradition. See Binnick for a recent survey.[4] Furthermore there is a long list of grammarians contemporaneous with Jespersen who independently produced analyses of tenses. See, for example, Curme, Kruisinga and Poutsma. Jespersen, however, is particularly thorough and insightful and, unlike his predecessors and contemporaries, he continues to be widely read (or at least cited) by linguists and philosophers. Jespersen's treatment of tense and

aspect in English can be summarized as follows:

Time. It is important to distinguish *time* from *tense.* Tense is the linguistic device which is used (among other things) for expressing time relations. For example, *I start tomorrow* is a present tense statement about a future time. To avoid time-tense confusion it is better to reserve the term *past* for time and to use *preterit* and *pluperfect* for the linguistic forms that are more commonly called past tense and past perfect. Time must be thought of as something that can be represented by a straight line, divided by the present moment into two parts: the past and the future. Within each of the two divisions we may refer to some point as lying either before or after the main point of which we are speaking. For each of the seven resulting divisions of time there are *retrospective* and *prospective* versions. These two notions are not really a part of time itself, but have rather to do with the perspective from which an event on the time line is viewed. The prospective present time, for example, is a variety of present that looks forward into the future. In summary, time can be pictured by the diagram below. The three divisions marked with A's are past; those marked with C's are future. The short pointed lines at each division indicate retrospective and prospective times.



Tense morphology. The English verb has only two tenses proper, the present tense and the preterit. There are also two tense phrases, the perfect (e.g., *I have written*) and the pluperfect or anteperfect (e.g., *I had written*). (Some verbs, including *can, may, must, ought, shall,* and *will,* cannot form perfects and pluperfects.) Corresponding to each of the four tenses and tense phrases there is an *expanded* (what is more commonly called today the *progressive*) form. For example, *had been writing* is the expanded pluperfect of *write.* It is customary to admit also future and future perfect tenses, as in *I will write* and *I shall have written*. But these constructions lack the fixity of the others. On the one hand, they are often used to express nontemporal ideas (e.g., volition, obstinacy) and on the other hand future time can be indicated in many other ways.

The present tense is primarily used about the present time, by which we mean an interval containing the present moment whose length varies according to circumstances. Thus the time we are talking about in *He is hungry* is shorter than in *None but the brave deserve the fair*. Tense tells us nothing about the duration of that time. The same use of present is found in expressions of intermittent occurrences (*I get up every morning at seven* and *Whenever he calls, he sits close to the fire*). Different uses of the present occur in statements of what might be found at all times

by all readers (*Milton defends the liberty of the press in his Areopagitica*) and in expressions of feeling about what is just happening or has just happened (*That's capital!*). The present can also be used to refer to past times. For example, the *dramatic* or *historical* present can alternate with the preterit: *He perceived the surprise, and immediately pulls a bottle out of his pocket, and gave me a dram of cordial*. And the present can play the same role as the perfect in subordinate clauses beginning with *after*: *What happens to the sheep after they take its kidney out?* Present tense can be used to refer to future time when the action described is considered part of a plan already fixed: *I start for Italy on Monday.* The present tense can also refer to future events when it follows *I hope, as soon as, before,* or *until.*

The perfect is actually a kind of present tense that seems to connect the present time with the past. It is both a retrospective present, which looks upon the present as a result of what happened in the past and an inclusive present, which speaks of a state that is continued from the past into the present time (or at least one that has results or consequences bearing on the present time).

The preterit differs from the perfect in that it refers to some time in the past without telling anything about its connection with the present moment. Thus *Did you finish?* refers to a past time while *Have you finished?* is a question about present status. It follows that the preterit is appropriate with words like *yesterday* and *last year* while the perfect is better with *today, until now* and *already*. *This morning* requires a perfect tense when uttered in the morning and a preterit in the afternoon. Often the correct form is determined by context. For example, in discussing a schoolmate's Milton course, *Did you read <u>Samson Agonistes</u>?* is appropriate, whereas in a more general discussion *Have you read <u>Samson Agonistes</u>?* would be better. In

comparing past conditions with present the preterit may be used (*English is not what it was*), but otherwise vague times are not expressed with the preterit but rather by means of the phrase *used to* (*I used to live at Chelsea*). The perfect often seems to imply repetition where the preterit would not. (Compare *When I have been in London*, with *When I was in London*).

The pluperfect serves primarily to denote before-past time or retrospective past, two things which cannot easily be kept apart. (An example of the latter use is *He had read the whole book before noon.*) After *after, when,* or *as soon as*, the pluperfect is interchangeable with the preterit.

The expanded tenses indicate that the action or state denoted provides a temporal frame encompassing something else described in the sentence or understood from context. For example, if we say *He was writing when I entered*, we mean that his writing (which may or may not be completed now) had begun, but was not completed, at the moment I entered. In the expanded present the shorter time framed by the expanded time is generally considered to be *very recently.* The expanded tenses also serve some other purposes. In narration simple tenses serve to carry a story forward while expanded tenses have a retarding effect. In other cases expanded tense forms may be used in place of the corresponding simple forms to indicate that a fact is already known rather than new, than an action is incomplete rather than complete or that an act is habitual rather than momentary. Finally, the expanded form is used in two clauses of a sentence to mark the simultaneity of the actions described. (In that case neither really frames the other.)

In addition to the uses already discussed, all the tenses can have somewhat different functions in passive sentences and in indirect speech. They also have uses apparently unrelated to temporal reference. For example, forms which are primarily used to indicate past time are

often used to denote unreality, impossibility, improbability or non-fulfillment, as in *If John had arrived on time, he would have won the prize*.[5]

Tense syntax. In the preceding discussion we started with the English tense forms and inquired about their meanings. Alternatively we can start with various temporal notions and ask how they can be expressed in English. If we do so, several additional facts emerge:

(i) The future time can be denoted by present tense (*He* ***leaves*** *on Monday*), expanded present tense (*I* ***am dining*** *with him on Monday*), *is sure to, will, shall, come to* or *get to.*

(ii) The after-past can be expressed by *would, should, was to, was destined to,* expanded preterit (*They* ***were going out*** *that evening* and *When he came back from the club she* ***was dressing***) or *came to (In a few years he came to control all the activity of the great firm*).

(iii) The before-future can be expressed by *shall have, will have* or present (*I shall let you know as soon as I* ***hear*** *from them* or ***Wait*** *until the rain stops*).

(iv) The after-future is expressed by the same means as the future (*If you come at seven, dinner* ***will soon*** *be ready*).

(v) Retrospective pasts and futures are not distinguished in English from before-pasts and before-futures. (But retrospective presents, as we have seen, are distinct from pasts. The former are expressed by the perfect, the latter by the preterit.)

(vi) Prospectives of the various times can be indicated by inserting expressions like *on the point of, about to* or *going to.* For example, *She is about to cry* is a prospective present.

2. *Reichenbach*. In his general outlook Reichenbach makes a sharp and deliberate break with the

tradition of grammarians like Jespersen. Jespersen saw himself as studying the English language by any means that might prove useful (including historical and comparative investigations). Reichenbach saw himself as applying the methods of contemporary logic in a new arena. Thus, while Jespersen's writings about English comprise a half dozen scholarly treatises, Reichenbach's are contained in a chapter of an introductory logic text. (His treatment of tense occupies twelve pages.) Where Jespersen catalogs dozens of uses for an English construction, Reichenbach is content to try to characterize carefully a single use and then to point out that this paradigm does not cover all the cases. While Jespersen uses, and occasionally praises, the efforts of antecedent and contemporary grammarians, Reichenbach declares that the state of traditional grammar is hopelessly muddled by its two-millennial ties to a logic that cannot account even for the simplest linguistic forms.

Despite this difference in general outlook, however, the treatment of tenses in Reichenbach is quite similar to that in Jespersen. Reichenbach's chief contribution was probably to recognize the importance of the distinction between what he calls the *point of the event* and the *point of reference* (and the relative unimportance and obscurity of Jespersen's notions of prospective and retrospective time.) In the sentence *Peter had gone,* according to Reichenbach, the point of the event is the time when Peter went. The point of reference is a time between this point and the point of speech, whose exact location must be determined by context. Thus Reichenbach's account of the past perfect is very similar to Jespersen's explanation that the past perfect indicates a 'before past' time. Reichenbach goes beyond Jespersen, however, in two ways.

First, Reichenbach is a little more explicit about his notion of reference times than is

Jespersen about the time of which we are speaking. He identifies the reference time in a series of examples and mentions several rules that might be useful in determining the reference time in other examples. Temporally specific adverbials like *yesterday, now* or *November 7, 1944,* for example, are said to refer to the reference point. Similarly, words like *when, after,* and *before* relate the reference time of a adjunct clause to that of the main clause. And if a sentence does not say anything about the relations among the reference times of its clauses, then every clause has the same point of reference.

Second, Reichenbach argues that the notion of reference time plays an important role in *all* the tenses. The present perfect, for example, is distinguished by the fact that the event point is before the point of reference and the point of reference coincides with the point of speech. (So *I have seen Sharon* has the same meaning as *Now I have seen Sharon*.) In general, each tense is determined by the relative order of the point of event (E), the point of speech (S), and the point of reference (R). If R precedes S we have a kind of past tense, if S precedes R we have a kind of future tense and if R coincides with S we have a kind of present. This explains Jespersen's feeling that the simple perfect is a variety of the present. Similarly the labels anterior, posterior and simple indicate that E precedes, succeeds or coincides with R. The account is summarized in the following table.

Structure	New Name	Traditional Name
E__R__S	Anterior past	Past perfect
E, R__S	Simple past	Simple past
R__E__S		
R__S, E	Posterior past	----------
R__S__E		
E__S, R	Anterior present	Present perfect
S, R, E	Simple present	Present
S, R__E	Posterior present	Simple future
S__E__R		
S, E__R	Anterior future	Future perfect
E__S__R		
S__R, E	Simple future	Simple future
S__R__E	Posterior future	----------

Each of the tenses on this table also has an expanded form which indicates, according to Reichenbach, that the event covers a certain stretch of time.

Notice that the list of possible tenses is beginning to resemble more closely the list of tenses realized in English. According to Jespersen there are seven divisions of time, each with simple, retrospective and prospective versions. This makes twenty-one possible tenses. According to Reichenbach's scheme there should be thirteen possible tenses, corresponding to the thirteen orderings of E, S, and R. Looking more closely at Reichenbach, however, we see

that the *tense* of a sentence is determined only be the relative order of S and R, and the *aspect* by the relative order of R and E. Since there are three possible orderings of S and R, and independently three possible orderings of R and E, there are really only nine possible complex tenses (seven of which are actually realized in English).[6]

Finally, Reichenbach acknowledges that actual language does not always keep to the scheme set forth. The expanded forms, for example, sometimes indicate repetition rather than duration: *Women are wearing larger hats this year.* And the present perfect is used to indicate that the event has a certain duration which reaches up to the point of speech: *I have lived here for ten years.*

3. *Montague*. Despite Reichenbach's rhetoric, it is probably Montague, rather than Reichenbach, who should be credited with showing that modern logic can be fruitfully applied to the study of natural language. Montague actually had very little to say about tense, but his writings on language have been very influential among those who do have something to say. Two general principles underlie Montague's approach.

(1a) Compositionality. The meaning of an expression is determined by the meaning of its parts.

(1b) Truth conditions. The meaning of a declarative sentence is something that determines the conditions under which that sentence is true.

Neither of these principles, of course, is original with Montague, but it is Montague who shows how these principles can be used to motivate an explicit account of the semantics of particular English expressions.

Initially, logic served only as a kind of paradigm for how this can be done. One starts with precisely delineated sets of *basic expressions* of various categories. *Syntactic rules* show how complex expressions can be generated from the basic ones. A class of permissible *models* is specified, each of which assigns interpretations to the basic expressions. *Rules of interpretation* show how the interpretation of complex expressions can be calculated from the interpretations of the expressions from which they are built.

The language of classical predicate logic, for example, contains predicates, individual variables, quantifiers, sentential connectives, and perhaps function symbols. Generalizations of this logic are obtained by adding additional expressions of these categories (as is done in modal and tense logic) or by adding additional categories (as is done in higher order logics). It was Montague's contention that if one generalized enough, one could eventually get English itself. Moreover, clues to the *direction* this generalization should take are provided by modal and tense logic. Here sentences are interpreted by functions from possible worlds (or times or *indices* representing aspects of context). English, for Montague, is merely an exceedingly baroque intensional logic. To make this hypothesis plausible, Montague constructed, in [1970], [1970a] and [1973], three 'fragments' of English of increasing complexity. In his final fragment, commonly referred to as PTQ, Montague finds it convenient to show how the expressions can be translated into an already-interpreted intensional logic rather than to specify an interpretation directly. The goal is now to find a translation procedure by which every expression of English can be translated into a (comparatively simple) intensional logic.

We will not attempt here to present a general summary of PTQ. (Readable introductions to Montague's ideas can be found in Montague [1974] and Dowty *et al*.) We will, however, try

to describe its treatment of tense. To do so requires a little notation.

Montague's intensional logic contains tense operators **W** and **H** meaning roughly *it will be the case that* and *it was the case that*. It also contains an operator ^ that makes it possible to refer to the intension of an expression. For example, if a is an expression referring to the object **a**, then ^a denotes the function that assigns **a** to every pair of a possible world ***w*** and a time ***t***.

Among the expressions of English are *terms* and *intransitive verb phrases*. An intransitive verb phrase *B* is translated by an expression **B'** which denotes a function from entities to truth values. (That is, **B'** is of type <*e,t*>.) A term *A* is translated by an expression **A'** which denotes a function whose domain is intensions of functions from entities to truth values and whose range is truth values. (That is, **A'** is of type <<*s,*<*e, t*>>,*t*>.) Tense and negation in PTQ are treated together. There are six ways in which a term may be combined with an intransitive verb phrase to form a sentence. These generate sentences in the present, future, present perfect, negated present, negated future and negated present perfect forms. The rules of translation corresponding to these six constructions are quite simple. If *B* is an intransitive verb phrase with translation **B'** and *A* is a term with translation **A'** then the translations of the six kinds of sentences that can be formed by combining *A* and *B* are just **A'**(^**B'**), **WA'**(^**B'**), **HA'**(^**B'**), ¬**A'**(^**B'**), ¬**WA'**(^**B'**) and ¬**HA'**(^**B'**).

A simple example will illustrate. Suppose that *A* is *Mary* and that *B* is *sleeps*. The future tense sentence *Mary will sleep* is assigned translation **WMary(^sleeps)**. **Mary** denotes that function which assigns 'true' to a property P in world ***w*** at time ***t*** if and only if Mary has P in ***w*** at ***t***. The expression **^sleeps** denotes the property of sleeping, i.e. the function *f* from indices to functions from individuals to truth values such that *f*(<***w,t***>)(*a*) = 'true' if and only if *a* is an

individual who is asleep in world ***w*** at time ***t*** (for any world ***w***, time ***t***, and individual *a*). Thus **Mary(^sleeps)** will be true at <***w***,***t***> if and only if Mary is asleep in ***w*** at ***t***. Finally, the sentence **WMary(^sleeps)** is true in a world ***w*** at a time ***t*** if and only if **Mary(^sleeps)** is true at some <***w***,***t'***>, where ***t'*** is a later time than ***t***.

This treatment is obviously crude and incomplete. It was probably intended merely as an illustration of now tense *might* be handled within Montague's framework. Nevertheless, it contains the interesting observation that the past tense operator found in the usual tense logics corresponds more closely to the present perfect tense than it does to the past. In saying *John has kissed Mary* we seem to be saying that there was *some* time in the past when *John kisses Mary* was true. In saying *John kissed Mary*, we seem to be saying that *John kisses Mary* was true at *the* time we happen to be talking about. This distinction between *definite* and *indefinite* past times was pointed out by Jespersen, but Jespersen does not seem to have thought it relevant to the distinction between present perfect and past.

Reichenbach's use of both event time and reference time, leading to a three-dimensional logic, may suggest that it will not be easy to add the past tenses to a PTQ-like framework. However, one of the differences between Reichenbach's reference time and event time seems to be that the former is often fixed by an adverbial clause or by contextual information whereas the latter is less often so fixed So it is approximately correct to say that the reference time is determinate whereas the event time is indeterminate. This may help explain the frequent remarks that only two times are needed to specify the truth conditions of all the tenses. In one sense these remarks are wrong. S, R and E all play essential roles in Reichenbach's explanation of the tenses. But only S and R ever need to be extracted from the context. All that we need to know about E

is its position relative to R and this information is contained in the sentence itself. Thus a tense logic following Reichenbach's analysis could be two-dimensional, rather than three-dimensional. If ***s*** and ***r*** are the points of speech and reference, for example, we would have $(s,r) \models$ PASTPERFECT(A) if and only if $r < s$ and, for some $t < r$, $t \models$A. (See section IV below.)

Still, it seems clear that the past tenses cannot be added to PTQ without adding something like Reichenbach's point of reference to the models. Moreover, adherence the idea that there should be a separate way of combining tenses and intransitive verb phrases for every negated and unnegated tense would be cumbersome and would miss important generalizations. Montague's most important legacies to the study of tense were probably his identification of meaning with truth conditions, and his high standards of rigor and precision. It is striking that Jespersen, Reichenbach and Montague say successively less about tense with correspondingly greater precision. A great deal of the contemporary work on the subject can be seen as an attempt to recapture the insights of Jespersen without sacrificing Montague's precision.

III. CONTEMPORARY VIEWS

In Sections A and B below we outline what seem to us to be two key issues underlying contemporary research into the semantics of tense. The first has to do with whether tense should be analyzed as an operator or as something that refers to particular time or times; this is essentially a type-theoretic issue. The second pertains to a pair of truth-conditional questions which apparently are often confused with the type-theoretic ones: (i) *does the semantics of tense involve quantification over times, and if so how does this quantification arise?*, and (ii) *to what extent is the set of times relevant to a particular tensed sentence restricted or made determinate*

by linguistic or contextual factors? Section C then outlines how contemporary analytical frameworks have answered these questions. Finally, in Section D we examine in more detail some of the proposals which have been made within these frameworks about the interpretation of particular tenses and aspects.

A. *Types for Tense*

The analyses of Reichenbach and Montague have served as inspiration for two groups of theorists. Montague's approach is the one more familiar from traditional tense logics developed by Prior and others. The simplest non-syncategorematic treatment of tense which could be seen as essentially that of Montague would make tenses propositional operators, expressions of type $\langle\langle s, t\rangle, t\rangle$ or $\langle\langle s, t\rangle, \langle s, t\rangle\rangle$, that is, either as functions from propositions to truth values or as functions from propositions to propositions (where propositions are taken to be sets of world-time pairs). For example, the present perfect might have the following interpretation:

(2) **PrP** denotes that function *f* from propositions to propositions such that, for any proposition p, *f*(p) = the proposition q, where for any world *w* and time *t*, q(<*w*,*t*>)= 'true' iff for some time *t′* preceding *t*, p(<*w*,*t′*>) = 'true'.

Two alternative, but closely related, views would take tense to have the type of a verb phrase modifier $\langle\langle s, \langle e, t\rangle\rangle, \langle e, t\rangle\rangle$ (Bäuerle, Kuhn) or as a 'mode of combination' in $\langle$type(TERM)$, \langle\langle s,\langle e,t\rangle\rangle,t\rangle\rangle$ or $\langle\langle s, \langle e,t\rangle\rangle,\langle$type(TERM)$,t\rangle\rangle$. We will refer to these approaches as representative of the *operator* view of tense.

The alternative approach is more directly inspired by Reichenbach's views. It takes the semantics of tense to involve reference to particular times. This approach is most thoroughly

worked out within the framework of Discourse Representation Theory (DRT; Kamp, Kamp and Rohrer, Hinrichs, Partee), but for clarity we will consider the type-theoretic commitments of the neo-Reichenbachian point of view through the use of a Predicate Calculus-like notation. We may take a tense morpheme to introduce a free variable to which a time can be assigned. Depending on which tense morpheme is involved, the permissible values of the variable should be constrained to fall within an appropriate interval. For example, the sentence *Mary slept* might have a logical form as in (3).

(3) **PAST**(t) & AT(t, **sleeps**(**Mary**))

With respect to an assignment g of values to variables, (3) should be true if and only if $g(t)$ is a time that precedes the utterance time and one at which Mary sleeps. On this approach the semantics of tense is analogous to that of pronouns, a contention defended most persuasively by Partee.

A more obviously Reichenbachian version of this kind of analysis would introduce more free variables than simply t in (3). For example, the pluperfect *Mary had slept* might be rendered as in (4):

(4) **PAST**(r) & $t<r$ & AT(t, **sleeps**(**Mary**))

This general point of view could be spelled out in a wide variety of ways. For example, times might be taken as arguments of predicates, or events and states might replace times. We refer to this family of views as *referential*.

B. *Quantification and Determinacy*

4. *Quantification.* In general, the operator theory has taken tense to involve quantification over times. Quantification is not an inherent part of the approach, however; one might propose a semantics for the past tense of the following sort:

(5) $(r,u) \vDash \mathbf{PAST}(S)$ iff $r<u$ and $(r,r) \vDash S$.

Such an analysis of a non-quantificational past tense might be seen as especially attractive if there are other tense forms that are essentially quantificational. An operator-based semantics would be a natural way to introduce this quantification, and in the interest of consistency one might then prefer to treat all tenses as operators--just as PTQ argues that all NP's are quantifiers because some are inherently quantificational. On the other hand, if no tenses are actually quantificational it might be preferable to utilize a less powerful overall framework.

The issue of quantification for the referential theory of tense is not entirely clear either. If there are sentences whose truth conditions must be described in terms of quantification over times, the referential theory cannot attribute such quantification to the tense morpheme. But this does not mean that such facts are necessarily incompatible with the referential view. Quantification over times may arise through a variety of other, more general, means. Within DRT and related frameworks, several possibilities have been discussed. The first is that some other element in the sentence may bind the temporal variable introduced by tense. An adverb of quantification like *always, usually,* or *never* would be the classical candidate for this role.

(6) When it rained, it always poured.

(7) $\forall t$ [(**PAST**(t) & AT(t, **it-rains**)) → (**PAST**(t) & AT(t, **it-pours**))]

DRT follows Lewis [1975] in proposing that *always* is an unselective universal quantifier which may bind any variables present in the sentence. Hinrichs and Partee point out that in some cases it may turn out that a variable introduced by tense is thus bound; their proposals amount to assigning (6) a semantic analysis along the lines of (7).

The other way in which quantification over times may arise in referential analyses of tense is through some form of default process. The most straightforward view along these lines proposes that, in the absence of explicit quantificational adverbs, the free variable present in a translation like (3), repeated here, is subject to a special rule that turns it into a quantified formula like (8):

(3) **PAST**(t) & AT(t, **sleeps**(**Mary**))

(8) $\exists t$ [**PAST**(t) & AT(t, **sleeps**(**Mary**))]

This operation is referred to as *existential closure* by Heim; something similar is proposed by Parsons (1995). It is also possible to get the effect of existential quantification over times through the way in which the truth of a formula is defined. This approach is taken by DRT as well as Heim (1982, Ch. III). For example, a formula like (3) would be true with respect to a model M if and only if there is *some* function g from free variables in (3) to appropriate referents in M such that $g(t)$ precedes the utterance time in M and $g(t)$ is a time at which Mary is asleep in M.

To summarize, we may say that one motivation for the operator theory of tense comes from the view that some tense morphemes are inherently quantificational. The referential

analysis, in contrast, argues that all examples of temporal quantification are to be attributed not to tense but to independently needed processes.

5. *Determinacy*. An issue which is often not clearly distinguished from questions of the type and quantificational status of tense is that of the determinacy or definiteness of tense. Classical operator-based tense logics treat tense as all but completely indeterminate: a past tense sentence is true if and only if the untensed version is true at *any* past time. On the other hand, Reichenbach's referential theory seemingly considers tense to be completely determinate: a sentence is true or false with respect to the *particular* utterance time, reference time, and event time appropriate for it. However, we have already seen that a referential theory might allow that a time variable can be bound by some quantificational element, thus rendering the temporal reference less determinate. Likewise, we have seen that an operator-based theory may be compatible with completely determinate temporal reference, as in (5). In this section, we would like to point out how varying degrees of determinacy can be captured within the two systems.

If temporal reference is fully indeterminate, it is natural to adopt an operator view: PAST(B) is true at t if and only if B is true at some $t'<t$. A referential theory must propose that in every case the time variable introduced by tense is bound by some quantificational operator (or effectively quantified over by default, perhaps merely through the effects of the truth definition). In such cases it seems inappropriate to view the temporal parameters as 'referring' to times.

If temporal reference is fully determinate, the referential theory need make no appeal to any ancillary quantification devices. The operator theory may use a semantics along the lines of (3). Alternatively, tense might be seen as an ordinary quantificational operator whose domain of

quantification has been severely restricted. We might implement this idea as follows: Suppose that each tense morpheme bears an index, as *Mary* $PAST_3$ *sleeps.* Sentences are interpreted with respect to a function R from indices to intervals. (The precedence order is extended from instants to intervals and instants in the appropriate way, with < indicating 'completely precedes'.) The formula in (9a) would then have the truth conditions of (9b).

(9a) $\mathbf{PAST_3}$ (**sleeps**(**Mary**))

(9b) (R,*u*) ⊨ $\mathbf{PAST_3}$(**sleeps**(**Mary**)) iff for some time *t*=R(3), *t*<*u*

and (R,*t*) ⊨ **sleeps**(**Mary**).

Plainly, R in (9b) is providing something very similar to that of the reference time in Reichenbach's system. This can be seen by the fact that the identity of R(3) should be fixed by temporal adverbs like *yesterday*, as in *Yesterday, Mary slept.*

Finally, we should examine what could be said about instances of tense which are partially determinate. The immediately preceding discussion makes it clear what the status of such examples would be within an operator account; they would simply exemplify restricted quantification (Bennett-Partee, Kuhn). Instead of the analysis in (9), we would propose that R is a function from indices to sets of intervals, and give the truth conditions as in (10).

(10) (R,*u*) ⊨ $\mathbf{PAST_3}$(**sleeps**(**Mary**)) iff for some time *t*∈R(3), *t*<*u*

and (R,*t*) ⊨ **sleeps**(**Mary**).

According to (10), (9a) is true if and only if Mary was asleep at some past time which is within the set of contextually relevant past times. Temporal quantification would thus be seen as no different from ordinary nominal quantification, as when *Everyone came to the party* is taken to assert that everyone *relevant* came to the party.

Referential analyses of tense would have to propose that partial determinacy arises when temporal variables are bound by restricted quantifiers. Let us consider a Reichenbach-style account of *Mary slept* along the lines of (11).

(11) $\exists t$ [**PAST**(r) & $t \in r$ & AT(t, **sleeps**(**Mary**))]

The remaining free variable in (11), namely r, will have to get its value (the reference *set*) from the assignment function g. The formula in (11) has $t \in r$ where Reichenbach would have $t=r$; the latter would result in completely determinate semantics for tense, while (11) results in restricted quantification. The sentence is true if and only if Mary slept during some past interval contained in $g(r)$.

The only difference between (10) and (11) is whether the quantificational restriction is represented in the translation language as a variable, the r in (11), or as a special index on the operator, the subscripted *3* in (10). In each case, one parameter of interpretation must be some function which identifies the set of relevant times for the quantification. In (11), it is the assignment function, g, while in (10) it is R. Clearly at this point the differences between the two theories are minor.

To summarize, we need to distinguish three closely related ways in which theories of tense may differ: (i) They may take tense to be an operator or to introduce elements which refer to times; (ii) they may involve quantification over times through a considerable variety of means--the inherent semantics of tense itself, the presence of some other quantificational element within the sentence, or a default rule; and (iii) they may postulate that the temporal reference of sentences is fully determinate, fully indeterminate, or only partially determinate.

C. *Major Contemporary Frameworks*

Most contemporary formal work on the semantics of tense takes place within two frameworks: Interval Semantics and Discourse Representation Theory. In this section we describe the basic commitments of each of these, noting in particular how they settle the issues discussed in A and B above. We will then consider in a similar vein a couple of other influential viewpoints, those of Situation Semantics (Cooper) and the work of Enç [1986, 1987].

By *Interval Semantics* we refer to the framework which has developed out of the Intensional Logic of Montague's PTQ. There are a number of implementations of a central set of ideas; for the most part these differ in fairly minor ways, such as whether quantification over times is to be accomplished via operators or explicit quantifiers. The key aspects of Interval Semantics are: (i) the temporal part of the model consists of set I of *intervals,* the set of open and closed intervals of the reals, with precedence and temporal overlap relations defined straightforwardly; (ii) the interpretation of sentences depends on an *evaluation interval* or *event time*, an *utterance time*, and perhaps a *reference interval* or set of reference intervals; (iii) interpretation proceeds by translating natural language sentences into some appropriate higher-order logic, typically an intensional -calculus; and (iv) tenses are translated by quantificational operators or formulas involving first-order quantification to the same effect. The motivation for (i) comes initially from the semantics for the progressive, a point which we will see in D below. We have already examined the motivation for (ii), though in what follows we will see more clearly what issues arise in trying to understand the relationship between the reference interval and the evaluation

interval. Points (iii) and (iv) are implementation details with which we will not much concern ourselves.

From the preceding, it can be seen what claims Interval Semantics makes concerning the issues in A and B. Tense has the type of an operator. It is uniformly quantificational, but shows variable determinacy, depending on the nature of the reference interval or intervals.

Discourse Representation Theory is one of a number of theories of *dynamic interpretation* to be put forth since the early 1980's; others include File Change Semantics (Heim) and Dynamic Montague Grammar (Groenendijk and Stokhof). What the dynamic theories share is a concern with the interpretation of multi-sentence texts, concentrating on establishing means by which information can be passed from one sentence to another. The original problems for which these theories were designed had to do with nominal anaphora, in particular the relationships between antecedents and pronouns in independent sentences like (12) and donkey sentences like (13).

(12) A man walked in. He sat down.

(13) When a man walks in, he always sits down.

Of the dynamic theories, by far the most work on tense has taken place within DRT. It will be important over time to determine whether the strengths and weaknesses of DRT analyses of tense carry over to the other dynamic approaches.

As noted above, work on tense within DRT has attempted to analogize the treatment of tense to that of nominal anaphora. This has resulted in an analytical framework with the following general features: (i) the temporal part of the model consists of a set of *eventualities* (events, processes, states, etc.), and possibly of a set of intervals as well; (ii) the semantic

representation of a discourse (or sub-part thereof) contains explicit variables referring to reference times, events, and the utterance time; (iii) interpretation proceeds by building up a *Discourse Representation Structure* (DRS), a partial model consisting of a set of objects (*discourse markers*) and a set of conditions specifying properties of and relations among them; the discourse is true with respect to a model M if and only if the partial model (DRS) can be embedded in the full model M; (iv) tenses are translated as conditions on discourse markers representing events and/or times. For example, consider the discourse in (14).

(14) Pedro entered the kitchen. He took off his coat..

We might end up with discourse markers representing Pedro (x), the kitchen (y), the coat (z), the event of entering the kitchen (e_1), the event of taking off the coat (e_2), the utterance time (u), the reference time for the first sentence (r_1) and the reference time for the second sentence (r_2). The DRS would contain at least the following conditions: **Pedro=*x*, kitchen(*y*), coat(*z*), entering(e_1, *x*, *y*)**, **taking-off(e_2, *x*, *z*)**, $r_1 < u$, $r_2 < u$, $r_1 < r_2$, $e_1 \circ r_1$, and $e_2 \circ r_2$ (where $\circ$ represents temporal overlap). The algorithms for introducing conditions may be rather complex, and typically are sensitive to the aspectual class of the eventualities represented (that is, whether they are events, processes, states, etc.).

DRT holds a referential theory of tense, treating it via discourse markers plus appropriate conditions. It therefore maintains that tense is not inherently quantificational, and that any quantificational force which is observed must come from either an independent operator, as with (6), or default rule. Given the definition of truth mentioned above, tense will be given a default existential quantificational force--the DRS for (14) will be true if there is *some* mapping from discourse markers to entities in the model satisfying the conditions. The DRT analysis of tense

also implies that temporal reference is highly determinate, since the events described by a discourse typically must overlap temporally with a contextually determined reference time.

Closely related to the DRT view of tense are a pair of *indexical* theories of tense. The first is developed by Cooper within the framework of *Situation Semantics* (Barwise and Perry 1983). Situation Semantics constructs objects known as *situations* or *states of affairs* set-theoretically out of properties, relations, and individuals (including space-time locations). Let us say that the situation of John loving Mary is represented as <*l*, <<**love**, **John**, **Mary**>, 1>>, with *l* being a spatiotemporal location and 1 representing 'truth'. A set of states of affairs is referred to as a *history*, and it is the function of a sentence to describe a history. A simple example is given in (15).

(15) *John loved Mary* describes a history *h* with respect to a spatiotemporal location *l* iff <*l*, <<**love**, **John**, **Mary**>, 1>> ∈ h.

Unless some theory is given to explain how the location *l* is arrived at, a semantics like (15) will of course not enlighten us much as to the nature of tense. Cooper proposes that the location is provided by a *connections function*; for our purposes a connections function can be identified with a function from words to individuals. When the word is a verb, a connections function *c* will assign it a spatiotemporal location. Thus,

(16) *John loved Mary* describes a history *h* with respect to a connections function *c* iff <*c*(*loved*), <<**love**, **John**, **Mary**>, 1>> ∈ *h*.

Cooper's theory is properly described as an 'indexical' approach to tense, since a tensed verb directly picks out the location which the sentence is taken to describe.[7]

Enç's analysis of tense is somewhat similar to Cooper's. She proposes that tense morphemes refer to intervals. For example, the past tense morpheme *-ed* might refer, at an utterance time u, to the set of moments preceding u. For Enç, a verb is a semi-indexical expression, denoting a contextually relevant subrelation of the relation which it is normally taken to express—e.g., any occurrence of *kiss* will denote a subset of {<x, y> : x kisses y (at some time)}. Tense serves as one way of determining which subrelation is denoted. The referent of a verb's tense morpheme serves to constrain the denotation of the verb, so that, for instance, the verb *kissed* must denote a set of pairs of individuals where the first kissed the second during the past, i.e. during the interval denoted by the tense.

(17) *kissed* denotes a (contextually relevant) subset of {<x, y> : for some t∈**-ed**, x kissed y at t}.

In (17), **-ed** is the set of times denoted by *-ed*, i.e. that set of times preceding the utterance time.

Both Enç's theory and the Situation Semantics approach outlined above seem to make the same commitments on the issues raised in Sections A and B as DRT. Both consider tense to be non-quantificational and highly determinate. They are clearly referential theories of tense, taking its function to be to pick out a particular time with respect to which the eventualities described by the sentence are temporally located.

D. *The Compositional Semantics of Individual Tenses and Aspects*

Now that we have gone through a general outline of several frameworks which have been used to semantically analyze tense in natural language, we turn to seeing what specific claims have been

made about the major tenses (present, past, and future) and aspects (progressive and perfect) in English.

6. *Tense.*

Present Tense. In many contemporary accounts the semantic analysis of the present underlies that of all the other tenses.[8] But despite this allegedly fundamental role, the only use of the present that seems to have been treated formally is the 'reportive' use, in which the sentence describes an event that is occurring or a state that obtains at the moment of utterance.[9] The preoccupation with reportive sentences is unfortunate for two reasons. First, the reportive uses are often the less natural ones--consider the sentence *Jill walks to work* (though many languages do not share this feature with English). Second, if the present tense is taken as fundamental, the omission of a reading in the present tense can be transferred to the other tenses. (*John walked to work* can mean that John habitually walked to work.) The neglect is understandable, however, in view of the variety of uses the present can have and the difficulty of analyzing them. One encounters immediately, for example, the issue discussed below.

Statives and non-statives. There is discussion in the philosophical literature beginning with Aristotle about the kinds of verb phrases there are and the kinds of things verb phrases can describe. Details of the classification and terminology vary widely. One reads about events, processes, accomplishments, achievements, states, activities and performances. The labels are sometimes applied to verb phrases, sometimes to sentences and sometimes to eventualities. There seems to be general agreement, however, that some kind of classification of this kind will

be needed in a full account of the semantics of tense. In connection with the present tense there is a distinction between verb phrases for which the reportive sense is easy (e.g., *John knows Mary, The cat is on the mat, Sally is writing a book*) and those for which the reportive sense is difficult (e.g., *John swims in the channel*, *Mary writes a book*). This division almost coincides with a division between verb phrases that have a progressive form and those that do not. (Exceptions - noted by Bennett and Partee - include *John lives in Rome* and *John resides in Rome*, both of which have easy reportive uses but common progressive forms.) It also corresponds closely to a division of sentences according to their behavior in the presence of *when* clauses. The sentence *John went to bed when the cat came in* indicates that John went to bed after the cat came in, while *John went to bed when the cat was on the mat* suggests that the cat remained on the mat for some time after John went to bed. In general, the sentences for which appended *when* clauses can be paraphrased using *just after* correspond to those with difficult reportive uses and common progressive forms. The sentences for which appended *when* clauses can be paraphrased using *still at the time* correspond to those with easy reportive uses and no common progressive forms. (Possible exceptions are 'inceptive readings' in *I knew her when I saw her* and *I hated him when he told the joke*; see the discussion in Section 9 below.)

The correspondence among these three tests suggests that they reflect some fundamental ways in which language users divide the world. The usual suggestion is that sentences in the first class (easy reportive readings, no progressives and *when = still at the time*) describe *states*. States are distinguished by the fact that they seem to have no temporal parts. The way Emmon Bach puts it is that it is possible to imagine various states obtaining even in a world with only one time, whereas it is impossible to imagine events or processes in such a world. (Other

properties that have been regarded as characteristic of states are described in Section IV.B below.) Sentences that describe states are *statives*; those that do not are *non-statives*.

There is some disagreement about whether sentences in the progressive are statives. The fact that Harry is building a house, for example, can go on at discontinuous intervals and the fact that Mary is swimming in the Channel is composed of a sequence of motions, none of which is itself swimming, lead Gabbay and Moravcsik to the conclusion that present progressives do not denote states. But according to the linguistic tests discussed above progressives clearly do belong with the state sentences. For this reason, Vlach, Bach, and Bennett all take the other side. The exact importance of this question depends on what status one assigns to the property of being a stative sentence. If it means that the sentence implies that a certain kind of eventuality known as a state obtains, then it seems that language users assume or pretend that there is some state that obtains steadily while Mary makes the swimming motions and another while Harry is involved in those house-building activities. On the other hand, if 'stative' is merely a label for a sentence with certain temporal properties, for example passing the tests mentioned above, then the challenge is just to assign a semantics to the progressive which gives progressive sentences the same properties as primitive statives; this alternative does not commit us to the actual existence of states (cf. Dowty's work). Thus, the implications of deciding whether to treat progressives as statives depends on one's overall analytical framework, in particular on the basic eventuality/time ontology one assumes.

A recent analysis of the present tense which relates to these issues has been put forth by Cooper. As mentioned above, Cooper works within the Situation Semantics framework, and is thereby committed to an analysis of tense as an element which describes a spatiotemporal region.

A region of this kind is somewhat more like an eventuality, e.g. a state, than a mere interval of time; however, it does not entail a full-blown eventuality theory in that it doesn't (necessarily) propose primitive classes of states, events, processes, etc. Indeed, Cooper proposes to define states, activities, and accomplishments in terms very similar to those usual in interval semantics. For instance, stative and process sentences share the property of describing some temporally included sublocation of any spatiotemporal location which they describe (*temporal ill-foundedness*); this is a feature similar to the *subinterval property*, which arises in purely temporal analyses of the progressive (see III.D.7 below).

Cooper argues that this kind of framework allows an explanation for the differing effects of using the simple present with stative, activity, and accomplishment sentences. The basic proposal about the present tense is that it describes a present spatiotemporal location--i.e. the location of discourse. Stative sentences have both temporal ill-foundedness and the property of *independence of space*, which states that, if they describe a location *l*, they also describe the location *l*+ which is *l* expanded to include all of space. This means that if, for example, John loves Mary anywhere for a length of time including the utterance time, *John loves Mary* will describe all of space for the utterance time. This, according to Cooper, allows the easy use of the present tense here. It seems, though, that to get the result we need at least one more premise: either a stative must describe any spatial sublocation of any location it describes (so that it will precisely describe the utterance location) or we must count the location of utterance for a stative to include all of space.

Activity sentences do not have independence of space. This means that, if they are to be true in the present tense, the utterance location will have to correspond spatially to the event's

location. This accounts for the immediacy of sentences like *Mary walks away*. On the other hand, they do have temporal ill-foundedness, which means that the sentence can be said even while the event is still going on. Finally, accomplishment sentence lack the two above properties but have *temporal well-foundedness,* a property requiring them not to describe of any temporal subpart of any location they describe. This means that the discourse location of a present tense accomplishment sentence will have to correspond exactly to the location of the event being described. Hence such sentences have the sense of narrating something in the vicinity just as it happens (*He shoots the ball!*)

Cooper goes on to discuss how locations other than the one where a sentence is actually uttered may become honorary utterance locations. This happens, for example, in the historical present or when someone narrates events they see on TV (following Ejerhed). Cooper seems correct in his claim that the variety of ways in which this occurs should not be a topic for formal semantic analysis; rather it seems to be understandable only in pragmatic or more general discourse analytic terms.

Past Tense. Every account of the past tense except those of Dowty and Parsons accommodates in some way the notion that past tense sentences are more definite than the usual tense logic operators. Even Dowty and Parsons, while claiming to treat the more fundamental use of the past tense, acknowledge the strength of the arguments that the past can refer to a definite time. Both cite Partee's example:

> When uttered, for instance, half way down the turnpike such a sentence [as *I didn't turn off the stove*] clearly does not mean that there exists some time in the past at which I did

not turn off the stove or that there exists no time in the past at which I turned off the stove.

There are, however, some sentences in which the past does seem completely indefinite. We can say, for example, *Columbus discovered America* or *Oswald killed Kennedy* without implying or presupposing anything about the date those events occurred beyond the fact that it was in the past. It would be desirable to have an account of the past that could accommodate both the definite and indefinite examples. One solution, as discussed in Section B, is that we interpret the past as a quantifier over a set of possible reference times.[10] *I left the oven on* is true now only if the oven was left on at one of the past times I might be referring to. The context serves to limit the set of possible reference times. In the absence of contextual clues to the contrary the set comprises *all* the past times and the past is completely indefinite. In any case, the suggestion that the context determines a set of possible reference times seems more realistic than the suggestion that it determines a unique such time.

There is still something a little suspicious, however, about the notion that context determines a reference interval or a range of reference times for past tense sentences to refer to. One would normally take the 'context of utterance' to include information like the time and place the utterance is produced, the identity of the speaker and his audience, and perhaps certain other facts that the speaker and his audience have become aware of before the time of the utterance. But in this case it is clear that *Baltimore won the Pennant* and *Columbus discovered America* uttered in *identical* contexts would have *different* reference times.

A way out of the dilemma might be to allow the sentence itself to help identify the

relevant components of a rich utterance context. Klein [1994] emphasizes the connection between the topic or background part of a sentence and its reference time (for him *topic time*). A full explanation of the mechanism will require taking into account the presupposition-focus structure of a sentence--that is, what new information is being communicated by the sentence. For example, when a teacher tells her class *Columbus discovered America,* the sentence would most naturally be pronounced with focal intonation on *Columbus*:

(18) COLUMBUS discovered America.

(19) ??Columbus discovered AMERICA.

??Columbus DISCOVERED America.

The teacher is presupposing that someone discovered America, and communicating the fact that the discovery was made by Columbus. Similarly, when the teacher says *Bobby discovered the solution to problem number seven*, teacher and students probably know that Bobby was trying to solve problem number seven. The new information is that he succeeded. In those cases it is plausible to suppose that possible reference times would be the times at which the sentence's presupposition is true - the time of America's discovery and the times after which Bobby was believed to have started working on the problem. (As support for the latter claim consider the following scenario. Teacher assigns the problems at the beginning of class period. At the end she announces *Bobby discovered the solution to problem seven.* Susy objects *No he didn't. He had already done it at home.*)

A variety of theories have been proposed in recent years to explain how the intonational and structural properties of a sentence serve to help identify the presuppositions and 'new information' in a sentence.[11] We will not go into the details of these here, but in general we can

view a declarative sentence as having two functions. First, it identifies the relevant part of our mutual knowledge. Second, it supplies a new piece of information to be added to that part. It is the first function that helps delimit possible reference times. Previous discourse and non-linguistic information, of course, also play a role. When I say *Baltimore won the Pennant* it matters whether we have just been talking about the highlights of 1963 or silently watching this week's Monday Night Baseball.

Frequency. Bäuerle and von Stechow point out that interpreting the past tense as a quantifier ranging over possible reference times (or over parts of the reference time) makes it difficult to explain the semantics of frequency adverbs. Consider, for example, the sentence *Angelika sneezed exactly three times*, uttered with reference to the interval from two o'clock to three o'clock yesterday morning. We might take the sentence to mean that there are exactly three intervals between two and three with reference to which *Angelika sneezed* is true. But if *Angelika sneezed* means that she sneezed at least once within the time interval referred to, then whenever there is one such interval there will be an infinite number of them. So *Angelika sneezed exactly three times* could never be true. Alternatively we might take the sentence to mean that there was at least one time interval within which Angelika sneezed-three-times. But the intervals when Angelika sneezed three times will contain subintervals in which she sneezed twice. So in this case *Angelika sneezed exactly three times* would imply *Angelika sneezed exactly twice.*

This problem leads Bäuerle and von Stechow to insist that the past tense itself indicates simply that the eventuality described occupies that part of the reference time that lies in the past.

On this interpretation, it does make sense to say that *Angelika sneezed three times* means that there were three times with reference to which *Angelika sneezed* is true. Tichý, using a different framework, arrives at a similar analysis. Unfortunately, this position also has the consequence that the simple sentence *Angelika sneezed,* taken literally, would mean that Angelika's sneeze lasted for the full hour between two and three. Bäuerle-von Stechow and Tichý both suggest that past tense sentences without explicit frequency operators often contain an *implicit* 'at least once' adverb. In a full treatment the conditions under which the past gets the added implicit adverb would have to be spelled out, so it is not clear how much we gain by this move. The alternative would seem to be to insist that the 'at least once' qualification is a normal part of the meaning of the tense which is dropped in the presence of frequency adverbs. This seems little better.

Vlach handles the frequency problem by allowing sentences to be true either 'in' or 'at' a time interval. *Angelika sneezed exactly three times* is true *at* the reference interval if it contains exactly three subintervals *at* which Angelika sneezes. On the other hand *Angelika sneezed* would normally be taken to assert that Angelika sneezed *in* the reference interval, i.e., that there is at least one time in the interval at which she sneezed. Again, a complete treatment would seem to require a way of deciding, for a given context and a given sentence, whether the sentence should be evaluated in or at the reference time.

We might argue that *all* the readings allowed by Vlach (or Bäuerle-von Stechow) are always present, but that language users tend to ignore the implausible ones - like those that talk about sneezes lasting two hours. But the idea that ordinary past tense sentences are riddled with ambiguities is not appealing.

The DRT analysis, on which frequency adverbs are examples of adverbs of

quantification, can provide a somewhat more attractive version of the Bäuerle-von Stechow analysis. According to this view, *three times* binds the free time (or eventuality) variable present in the translation, as *always* did in (6)-(7) above. The situation is more straightforward when an additional temporal expression is present:

(20) On Tuesday, the bell rang three times.

(21) **three-times**$_t$(**past**(t) & **Tuesday**(t))(**rang**(**the-bell**, t))

Here *Tuesday* helps to identify the set of times *three-times* quantifies over. **Tuesday**(t) indicates that t is a subinterval of Tuesday. A representation of this kind would indicate that there were three assignments of times during Tuesday to t at which the bell rang, where we say that the bell rang at t iff t is precisely the full interval of bell-ringing. The issue is more difficult when there is no restrictive argument for the adverb, as with *Angelika sneezed three times*. One possibility is that it ranges over all past times. More likely, context would again provide a set of reference times to quantify over. In still other cases, as argued by Klein [1994], it ranges over times which are identified by the 'background' or presuppositions of the sentence. Thus, *Columbus sailed to AMERICA four times* means that, of the times when Columbus sailed somewhere, four were ones at which he sailed to America.

In terms of a DRT analysis, when there is no adverbial, as with *Angelika sneezed*, the temporal variable would be bound by whatever default process normally takes care of free variables ('existential closure' or another, as discussed above). This parallels the suggestion in terms of Bäuerle-von Stechow's analysis, that 'at least once' is a component of meaning which is 'dropped' in the presence of an overt adverbial. Thus, in the DRT account there wouldn't need to be a special stipulation for this.

There is still a problem with adverbials of duration, such as in *On Tuesday, the bell rang for five minutes*. This should be true, according to the above, if for some subinterval *t* of Tuesday, *t* is precisely the full time of the bell's ringing and *t* lasts five minutes. Whether the sentence would be true if the bell in fact rang for ten minutes depends on whether *for five minutes* means 'for at least five' or 'for exactly five'. If the former, the sentence would be true but inappropriate (in most circumstances), since it would generate an implicature that the bell didn't ring for more than five minutes. If the latter, it would be false. It seems better to treat the example via implicature, since it is not as bad as *The bell rang for exactly five minutes* in the same situation, and the implication seems defeasible (*The bell rang for five minutes, if not more.*)

Future Tense. The architects of fragments of English with tense seem to have comparatively little to say about the future. Vlach omits it from his very comprehensive fragment, suggesting he may share Jespersen's view that the future is not a genuine tense. Otherwise the consensus seems to be that the future is a kind of mirror image of the past with the exception, noted by Bennett and Partee, that the times to which the future can refer include the present. (Compare *He will now begin to eat* with *He now began to eat.*)

There appears to be some disagreement over whether the future is definite or indefinite. Tichý adopts the position that it is ambiguous between the two readings. This claim is difficult to evaluate. The sentence *Baltimore will win* can mean *Baltimore will win next week* or *Baltimore will win eventually.* But this difference can be attributed to a difference in the set of possible reference times as easily as to an ambiguity in the word *will.* It is of course preferable on methodological grounds to adopt a uniform treatment if possible.

7. *Aspect.*

The Progressive. Those who wrote about the truth conditions of English tenses in the 1960's assumed that sentences were to be evaluated at instants of time. Montague [1968] and Dana Scott each suggested a treatment of the present progressive according to which *Mary is swimming in the Channel* is true at an instant *t* if *Mary swims in the Channel* is true at every instant in an open interval that includes *t*. This account has the unfortunate consequence of making the present progressive form of a sentence imply its (indefinite) past. For a large class of sentences this consequence is desirable. If John is swimming in the Channel he did, at some very recent time, swim in the Channel. On the other hand there are many sentences for which this property does not hold. *John is drawing a circle* does not imply that John drew a circle. *Mary is climbing the Zugspitze* does not imply that Mary climbed the Zugspitze.

In Bennett-Partee, Vlach [1980] and Kuhn [1979] this difficulty avoided by allowing some present tense sentences to be evaluated at extended intervals of time as well as instants. *John is drawing a circle* means that the present instant is in the interior of an interval at which *John draws a circle* is true. The present instant can clearly be in such an interval even though *John drew a circle* is false at that instant. Sentences like *John swims in the Channel,* on the other hand, are said to have what Bennett and Partee label the *subinterval* property: their truth at an interval entails their truth at all subintervals of that interval. This stipulation guarantees that *Mary is swimming in the Channel* does imply *Mary swam in the Channel*.

Instantaneous events and gappy processes. Objections have been made to the Bennett-Partee analysis having to do with its application to two special classes of sentences. The first class

comprises sentences that cannot plausibly be said to be true at extended intervals, but that do have progressive forms. Vlach, following Gilbert Ryle, calls these achievement sentences. We will follow Gabbay-Moravcsik and Bach in calling them instantaneous event sentences. They include *Baltimore wins, Columbus reaches North America, Columbus leaves Portugal* and *Mary starts to sweat.* It seems clear that instantaneous event sentences fail all the tests for statives. But if they are really true only instantaneously then the interval analysis would predict that they would never form true progressives.

The second class contains just the sentences whose present progressive implies their indefinite past. These are the *process* sentences. The Bennett-Partee analysis (and its modalized variation discussed below) have the consequence that process sentences can't have 'gappy' progressives. If *I sat in the front row of the Jupiter theater* was true at the interval from two o'clock to four o'clock last Saturday afternoon, then *I was sitting in the front row of the Jupiter theater* was true at all instants between those times including, perhaps, some instants at which I was really buying popcorn. This according to Vlach, Bennett, and Gabbay-Moravcsik, is a conclusion that must be avoided.[12]

Vlach's solution to the problems of instantaneous events and gappy processes is to give up the idea that a uniform treatment of the progressive is possible. For every non-stative sentence *A,* according to Vlach, we understand a notion Vlach calls the *process of A* or, simply proc(*A*). The present progressive form of *A* simply says that our world is now in the state of proc(*A)*'s going on.

The nature of proc(*A*), however, depends on the kind of sentence *A* is. If *A* is a process sentence then proc(*A*) is 'the process that goes on when *A* is true.' For the other non-stative

sentences, proc(*A*) is a process that 'leads to' the truth of *A*, i.e., a process whose 'continuation...would eventually cause *A* to become true.' In fact, Vlach argues, to really make this idea precise we must divide the non-process, non-stative sentences into at least four subclasses.

The first subclass contains what we might (following Bach) call extended event sentences. Paradigm examples are *John builds a house* and *Mary swims across the Channel*. If an extended event sequence is true at an interval *I* then proc(*A*) starts at the beginning of *I* and ends at the end of *I*. For the second subclass (*John realizes his mistake, Mary hits on an idea*) proc is not defined at all. For the third class (*Mary finishes building the house, Columbus reaches North America*) the progressive indicates that the corresponding process is in its final stages. For the fourth class (*Max dies, The plane takes off*) proc must be a process that culminates in a certain state.

Vlach's account is intended only as a rough sketch. As Vlach himself acknowledges, there remain questions of clarification concerning the boundaries of the classes of sentences and the formulation of the truth conditions. Furthermore, Vlach's account introduces a new theoretical term. If the account is to be really enlightening we would like to be sure that we have an understanding of proc that is independent of, but consistent with, the truth conditions of the progressive. Even if all the questions of clarification were resolved, Vlach's theory might not be regarded as particularly attractive because it abandons the idea of a uniform account of the progressive. Not even the sources of irregularity are regular. The peculiarity of the truth conditions for the progressive form of a sentence *A* are explained sometimes by the peculiarity of *A*'s truth conditions, sometimes by the way proc operates on *A* and sometimes by what the

progressive says about proc(*A*). In this sense, Vlach's account is *pessimistic*. Other attempts have been made to give a more uniform account of the progressive. These *optimistic* theories may be divided into two groups depending on whether they propose that the progressive has a modal semantics.

Non-Modal Accounts. The analysis of Bennett-Partee discussed above was the first optimistic account presented developed in the formal semantic tradition. Since that time, two other influential non-modal proposals have been put forth. One is by Michael Bennett (Bennett[1981]) and one by Terence Parsons (Parsons[1985], [1990]). The accounts of Vlach, Bennett and Parsons (and presumably anyone else) must distinguish between statives and non-statives because of the differences in their ability to form progressives. Non-statives must be further divided between processes and events if the inference from present progressive to past is to be selectively blocked. But in the treatments of Bennett and Parsons, as opposed to that of Vlach, all the differences among these three kinds of sentences are reflected in the untensed sentences themselves. Tenses and aspects apply uniformly.

Bennett's proposal is extremely simple.[13] The truth conditions for the present perfect form of *A* (and presumably all the other forms not involving progressives) require that *A* be true at a *closed* interval with the appropriate location. The truth conditions for the progressive of *A* require that *A* be true in an open interval with the appropriate location. Untensed process sentences have two special properties. First, if a process sentence is true at an interval, it is true at all closed subintervals of that interval. Second, if a process sentence is true at every instant in an interval (open or closed) then it is true at that interval. Neither of these conditions need hold

for event sentences. Thus, if *John is building a house* is true, there must be an open interval at which *John builds a house* is true. But if there is no *closed* interval of that kind, then *John has built a house* will be false. On the other hand, *Susan is swimming* does imply *Susan has (at some time) swum* because the existence of an open interval at which *Susan swims* is true guarantees the existence of the appropriate closed intervals.

If this proposal has the merit of simplicity, it has the drawback of seeming very *ad hoc* - 'a logician's trick' as Bennett puts it. Bennett's explanatory remarks are helpful. Events have a beginning and an end. They therefore occupy closed intervals. Processes, on the other hand, need not. But a process is composed, at least in part, of a sequence of parts. If Willy walks then there are many subintervals such that the eventualities described by *Willy walks* are also going on at these intervals. Events, however, need not be decomposable in this way.

The account offered by Parsons turns out to be similar to Bennett's. Parson's exposition seems more natural, however, because the metaphysical underpinnings discussed above are exposed. Parsons starts with the assumption that there are three kinds of eventualities: *states, processes,* and *events*. Eventualities usually have *agents* and sometimes *objects*. An agent may or may not be *in* a state at a time. Processes may or may not be *going on* at a time. Events may or may not be *in development* at a time. In general, if *e* is an eventuality, we say that *e holds* at time *t* if the agent of *e* is in *e* at *t* or *e* is in development or going on at *t*. In addition, events can have the property of *culminating* at a time. The set of times at which an event holds is assumed to be an open interval and the time, if any, at which it culminates is assumed to be the least upper bound of the times at which it holds.

The structure of language mirrors this metaphysical picture. There are three kinds of

untensed sentences: statives, process sentences and event sentences. Tensed sentences describe properties of eventualities. Stative and process sentences say that an eventuality *holds* at a time. Event sentences say that an eventuality *culminates* at a time. So, for example, *John sleeps* can be represented as (22) and *Jill bought a cat* as (23):

(22) $\exists e \exists t[\mathbf{pres}(t) \wedge \mathbf{sleeping}(e) \wedge \mathbf{holds}(e,t) \wedge \mathbf{agent}(e,\mathbf{john})]$

(23) $\exists e \exists t \exists x[\mathbf{past}(t) \wedge \mathbf{buying}(e) \wedge \mathbf{culm}(e,t) \wedge \mathbf{agent}(e,\mathbf{jill}) \wedge \mathbf{cat}(x) \wedge \mathbf{obj}(e,x)]$

The treatment of progressives is remarkably simple. Putting a sentence into the progressive has no effect whatsoever, other than changing the sentence from a non-stative into a stative. This means that, for process sentences, the present and progressive are equivalent. *John swims* is true if and only if *John is swimming* is true. Similarly, *John swam* is true if and only if *John was swimming* is true. For event sentences, the change in classification does affect truth conditions. *John swam across the Channel* is true if the event described *culminated* at some past time. *John was swimming across the Channel*, on the other hand, is true if the state of John's swimming across the Channel *held* at a past time. But this happens if and only if the event described by *John swims across Channel* was *in development* at that time. So it can happen that *John was swimming across the Channel* is true even though John never got to the other side.

Landman (1992) points out a significant problem for Parsons theory. Because it is a purely extensional approach, it predicts that *John was building a house* is true if and only if there is a house *x* and a past event *e* such that *e* is an event of John building *x* and *e* holds. This seems acceptable. But Landman brings up examples like *God was creating a unicorn (when he changed his mind).* This should be true iff there is a unicorn *x* and a past event *e* such that *e* is an event of God creating *x* and *e* holds. But it may be that the process of creating a unicorn involves

some mental planning or magic words but doesn't cause anything to appear until the last moment, when all of a sudden there is a fully formed unicorn. Thus no unicorn need ever exist for the sentence to be true. Landman's problem arises because of Parsons' assumption that eventualities are described primarily by the verb alone, as a swimming, drawing, etc., and by thematic relations connecting them to individuals, as **agent**(*e*,**jill**) or **obj**(*e,x*). There is no provision for more complex descriptions denoting a property like 'house-building'. The question is how intrinsic this feature is to Parsons' analysis of tense and aspect. One could adjust his semantics of verbs to make them multi-place intensional relations, so that *John builds a house* could be analyzed as:

(24) $\exists e \exists t$[**past**(t) $\wedge$ **building**(e,**john**, **a house**) $\wedge$ **culm**(e,t)]

But then we must worry about how the truth conditions of **building**(e,**john**, **a house**) are determined on a compositional basis and how one knows what it is for an eventuality of this type to hold or culminate. However, while the challenge is real, it is not completely clear that it is impossible to avoid Landman's conclusion that the progressive cannot be treated in extensional terms.

It seems likely that, with the proper understanding of theoretical terms, Parsons, Vlach, and Bennett could be seen as saying very similar things about the progressive. Parsons' exposition seems simpler than Vlach's, however, and more natural than Bennett's. These advantages may have been won partly by reversing the usual order of analysis from ordinary to progressive forms. Vlach's account proceeds from A to proc(A) to the state of proc(A)'s holding. In Bennett's, the truth conditions for the progressive of A are explained in terms of those for A. If one compares the corresponding progressive and non-progressive forms on Parson's account,

however, one sees that in the progressive of an event sentence, something is *subtracted* from the corresponding non-progressive form. The relations between the progressive and non-progressive forms seem better accommodated by viewing events as processes plus culminations rather than by viewing processes as eventualities 'leading to' events.

On the other hand the economy of Parsons' account is achieved partly by ignoring some of the problems that exercise Vlach. The complexity of Vlach's theory increases considerably in the face of examples like *Max is dying*. To accommodate this kind of case Parsons has two options. He can say that they are ordinary event sentences that are in development for a time and then culminate, or he can say that they belong to a new category - achievement - of sentences that culminate but never hold. The first alternative doesn't take account of the fact that such eventualities can occur at an instant (compare *Max was dying and then died at 5:01* with *Jane was swimming across the Channel and then swam across the Channel at 5:01*). The second requires us to say that the progressive of these sentences, if it can be formed at all, involves a 'change in meaning' (cf. Parsons [1990] p. 24, 36). But the progressive *can* be formed and spelling out the details of the meaning changes involved will certainly spoil some of Parsons' elegance.

Unfinished progressives and Modal Accounts. According to the Bennett-Partee account of progressives, *John was building a house* does not imply that John built a house. It does, however, imply that John will eventually have built a house. Yet it seems perfectly reasonable to say:

(25) John was building a house when he died.

One attempt to modify the account to handle this difficulty is given by Dowty [1979]. Dowty's proposal is that we make the progressive a *modal* notion.[14] The progressive form of a sentence *A* is true at a time *t* in world *w* just in case *A* is true at an interval containing *t* in all worlds *w'* such that *w'* and *w* are exactly alike up to *t* and the course of events after *t* develops in the way most compatible with past events. The *w'*-worlds mentioned are referred to as 'inertia worlds'. (25) means that *John builds a house* is eventually true in all the worlds that are inertia worlds relative to ours at the interval just before John's death.

If an account like this is to be useful, of course, we must have some understanding of the notion of inertia world independent of its role in making progressive sentences true. The idea of a development maximally compatible with past events may not be adequate here. John's death and consequent inability to finish his house may have been natural, even inevitable, at the time he was building it. In Kuhn [1979] the suggestion is that it is the expectations of the language users that are at issue. But this seems equally suspect. It is quite possible that because of a bad calculation/we all mistakenly expect a falling meteor to reach earth. We would not want to say in this case that the meteor *is* falling to earth.

Landman attempts to identify in more precise terms the alternate possible worlds which must be considered in a modal semantics of the progressive. We may label his the *counterfactual analysis*, since it attempts to formalize the following intuition. Suppose we are in a situation in which John fell off the roof and died, and so didn't complete the house, though he would have finished it if he hadn't died. Then (25) is true *because* he would have finished if he hadn't died. Working this idea out requires a bit more complexity, however. Suppose not only that John fell off the roof and died, but also that if he hadn't fallen, he would have gotten ill and not finished

the house anyway. The sentence is still true, however, and this is because he would have finished the house if he hadn't fallen and died and hadn't gotten ill. We can imagine still more convoluted scenarios, where other dangers lurk for John. In the end, Landman proposes that (25) is true iff *John builds a house* would be true if nothing were to interrupt some activity that John was engaged in.

Landman formalizes his theory in terms of the notion of the *continuation branch* of an event e in a world w. He assumes an ontology wherein events have *stages* (cf. Carlson 1977); the notion of 'stage of an eventuality' is not defined in a completely clear way. Within a single world, all of the temporally limited subeventualities of *e* are stages of *e*. An eventuality *e'* may also be a stage of an eventuality *e* in another world. It seems that this can occur when *e'* is duplicated in the world of *e* by an eventuality which is a stage of *e*. The continuation branch of e in w, C(e, w), is a set of event-world pairs; C(e,w) contains all of the pairs <a,w> where a is a stage of e in w. If e is a stage of a larger event in some other possible world, we say that it *stops* in w (otherwise it simply ends in w). If e stops in w at time t, the continuation branch moves to the world w_1 most similar to w in which e does not stop at t. Suppose that e_1 is the event in w_1 of which e is a stage; then all pairs $<a,w_1>$, where a is a stage of e_1 in w_1, are also in C(e,w). If e_1 stops in w_1, the continuation branch moves to the world most similar to w_1 in which e_1 does not stop, etc. Eventually, the continuation branch may contain a pair $<e_n,w_n>$ where a house gets built in e_n. Then the continuation branch ends. We may consider the continuation branch to be the maximal extension of e. *John was building a house* is true in w iff there is some event in w whose continuation branch contains an event of John building a house.

Landman brings up one significant problem for his theory. Suppose Mary picks up her

sword and begins to attack the whole Roman army. She kills a few soldiers and then is cut down. Consider (26):

(26) Mary was wiping out the Roman army.

According to the semantics described above, (26) ought to be true. Whichever soldier actually killed Mary might not have, and so the continuation branch should move to a world in which he didn't. There some soldier kills Mary but might not have, so . . . . Through a series of counterfactual shifts, the continuation branch of Mary's attack will eventually reach a world in which she wipes out the whole army. Landman assumes that (26) ought not be true in the situation envisioned. The problem, he suggests, is that the worlds in which Mary kills a large proportion of the Roman army, while possible, are outlandishly unreasonable. He therefore declares that only 'reasonable worlds' may enter the continuation branch.

Landman's analysis of the progressive is the most empirically successful optimistic theory. Its major weaknesses are its reliance on two undefined terms: *stage* and *reasonable*. The former takes part in the definition of when an event stops, and so moves the continuation branch to another world. How do we know that the event in question that John was engaged in didn't end when he died? Lots of eventualities did end there; we wouldn't want to have *John was living to be 65* to be true simply because he would probably have lived that long if it weren't for the accident. We know that the construction event didn't end because we know it was supposed to be a house-building. Thus, Landman's theory requires a primitive understanding of when an event is complete, ending in a given world, and when it is not complete and so may continue on in another world. In this way, it seems to recast in an intensional theory Parsons' distinction between holding and culminating. The need for a primitive concept of reasonableness

of worlds is perhaps less troubling, since it could perhaps be assimilated to possible worlds analyses of epistemic modality; still, it must count as a theoretical liability.

Finally, we note that Landman's theory gives the progressive a kind of interpretation quite different from any other modal or temporal operator. In particular, since it is nothing like the semantics of the perfect, the other aspect we have considered, one wonders why the two should be considered members of a common category. (The same might be said for Dowty's theory, though his at least resembles the semantics for modalities.)

The Perfect. Nearly every contemporary writer has abandoned Montague's position that the present perfect is a completely indefinite past. The current view (e.g. McCord, Richards, Mittwoch) seems to be that the time to which it refers (or the range of times to which it might refer) must be an *Extended Now*, an interval of time that begins in the past and includes the moment of utterance. The event described must fall somewhere within this interval. This is plausible. When we say *Pete has bought a pair of shoes* we normally do not mean just that a purchase was made at some time in the past. Rather we understand that the purchase was made recently. The view also is strongly supported by the observation that the present perfect can always take temporal modifiers that pick out intervals overlapping the present and never take those that pick out intervals entirely preceding the present: *Mary has bought a dress since Saturday,* but not **Mary has bought a dress last week.* These facts can be explained if the adverbials are constrained to have scope over the perfect, so that they would have to describe an extended now.

There is debate, however, about whether the extended now theory should incorporate two

or even three readings for the perfect. The uncontroversial analysis, that suggested above, locates an event somewhere within the extended now. This has been called the *existential use.* Others have argued that there is a separate *universal* or *continuative use.* Consider the following, based on some examples of Mittwoch:

(27) Sam has lived in Boston since 1980.

This sentence is compatible with Sam's still living in Boston, or with his having come, stayed for a while, and then left. Both situations are compatible with the following analysis: the extended now begins in 1980, and somewhere within this interval Sam lives in Boston. However, supporters of the universal use (e.g. McCawley, Mittwoch, Michaelis) argue that the there is a separate reading which requires that Sam's residence in Boston continue at the speech time: (27) is true iff Sam lives in Boston throughout the whole extended now which begins in 1980.

Michaelis argues that the perfect has a third reading, the *resultative use.* A resultative present perfect implies that there is a currently existing result state of the event alluded to in the sentence. For example, *John has eaten poison* could be used to explain the fact that John is sick. Others (McCawley, Klein [1994]) argue that such cases should be considered examples of the existential use, with the feeling that the result is especially important being a pragmatic effect. At the least one may doubt analyses in terms of result state on the grounds that precisely which result is to be focused on is never adequately defined. Any event will bring about some new state, if only the state of the event having occurred, and most will bring about many. So it is not clear how this use would differ in its truth conditions from the existential one.

Stump argues against the Extended Now theory on the basis of the occurrence of perfects in nonfinite contexts like the following (his Chapter IV, (11); cf. McCord, Klein, Richards who

note similar data):

(28) Having been on the train yesterday, John knows exactly why it derailed.

Stump provides an analysis of the perfect which simply requires that no part of the event described be located after the evaluation time. In a present perfect sentence, this means that the event can be past or present, but not future. Stump then explains the ungrammaticality of **Mary has bought a dress last week* in pragmatic terms. This sentence, according to Stump, is truth conditionally equivalent to *John bought a dress last week.* Since the latter is simpler and less marked in linguistic terms, the use of the perfect should implicate that the simple past is inappropriate. But since the two are synonymous, it cannot be inappropriate. Therefore, the present perfect with a definite past adverbial has an implicature which can never be true. This is why it cannot be used (cf. Klein [1992] for a similar explanation).

Klein [1992, 1994] develops a somewhat different analysis of perfect aspect from those based on interval semantics. He concentrates on the relevance of the aspectual classification of sentences for understanding different 'uses' of the perfect. He distinguishes *0-state, 1-state,* and *2-state* clauses: A 0-state clause describes an unchanging state of affairs (*The Nile is in Africa*); a 1-state sentence describes a state which obtains at some interval while not obtaining at adjoining intervals (*Peter was asleep*); and a 2-state clause denotes a change from one lexically determined state to another (*John opened the window*). Here, the first state (the window's being closed) is called the *source state*, and the second (the window's being open) the *target state*. He calls the maximal intervals which precede and follow the interval at which a state holds its *pretime* and *posttime* respectively.

Given this framework, Klein claims that all uses of the perfect can be analyzed as the

reference time falling into the posttime of the most salient situation described by the clause. Since the states described by 0-state sentences have no posttime, the perfect is impossible (**The Nile has been in Africa*). With 1-state sentences, the reference time will simply follow the state in question, so that *Peter has been asleep* will simply indicate that Peter has at some point slept ('experiential perfect'). With 2-state sentences, Klein stipulates that the salient state is the source state, so that *John has opened the window* literally only indicates that the reference time (which in this case corresponds to the utterance time) follows a state of the window being closed which itself precedes a state of the window being open. It may happen that the reference time falls into the target state, in which case the window must still be open ('perfect of result'); alternatively, the reference time may follow the target state as well - i.e. it may be a time after which the window has closed again - giving rise to another kind of experiential perfect.

One type of case which is difficult for Klein is what he describes as the 'perfect of persistent situation', as in *We've lived here for ten years*. This is the type of sentence which motived the universal/continuative semantics within the Extended Now theory. In Klein's terms, here it seems that the reference time, the present, falls into the state described by a 1-state sentence, and not its posttime. Klein's solution is to suggest that the sentence describes a state which is a substate of the whole living-here state, one which comprises just the first ten years of our residency, a 'living-here-for-ten-years' state. The example indicates that we are in the posttime of this state, a fact which does not rule out that we're now into our eleventh year of living here. On the other hand, such an explanation does not seem applicable to other examples, such as *We've lived here since 1966.*

Existence presuppositions. Jespersen's observation that the present perfect seems to presuppose the present existence of the subject in cases where the past tense does not has been repeated and 'explained' many times. We are now faced with the embarrassment of a puzzle with too many solutions. The contemporary discussion begins with Chomsky, who argues that *Princeton has been visited by Einstein* is all right, but *Einstein has visited Princeton* is odd. James McCawley points out that the alleged oddity of the latter sentence actually depends on context and intonation. Where the existence presupposition does occur, McCawley attributes it to the fact that the present perfect is generally used when the present moment is included in an interval during which events of the kind being described *can* be true. Thus, *Have you seen the Monet exhibition?* is inappropriate if the addressee is known to be unable to see it. (*Did you* is appropriate in this case.) *Frege has contributed a lot to my thinking* is appropriate to use even though Frege is dead because Frege *can* now contribute to my thinking. *My mother has changed my diapers many times* is appropriate for a talking two year old, but not for a normal thirty year old. *Einstein has visited Princeton* is odd because Einsteinean visits are no longer possible. *Princeton has been visited by Einstein* is acceptable because Princeton's being visited *is* still possible.

In Kuhn [1983] it is suggested that the explanation may be partly syntactic. Existence presuppositions can be canceled when a term occurs in the scope of certain operators. Thus *Santa is fat* presupposes that Santa exists, but *According to Virginia, Santa is fat* does not. There are good reasons to believe that past and future apply to sentences, whereas perfect applies only to intransitive verb phrases. But in that case it is natural that presuppositions concerning the subject that do hold in present perfect sentences fail in past and future sentences.

Guenthner requires that at least one of the objects referred to in a present perfect sentence (viz., the topic of the sentence) must exist at utterance time. Often, of course, the subject will be the topic.

The explanation given by Tichý is that, in the absence of an explicit indication of reference time, a present perfect generally refers to the lifetime of its subject. If this does not include the present, then the perfect is inappropriate.

Overall, the question of whether these explanations are compatible, and whether they are equally explanatory, remains open.

8. *Tense in Intensional Contexts.*

The focus in all of the preceding discussion has been on occurrences of tense in simple sentences. A variety of complexities arise when one tries to accommodate tense in subordinate clauses. Of particular concern is the phenomenon known as *Sequence of Tense.* Consider the following:

(29) John believed that Mary left.

(30) John believed that Mary was pregnant.

Example (29) says that at some past time t John had a belief that at some time $t' < t$, Mary left. This reading is easily accounted for by a classic Priorean analysis: the time of evaluation is shifted into the past by the first tense operator, and then shifted further back by the second. (30), which differs from (29) in having a stative subordinate clause, has a similar reading, but has another as well, the so-called 'simultaneous reading', on which the time of Mary's alleged pregnancy overlaps with the time of John's belief. It would seem that the tense on *was* is not semantically active. A traditional way of looking at things is to think of the tense form of *was* as

triggered by the past tense of *believed* by a morphosyntactic sequence of tense (SOT) rule. Following Ogihara, we could formalize this idea by saying that a past tense in a subordinate clause governed by another past tense verb is deleted prior to the sentence's being interpreted. For semantic purposes, (30) would then be *John believed that Mary be (tenseless) pregnant.* Not every language has the SOT rule. In Japanese, for example, (30) would be expressed with present tense in the subordinate clause.

The SOT theory does not explain why simultaneous readings are possible with some clauses and not with others. The key distinction seems to be between *telic* and *atelic* eventualities; telic eventualities are those which, in Parsons' terms, culminate (achievements and accomplishments), while atelic eventualities do not (states and processes). Simultaneous readings are possible with atelic subordinate clauses. The data should presumably be related to that pertaining to *when* clauses discussed in Section 6; recall that the eventualities associated with atelic *when* clauses are typically interpreted as temporally overlapping the main clause, while the ones described by telic clauses are not: *John went to bed when the cat was on the mat* vs. *John went to bed when the cat came in.* Furthermore, as will be discussed in the next section, similar facts obtain with sequences of sentences in discourse. Anticipating Dowty's analysis of the latter phenomena, one might wonder whether the difference in (29)-(30) is a semantic one at all. Perhaps in both cases, the subordinate clause's eventuality must precede the time of John's believing, but general knowledge tells us that a state of being pregnant usually stretches for a fair amount of time. If the time at which the pregnancy is thought to obtain just precedes the belief by a short time, as a default one could conclude that the alleged pregnancy also continues beyond then, overlapping the belief time. (A problem might be *John believed Mary was hitting a golf*

ball, whose default reading is the simultaneous one, even though there is no reason to think the hitting must be prolonged.) In any case, it seems that the contrast of (29)-(30) should be related to the other, similar, differences between telic and atelic sentences.

Sentences like (31) pose special problems. One might expect for it to be equivalent to either (30), on the simultaneous reading, or (32).

(31) John believed that Mary is pregnant.

(32) John believed that Mary would now be pregnant.

A simultaneous interpretation would be predicted by a Priorian account, while synonymy with (32) would be expected by a theory which said that present tense means 'at the speech time'. However, as pointed out by Enç [1987], (31) has a different, problematical interpretation; it seemingly requires that the time of Mary's alleged pregnancy extend from the belief time up until the speech time. She labels this the *Double Access Reading* (DAR). Recent theories of SOT, in particular those of Ogihara [1989, 1995] and Abusch [1991, 1995], have been especially concerned with getting a correct account of such 'present under past' sentences.

Enç's analysis of tense in intensional contexts begins with the proposal that tense is a referential expression. She suggests that the simultaneous interpretation of (30) should be obtained through a 'binding' relationship between the two tenses, indicated by coindexing as in (33). The connection is similar to that holding with nominal anaphora, as in (34).

(33) John $PAST_1$ believed that Mary $PAST_1$ was pregnant.

(34) $John_1$ thinks that he_1 is smart.

This point of view lets Enç say that both tense morphemes have a usual interpretation. Her mechanisms entail that all members of a sequence of coindexed tense morphemes denote the

same time, and that each establishes the same temporal relationship as the highest ('first') occurrence. Ogihara elucidates the intended interpretation of examples like (33) by translating them into Intensional Logic.

(35) $t_1 < s^* \,\&\, \text{believe}'(t_1, j, \hat{}[t_1 < s^* \wedge \text{be-pregnant}(t_1, m)])$

Here s^* denotes the speech time. If the two tenses were not coindexed, as in (36), the second would introduce $t_2 < t_1$ to the translation:

(36) John PAST_1 believed that Mary PAST_2 was pregnant.

(37) $t_1 < s^* \,\&\, \text{believe}'(t_1, j, \hat{}[t_2 < t_1 \wedge \text{be-pregnant}(t_1, m)])$

This represents the non-simultaneous ('shifted') reading.

Accounting for the DAR is more complex. Enç proposes that there need to be two ways that temporal expressions may be linked. Expressions receive pairs of indices, so that with a configuration $A_{<i,j>}\ B_{<k,l>}$, if i=k, then A and B refer to the same time, while if j=l, then the time if B is included in that of A. The complement clause *that Mary is pregnant* is then interpreted outside the scope of the past tense. The present tense is linked to the speech time. As usual, however, the two tenses may be coindexed, but only via their second indices. This gives us something like (38).

(38) [Mary $\text{PRES}_{<0,1>}$ be pregnant] John $\text{PAST}_{<2,1>}$ believes x

This representation says that Mary is pregnant at the speech time and that the time of John's belief is a subinterval of Mary's pregnancy. Thus it encodes the DAR.

The mechanisms involved in deriving and interpreting (38) are quite complicated. In addition, examples discussed by Abusch [1988], Baker [1989] and Ogihara [1995] pose a serious difficulty for Enç's view.

(39) John decided a week ago that in ten days at breakfast he would say to his mother that they were having their last meal together.

Here, on the natural interpretation of the sentence, the past tense of *were* does not denote a time which is past with respect to either the speech time or any other time mentioned in the sentence. Thus it seems that the tense component of this expression cannot be semantically active.

As mentioned above, Ogihara proposes that a past tense in the right relation with another past tense may be deleted from a sentence prior to semantic interpretation. (Abusch has a more complex view involving feature passing, but it gets similar effects.) This would transform (39) into (40).

(40) John PAST decided a week ago that in ten days at breakfast he Ø woll say to his mother that they Ø be having their last meal together.

Notice that we have two deleted tenses (marked 'Ø') here. *Would* has become tenseless *woll*, a future operator evaluated with respect to the time of the deciding. Then breakfast time ten days after the decision serves as the time of evaluation for *he say to his mother that they be having their last meal together*. Since there are no temporal operators in this constituent, the time of the saying and that of the last meal are simultaneous.

The double access sentence (31) is more difficult story. Both Ogihara and Abusch propose that the DAR is actually a case of *de re* interpretation, similar to the famous Ortcutt examples of Quine (1956). Consider example (31), repeated here:

(31) John believed that Mary is pregnant.

Suppose John has glimpsed Mary two months ago, noticing that she is quite large. At that time he thought 'Mary is pregnant'. Now you and I are considering why Mary is so large, and I report

John's opinion to you with (31). The sentence could be paraphrased by *John believed of the state of Mary's being large that it is a state of her being pregnant.* (Abusch would frame this analysis in terms of a *de re* belief about an interval, rather than a state, but the difference between these two formulations appears slight.) Both Ogihara and Abusch give their account in terms of the analysis of *de re* belief put forward by Lewis [1979] and extended by Cresswell and von Stechow. These amount to saying that (31) is true iff the following conditions are met: (i) John stands in a suitable *acquaintance relation* R to a state of Mary's (such as her being large), in this case the relation of having glimpsed it on a certain occasion, and (ii) in all of John's belief-worlds, the state to which he stands in relation R is a state of Mary being pregnant.

A *de re* analysis of present under past sentences may hope to give an account of the DAR. Suppose we have an analysis of tense whereby the present tense in (31) entails that the state in question holds at the speech time. Add to this the fact that the acquaintance relation, that John had glimpsed this state at the time he formed his belief, entails that the state existed already at that time. Together these two points require that the state stretch from the time of John's belief up until the speech time. This is the DAR.

The preceding account relies on the acquaintance relation to entail that the state have existed already at the past time. The idea that it would do so is natural in light of Lewis' suggestion that the relation must be a causal one: in this case that John's belief has been caused, directly or indirectly, by the state. However, as Abusch [1995] points out, there is a problem with this assumption: it sometimes seems possible to have a future-oriented acquaintance relation. Consider Abusch's example (32) (originally due to Andrea Bonomi).

(32) Leo will go to Rome on the day of Lea's dissertation. Lia believes that she will go

to Rome with him then.

Here, according to Abusch, we seem to have a *de re* attitude by Lia towards the future day of Lea's dissertation. Since the acquaintance relation cannot be counted on to require in (31) that the time of Mary's being large overlaps the time when John formed his belief, both Abusch and Ogihara have had to introduce extra stipulations to serve this end. But at this point the explanatory force of appealing to a *de re* attitude is less clear.

There are further reasons to doubt the *de re* account, at least in the form presented. Suppose that we're wondering whether the explanation for Mary's appearance is that she's pregnant. John has not seen Mary at all, but some months ago her mother told John that she is, he believed her, and he reported on this belief to me. It seems that I could say (31) as evidence that Mary is indeed pregnant. In such a case it seems that the sentence is about the state *we're* concerned with, not the one which provided John's evidence.

9. *Tense and Discourse.*

One of the major contributions of DRT to the study of tense is its focus on 'discourse' as the unit of analysis rather than the sentence. Sentential analyses treat reference times as either completely indeterminate or given by context. In fact the 'context' that determines the time a sentence refers to may just be the sentences that were uttered previously. Theorists working within DRT have sought to provide a detailed understanding of how the reference time of a sentence may depend on the tenses of the sentence and its predecessors.

As mentioned above, DRS's will include events, states, and times as objects in the universe of discourse and will specify relations of precedence and overlap among them.

Precisely which relations hold depends on the nature of the eventualities being described, where once again the key distinction is between telic and atelic eventualities. Various similar algorithms for constructing DRS's are given by Kamp, Kamp and Rohrer, Hinrichs, and Partee, among others. Let us consider the following pair of examples:

(33) Mary was eating a sandwich. Pedro entered the kitchen.

(34) Pedro went into the hall. He took off his coat.

In (33), the first sentence describes an atelic eventuality, a process, whereas the second describes a telic event. The process is naturally taken to temporally contain the event. In contrast, in (34) both sentences describe telic events, and the resulting discourse indicates that the two happened in sequence.

A DRS construction procedure for these two could work as follows: With both the context provides an initial past reference time r_0. Whenever a past tense sentence is uttered, it is taken to temporally coincide with the past reference time. A telic sentence introduces a new reference time that follows the one used by the sentence, while an atelic one leaves the reference time unchanged. So, in (33), the same reference time is used for both sentences, implying temporal overlap, while in (34) each sentence has its own reference time, with that for the second sentence following that for the first.

Dowty [1986a] presents a serious critique of the DRT analysis of these phenomena. He points out that whether a sentence describes a telic or atelic eventuality is determined by compositional semantics, and cannot be read off of the surface form in any direct way. He illustrates with the pair (35)-(36).

(35) John walked. (activity)

(36) John walked to the station. (accomplishment)

Other pairs are even more syntactically similar (*John baked a cake* vs. *John baked cakes.*) This consideration is problematical for DRT because that theory takes the unit of interpretation to be the entire DRS. A complete DRS cannot be constructed until individual sentences are interpreted, since it must be determined whether sentences describe telic or atelic eventualities before relations of precedence and overlap are specified. But the sentences cannot be interpreted until the DRS is complete.

Dowty proposes that the temporal sequencing facts studied by DRT can be accommodated more adequately within interval semantics augmented by healthy amounts of Gricean implicature and common-sense reasoning. First of all, individual sentences are compositionally interpreted within a Montague Grammar-type framework. Dowty [1979] has shown how differences among states, processes, and telic events can be defined in terms of their temporal properties within interval semantics. (For example, as mentioned above, A is a stative sentence iff, if A is true at interval I, then A is true at all moments within I.) The temporal relations among sentence are specified by a single, homogeneous principle, the *Temporal Discourse Interpretation Principle* (TDIP), which states:

(37) **TDIP** Given a sequence of sentences $S_1, S_2, ..., S_n$ to be interpreted as a narrative discourse, the reference time of each sentence S_i (for i such that $1<i\leq n$) is interpreted to be:

(a) a time consistent with the definite time adverbials in S_i, if there are any;

(b) otherwise, a time which immediately follows the reference time of the previous sentence S_{i-1}.

Part (b) is the novel part of this proposal. It gives the same results as DRT in all-telic discourses like (34), but seems to run into trouble with atelic sentences like the one in (33). Dowty proposes that (33) really does describe a sequence of a process of Mary eating a sandwich followed by an event of Pedro entering the kitchen; this is the literal contribution of the example (Nerbonne [1986] makes a similar proposal.) However, common sense reasoning allows one to realize that a process of eating a sandwich generally takes some time, and so the time at which Mary was actually eating a sandwich might have started some time before the reference time and might continue for some time afterwards. Thus (33) is perfectly consistent with Mary continuing to do the dishes while Pedro entered the kitchen. In fact, Dowty would suggest, in normal situations this is just what someone hearing (33) would be likely to conclude.

Dowty's analysis has an advantage in being able to explain examples of inceptive readings of atelic sentences like *John went over the day's preplexing events once more in his mind. Suddenly, he was fast asleep. Suddenly* tells us that the state of being asleep is new. World knowledge tells us that he could not have gone over the days events in his mind if he were asleep. Thus the state must begin after the event of going over the perplexing events in his mind. DRT would have a more difficult time with this example; it would have to propose that *be asleep* is ambiguous between an atelic (state) reading and a telic (achievement) reading, or that the word *suddenly* cancels the usual rule for atelics.

As Dowty then goes on to discuss, there are a great many examples of discourses in which the temporal relations among sentences do not follow the neat pattern described by the DRT algorithms and the TDIP. Consider:

(38) Mary did the dishes carefully. She filled the sink with hot water. She added a

half cup of soap. Then she gently dipped each glass into the sudsy liquid.

Here all of the sentences after the first one describe events which comprise the dish-washing. To explain such examples, adherent of DRT must propose additional DRS construction procedures. Furthermore, there exists the problem of knowing which procedures to apply; one would need rules to determine which construction procedures apply before the sentences within the discourse are interpreted, and it is not clear whether such rules can be formulated in a way that doesn't require prior interpretation of the sentences involved. Dowty's interval semantics framework, on the other hand, would say that the relations among the sentences here are determined pragmatically, overriding the TDIP. The weakness of this approach is its reliance on an undeveloped pragmatic theory.

IV. TENSE LOGICS FOR NATURAL LANGUAGE

A. Motivations

General surveys of tense logic are contained elsewhere in this Handbook (**). In this section we consider relations between tense logic and tense and aspect in natural language. Work on tense logic, even among authors concerned with linguistic matters, has been motivated by a variety of considerations that have not always been clearly delineated. Initially, tense logic seems to have been conceived as a generalization of classical logic that could better represent logical forms of arguments and sentences in which tense plays an important semantic role. To treat such items within classical logic requires extensive "paraphrase". Consider the following example from Quine [1982]:

(39) George V married Queen Mary, Queen Mary is a widow, therefore George V married a widow.

An attempt to represent this directly in classical predicate logic might yield

(39a) Mgm, Wm ⊨ ∃x(Mgx∧Wx),

which fallaciously represents it as valid. When appropriately paraphrased, however, the argument becomes something like:

(40) Some time before the present is a time when George V married Queen Mary, Queen Mary is a widow at the present time, therefore some time before the present is a time at which George V married a widow.

which, in classical logic, is represented by the nonvalid:

(40a) ∃t(Tt∧Btn∧Mgmt), Wmn ⊨ ∃t(Tt∧Btn∧∃x(Wxn∧Mgmt)).

If we want a logic that can easily be *applied* to ordinary discourse, however, such extensive and unsystematized paraphrase may be unsatisfying. Arthur Prior formulated several logical systems in which arguments like (39) could be represented more directly and, in a series of papers and books in the fifties and sixties, championed, chronicled and contributed to their development. (See especially [1957], [1967] and [1968].) A sentence like *Queen Mary is a widow* is not to be represented by a formula that explicitly displays the name of a particular time and that is interpreted simply as *true* or *false*. Instead it is represented as Wm, just as in (39), where such formulas are now understood to be true or false only relative to a time. Past and future sentences are represented with the help of *tense logical operators* like those mentioned in previous sections. In particular, most of Prior's systems contained the past and future operators with truth conditions:

(41) $t \vDash \mathsf{P}A$ if and only if $\exists s(s<t \ \& \ s \vDash A)$

$t \vDash \mathsf{F}A$ if and only if $\exists s(t<s \ \& \ s \vDash A)$

(where $t \vDash A$ means A is true at time t and $s<t$ means time s is before time t). This allows (39) to be represented:

(39b) $\mathsf{P}Mgm, Wm \vDash \mathsf{P}\exists x(Mgx \wedge Wx)$.

Quine himself thought that a logic to help prevent us misrepresenting (39) as (39a) would be "needlessly elaborate". "We do better," he says, "to make do with a simpler logical machine, and then, when we want to apply it, to paraphrase our sentences to fit it." In this instance, Quine's attitude seems too rigid. The advantages of the simpler machine must be balanced against a more complicated paraphrase and representation. While (40a) may represent the form of (40), it does not seem to represent the form of (39) as well as (39b) does. But if our motivation for constructing new tense logics is to still better represent the logical forms of arguments and sentences of natural language, we should be mindful of Quine's worries about their being needlessly elaborate. We would not expect a logical representation to capture all the nuances of a particular tense construction in a particular language. We would expect a certain economy in logical vocabulary and rules of inference.

Motivations for many new systems of tense logic may be seen as more semantical than logical. A semantics should determine, for any declarative sentence S, context C, and possible world W, whether the thought expressed when S is uttered in C is true of W. As noted in previous sections, the truth conditions associated with Prior's P and F do not correspond very closely to those of English tenses. New systems of tense logic attempt to forge a closer correspondence. This might be done with the view that the tense logic would become a

convenient *intermediary* between sentences of natural language and their truth conditions. That role was played by tensed intensional logic in Montague's semantics. An algorithm translates English sentences into formulas of that system and an inductive definition specifies truth conditions for the formulas. As noted above, Montague's appropriation of the Priorean connectives into his intensional logic make for a crude treatment of tense, but refined systems might serve better. Specifications of truth conditions for the tensed intensional logic (and, more blatantly for the refined tense logics), often seem to use a first order theory of temporal precedence (or containment, overlap, etc.) as yet another intermediary. (Consider clauses 41 above, for example.) One may wonder, then, whether it wouldn't be better to skip the first intermediary and translate English sentences directly into such a first order theory. Certainly the most perspicuous way to give the meaning of a particular English sentence is often to "translate" it by a formula in the language of the first order theory of temporal precedence, and this consideration may play a role in some of the complaints against tense logics found, for example, in [van Benthem] and [Massey]. Presumably, however, a *general* translation procedure could be simplified by taking an appropriate tense logic as the target language.

There is also another way to understand the attempt to forge a closer correspondence between tense logical connectives and the tense constructions of natural language. We may view tense logics as "toy" languages, which, by isolating and idealizing certain features of natural language, help us to understand them. On this view, the tense logician builds models or simulations of features of language, rather than parts of linguistic theories. This view is plausible for, say Kamp's logic for "now" and Galton's logic of aspect (see below), but it is difficult to maintain for more elaborate tense logics containing many operators to which no natural language

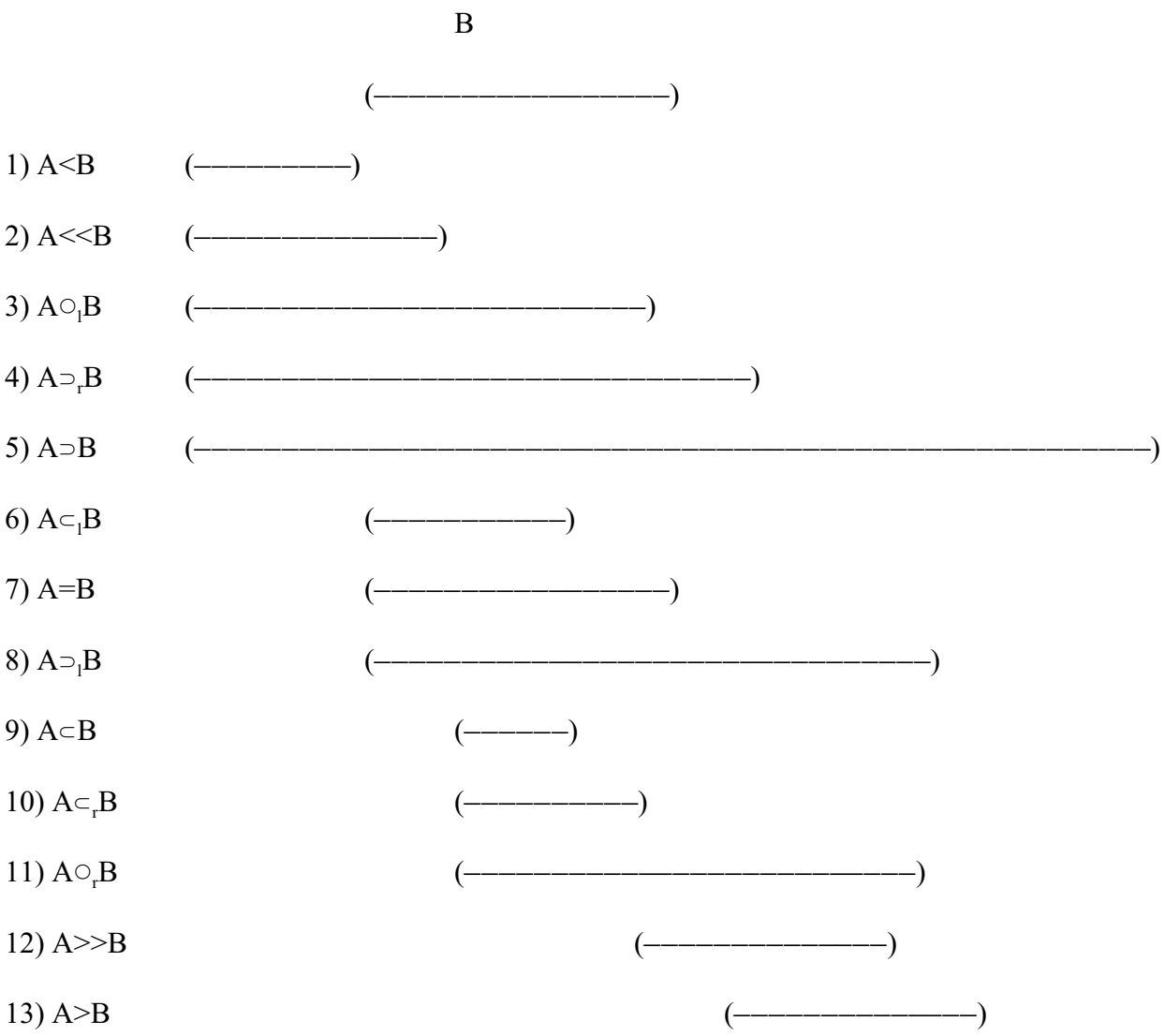
expressions correspond.

Systems of tense logic are sometimes defended against classical first order alternatives on the grounds that they don't commit language users to an ontology of temporal moments, since they don't explicitly quantify over times. This defense seems misguided on several counts. First, English speakers do seem to believe in such an ontology of moments, as can be seen from their use of locutions like "at three o'clock sharp". Second, it's not clear what kind of "commitment" is entailed by the observation that the language one uses quantifies over objects of a certain kind. Quine's famous dictum, "to be is to be the value of a bound variable," was not intended to express the view that we are committed to what we quantify over in ordinary language, but rather that we are committed to what our best scientific theories quantify over, when these are cast in first order logic. There may be some weaker sense in which, by speaking English, we may be committing ourselves to the existence of entities like chances, sakes, average men and arbitrary numbers, even though we may not believe in these objects in any ultimate metaphysical sense. Perhaps we should say that *the language* is committed to such objects. (See Bach [1981]) But surely the proper test for this notion is simply whether the best interpretation of our language requires these objects: "to be is to be an element of a model." And, whether we employ tense logics or first order theories, our best models do contain (point-like and/or extended) times. Finally, even if one were sympathetic to the idea that the weaker notion of commitment was revealed by the range of first order quantifiers, there is reason to be suspicious of claims that a logic that properly models any substantial set of the temporal features of English would have fewer ontological commitments than a first order theory of temporal precedence. For, as Cresswell has argued in detail ([1990], [1996]), the languages of such logics turn out to be

equivalent in expressive power to the language of the first order theories. One might reasonably suppose in this case that the ontological commitments of the modal language should be determined by the range of the quantifiers of its first order equivalent. The proper defense of tense logic's replacement of quantifiers by operators, then, is linguistic rather than metaphysical.

B. Interval based logics

One of the most salient differences between the traditional tense logical systems and natural language is that all the formulas of the former are evaluated at instants of time, whereas at least some of the sentences of the latter seem to describe what happens at extended temporal periods. We are accustomed to thinking of such periods as comprising continuous stretches of instants, but it has been suggested, at least since Russell, that extended periods are the real objects of experience, and instants are abstractions from them. Various recipes for constructing instants from periods are contained in Russell, van Benthem [1991], Thomason ([1984], [1989]) and Burgess [1984]. Temporal relations among intervals are more diverse than those among instants, and it is not clear which of these relations should be taken as primitive for an interval based tense logic. The following table shows 13 possible relations that an interval A can bear to the fixed interval B.



We can think of < and > as precedence and succession, << and >> as immediate precedence and succession and ⊂, ⊃, and ○ as inclusion, containment and overlap. The subscripts l and r are for "left" and "right". Under reasonable understandings of these notions and reasonable assumptions about the structure of time, these can all be defined in elementary logic from precedence and inclusion. For example, A<<B can be defined by A<B ∧ ¬∃x(A<x∧x<B), and $A\circ_l B$ by ∃x(x⊂A∧x<B)∧(∃x)(x⊂A∧x⊂B). It does not follow, however, that a tense operator

based on any of these relations can be defined from operators based on < and ⊂. Just as instant based tense logics include both P and F despite the fact that > is elementarily definable from <, we may wish to include operators based on a variety of the relations above in an interval based tense logic. For each of the relations R listed in the above chart, let [R] and <R> be the box and diamond operators defined with R as the accessibility relation. (We are presupposing some acquaintance with the Kripke semantics for modal logics here. See Bull and Segerberg in this *Handbook* for background.) Then <<> and <>> are interval analogs of Prior's P and F, and <⊂> is a connective that Dana Scott suggested as a rough analog of the progressive. Halpern and Shoham (and Shoham [1988]) point out that if we take the three converse pairs [<<] and [>>], $[\subset_l]$ and $[\supset_l]$ and $[\subset_r]$ and $[\supset_r]$ as primitive we can give simple definitions of the connectives associated with the remaining relations:

$[<]=[<<][<<]$ $[>]=[>>][>>]$

$[\supset]=[\supset_l][\supset_r]$ $[\subset]=[\subset_l][\subset_r]$

$[\circ_l]=[\supset_l][\subset_r]$ $[\circ_r]=[\supset_r][\subset_l]$

If it is assumed that intervals always contain durationless atoms, i.e., subintervals s such that $\neg\exists t(t\subset s)$, then Venema shows that we can do better. For then $[\supset_l]\perp$ and $[\supset_r]\perp$ will be true only at atoms, and there are formulas $[l]A=(A\wedge[\supset_l]\perp)\vee<\supset_l>(A\wedge[\supset_l]\perp)$ and $[r]A=(A\wedge[\supset_l]\perp)\vee<\supset_r>(A\wedge[\supset_l]\perp)$ saying that A is true at the left and right "endpoints" of an interval. [<<] and [>>] can now be defined by $[r][\subset_l]$ and $[l][\subset_r]$. (The assumption that there are durationless "intervals" undercuts the idea that instants are mere abstractions, but it seems appropriate for linguistic applications of tense logic, since language users do, at some level, presume the existence of both intervals and instants.)

Call the tense-logical language with operators $[\subset_l]$, $[\supset_l]$, $[\subset_r]$ and$[\supset_r]$, HSV in honor of its inventors. Since HSV can so easily express all the relations on the table above, one might expect it to be sufficient to express any temporal relations that common constructions in natural language do. As Venema shows, however, there are limitations to its expressive power. Consider the binary connective /* such that $(s,t)\models(A/\!\backslash^*B)$ iff, for some r, $s<r<t$, $(s,r)\models A$ and $(r,t)\models B$). Lloyd Humberstone argues that /* is the tense logical connective that properly expresses temporal conjunction, i.e., *and* in the sense of *and next*. But no formula in HSV can express /*. Further, as Venema shows, there is a sense in which this expressive poverty is unavoidable in interval logics. Call a model $M=(I,\subset_l,\subset_r.\supset_l,\supset_r,V)$ for HSV "instant generated" if there is some nonempty set T ordered by < such that I is the set of all $(x,y)\in(T\times T)$ for which $x\leq y$, and $\subset_l,\subset_r.\supset_l$ and $\supset_r$ are the appropriate relations on I. (For example $(r,s)\supset_l(u,v)$ iff u=r and s>v.) Instant generated HSV-models, then, are models in which formulas are evaluated at pairs of indices, i.e., they are two-dimensional models. The truth conditions for the connectives determine a translation the that maps formulas of HSV to "equivalent" formulas in predicate logic with free variables r and s. Similar translations could be obtained for any language in which the truth conditions of the connectives can be expressed in elementary logic. Venema shows, however, that for no finite set of connectives will this translation include in its range every formula with variable r and s. This result holds even when the equivalent formulas are required to agree only on models for which the instants form a dense linear order. This contrasts with a fundamental result in instant-based tense logics, that for dense linear orders, the two connectives "since" and "until" are sufficient to express everything that can be said in elementary logic with one free variable. (See Burgess [19**]).

Several authors have suggested that in tense logics appropriate for natural language there should be constraints on the set of intervals at which a formula can be true. The set $\|A\|_M$ of indices at which formula A is true in model M is often called the truth set of A. Humberstone requires that valuations be restricted so that truth sets of sentence letters be closed under containment. That "downward closure" property seems natural for stative sentences (see section ID). The truth of *The cat is on the mat* at the interval from two to two to two thirty apparently entails its truth at the interval from two ten to two twenty. But downward closure is not preserved under ordinary logical negation. If *The cat is on the mat* is true at (2:00,2:30) and all its subintervals, but not at (1:30, 3:00) then ¬(*the cat is on the mat*) is true at (1:30,3:00) but not all of its subintervals. Humberstone suggests a stronger form of negation, which we might call [¬]. [¬]A is true at interval i if A is false at all subintervals of i. Such a negation may occur in one reading of *The cat isn't on the mat.* It can also be used to express a more purely tense logical connective: [⊃] can be defined as [¬][¬]. We obtain a reasonable tense logic by adding the standard past and future connectives <<> and <>>.

Statives also seem to obey an upward closure constraint. If A is true in each of some sequence of adjoining or overlapping intervals, it is also true in the "sum" of those intervals. Peter Röper observes that, in the presence of downward closure, upwards closure is equivalent to the condition that A is true in i if it is true "almost everywhere" in i, i.e., if every subinterval of i contains a subinterval at which A is true. (See Burgess [1982a] for an interesting list of other equivalents of this and related notions.) Following Röper, we may call a truth set homogeneous if it satisfies both upwards and downwards closure. Humberstone's strong negation preserves

homogeneity, but the tense connectives <<> and <>> do not. For suppose the temporal intervals are the open intervals of some densely ordered set of instants, and A is true only at (s,t) and its subintervals. Then the truth set of A is homogeneous. But every proper subinterval of (s,t) verifies <>>A, and so every subinterval of (s,t) contains a subinterval that verifies the formula, whereas (s,t) itself does not verify the formula, and so the truth set of <<>A is not homogeneous. To ensure that homogeneity is preserved, Röper replaces the standard truth conditions for the future operator by a condition stating that <<>A is true at i if every subinterval of i contains a subinterval i' such that A is true at some w>i'. The past operator is similarly altered. This ensures that all formulas have homogeneous truth sets and the resulting system admits a simple axiomatization. One may wonder whether the future and past tenses of statives really are themselves statives in natural language, and thus whether homogeneity really ought to be preserved. But if one is thoroughgoing (as Humberstone and Röper seem to be, but Venema does not), about the attitude that (extended) intervals are the genuine temporal objects, then it does seem reasonable to suppose that for stative A, A→<>>A and A→<<>A are logical truths. If the cat is on the mat, then, if one looks sufficiently close to the present, it will be on the mat, and if one looks sufficiently close in the other direction, it was on the mat. For otherwise we would have to believe that the present was the instant at which it came or left. Indeed, the "present implies past" property was cited by Aristotle as a distinguishing feature of "energaie," a category that surely includes the statives. The formulas A→<<>A and A→<>>A are not theorems of HSV or standard tense logics unless < is reflexive, but they are theorems of Röper's homogeneous interval tense logic.

C. 'Now', 'then', and keeping track of times

Another way in which natural language differs from Priorean tense logics is its facility in conveying that the eventualities described in various scattered clauses of a sentence obtain simultaneously. Consider first an example in which exterior and interior clauses describe what obtains at the moment of utterance.

(42)This is 1996 and one day everyone now alive will be dead.

If we represent this as $P \wedge \forall x(Lx \rightarrow FDx)$, we fail to imply that those alive today will all be dead at a common future moment. If we pull the future operator outside the quantifier, we get $P \wedge F\forall x(Lx \rightarrow Dx)$, which wrongly implies that there will be a time when live people are (simultaneously) dead. A solution (following Kamp [1971] and Prior [1968]) is to evaluate formulas at pairs of times, the first of which "keeps track" of the moment of utterance and the second of which is used to evaluate expressions inside tense operators. $(s,t) \models A$ can be understood as asserting that A is true at t when part of an expression uttered at s. The truth conditions for the Priorean operators use the second coordinate: $(s,t) \models PA$ iff $\exists t' < t$ $(s,t') \models A$ and $(s,t) \models FA$ iff $\exists t' > t$ $(s,t') \models A$. A new connective N corresponding to the adverb *now* is added satisfying $(s,t) \models NA$ iff $(s,s) \models A$. Validity in a model is to be understood as truth whenever uttered, i.e., $M \models A$ iff for every time t in M, $(t,t) \models A$. On this understanding $A \leftrightarrow NA$ is valid, so it may appear that N is vacuous. Its effect becomes apparent when it appears within the scope of the other tense operators. $P(A \leftrightarrow NA)$, for example, is false when A assumes a truth value at utterance time that differs from the value it had until then. This condition can still be expressed without the new connective by $(A \wedge \neg PA) \vee (\neg A \wedge \neg P \neg A)$, and in general, as Kamp shows, N is

eliminable in propositional Priorean tense logics. If the underlying language has quantifiers, however, N does increase its expressive power. For example, the troublesome example above can be represented as

(42a) P∧Fx(NLx→Dx).

The new connective can be used to ensure that embedded clauses get evaluated after the utterance moment as well as simultaneously with it. Consider Kamp's

(43) A child was born who will be king.

To represent this as P(A∧FB) would imply only that the child is king after its birth. To capture the sense of the English *will*, that the child is king after the utterance moment, we need P(A∧NFB).

Vlach [1973] shows that in a somewhat more general setting N can be used to cause evaluation of embedded clauses at still other times. Take the sentence *It is three o'clock and soon Jones will cite all those who are now speeding*, which has a structure like (42), and put it into the past:

(44) It was three o'clock and Jones would soon cite those who were then speeding.

We cannot represent this by simply applying a past operator to (42a) because the resulting formula would imply that Jones was going to ticket those who were speeding at the time of utterance. Vlach suggests we add an "index" operator to the language with truth conditions very similar to N's.

(s,t)⊨IA iff (t,t)⊨A

If an N occurs within the scope of an I it can be read as *then.* This allows, for example, the

sentence (44) to be represented as

$\mathbf{P}\mathbf{I}(P \wedge \forall x(\mathbf{N}Sx \rightarrow Cx)$.

In general, if A contains no occurrence of $\mathbf{I}$, the utterance time is "fixed" in the sense that the truth value of A at $\langle u, t\rangle$ depends on the truth values of its subformulas at pairs $\langle u, t'\rangle$. The occurrence of an $\mathbf{I}$ "shifts" the utterance time so that evaluating A at $\langle u, t\rangle$ may require evaluating the subformulas that are within the scope of the $\mathbf{I}$ at pairs $\langle u', t'\rangle$ for u' different than u.

With Kamp's *now*, we can keep track of the utterance time and one other time. With Vlach's *then*, we still track two times, although neither need coincide with utterance. Several authors have suggested that a tense-logical system adequate to represent natural language must allow us to keep track of more than two times. The evidence is not entirely convincing, but it has motivated some interesting revisions in the Priorean framework. Gabbay ([1974], [1976]) points to examples like the following:

(45) John said he would come.

(46) Ann will go to a school her mother attended and it will become better than Harvard,

which, he maintains, have interpretations suggested by the formulas

(45a) $\exists t_1 < t_0$(John says at t_1 that $\exists t_2(t_1 < t_2 < t_0 \wedge$ John comes at t_2))

(46a) $\exists t_1 > t_0\ \exists s$(s is a school $\wedge$ Ann goes to s at $t_1 \wedge \exists t_2 < t_0$(Ann's mother goes to s at $t_2 \wedge$ $\exists t_3 > t_1$ (s is better than Harvard at t_3))).

Saarinen's exhibits include

(47) Every man who ever supported the Vietnam War believes now that one day he will

have to admit that he was an idiot then, interpreted as

(47a) $\forall x$(x is a man $\rightarrow \forall t_1 < t_0$(x supports the Vietnam War at t_1)$\rightarrow$ (x believes at t_0 that $\exists t_2 > t_0$(x has to admit at t_2 that x is an idiot at t_1)), and

(48) Joe said that a child had been born who would become ruler of the world,

which, Saarinen argues, has at least the two readings

(48a) $\exists t < t_0$(Joe says at t that $\exists s < t \exists x$(Child x $\wedge$ Born x s $\wedge \exists u > s$ Ruler x u)))

(48b) $\exists t < t_0$(Joe says at t that $\exists s < t \exists x$(Child x $\wedge$ Born x s $\wedge \exists u > t$ Ruler x u)))

according to whether the sentence reported is *A child was born who would become ruler*, or *A child was born who will become ruler*. (Note that the sequence of tense theories discussed in III.D.8 above conflict with the readings proposed here for (45) and (48).[15])

Cresswell [1990] points to examples of a more explicitly quantificational form

(49)There will be times such that all persons now alive will be A_1 at the first or A_2 at the second or...A_n at the nth.

(49a) $\exists t_1 ... \exists t_n (t_0 < t_1 \wedge ... \wedge t_0 < t_n \wedge \forall x$(x is alive at $t_0 \rightarrow$(x is A_1 at $t_1 \vee ... \vee$x is A_n at t_n))).

Some of the troublesome examples could be expressed in a Priorean language. For example, for (46) we might propose:

(46b) $\exists s$(SCHOOLs $\wedge$ PATTEND ann's mother s $\wedge$ F(ATTEND ann s $\wedge$ FBETTER s harvard)))

But as a toy version of (46) or the result of applying a uniform English-to-tense-logic translation procedure, this may seem implausible. It requires a reordering of the clauses in (46), which removes *that her mother attended* from inside the scope of the main tense operator. Other

troublesome examples can be represented with the help of novel two-dimensional operators. For example, Gabbay suggests that the appropriate reading of (45) might be represented **PJohnsaythat**F_2A, where $\langle u,t\rangle \vDash \mathsf{F}_2A$ iff either $t < u$ and $\exists s(t < s < u$ **&** $\langle u, s\rangle \vDash A)$ or $u < t$ and $\exists s(u < s < t$ **&** $\langle u, s\rangle \vDash A)$. (A variety of other two dimensional tense operators are investigated in Åqvist and Guenthner ([1977], [1978]). This approach, however, seems somewhat *ad hoc*. In the general case, Gabbay argues, "we must keep record of the entire sequence of points that figure in the evaluation of a formula] and not only that, but also keep track of the kind of operators used."

We sketch below five more general solutions to the problem of tracking times. Each of these introduces an interesting formal system in which the times that appear at one stage in the evaluation of a formula can be remembered at later stages, but none of these seems to provide a fully accurate model of the time-tracking mechanisms of natural language.

1. Backwards-looking operators (Saarinen).

Add to the language of tense logic a special "operator functor" **D.** For any operator □, **D**(□) is a connective that "looks back" to the time at which the preceding □ was evaluated. For example, (47) can be represented

(47b) $\forall x($*x* is a man $\rightarrow \neg\mathsf{P}\neg($*x* supported the Vietnam war $\rightarrow$**D(**P**)(***x* **believesthat** $\mathsf{F}($*x*

hastoadmitthat D(D(P**))(***x* is an idiot))))))

if we have the appropriate **believesthat** and **hastoadmitthat** operators. Within a more standard language,

(50) $A\wedge\mathsf{F}(B\wedge\mathsf{P}(C\wedge\mathsf{F}(D\wedge$**D(**$\mathsf{P}$**)**$E)\wedge$**D(**$\mathsf{F}$**)**F)

is true at w iff $\exists x \exists y \exists z(w<x,\ y<x,\ y<z,\ w \vDash A,\ x \vDash B,\ y \vDash C,\ z \vDash D,\ x \vDash E$ and $y \vDash F)$. In this example **D**(P) and **D**(F) "look back" to the times at which the preceding P and F were evaluated, namely, x and y. This condition can expressed without the backwards operators by

(50a) $A \wedge F(B \wedge E \wedge P(C \wedge F \wedge FD))$,

but (as with 46b) this requires a reordering of the clauses, and (as with 47b) the reordering may be impossible in a richer formal language. It is a little hard to see how the semantics for **D** might be made precise in Tarski-style truth definition. Saarinen suggests a game-theoretic interpretation, in which each move is made with full knowledge of previous moves. Iterated **D**(□)'s look back to more distant □'s so that, for example,

$A \wedge P(B \wedge F(C \wedge F(D \wedge \mathbf{D}(F)\mathbf{D}(F)E) \wedge \mathbf{D}(P)F))$ is true at w iff $\exists x \exists y \exists z(x<w,\ x<y<z,\ w \vDash A,\ x \vDash B,\ y \vDash C,\ z \vDash D,\ x \vDash E$ and $w \vDash A)$. Logics based on this language would differ markedly from traditional ones. For example, if time is dense $FA \rightarrow FFA$ is valid when A does not contain **D**'s, but not when A is of the form **D**(F)B.

2. Dating sentences (Blackburn [1992], [1994]).

Add a special sort of sentence letters, each of which is true at exactly one moment of time. Blackburn thinks of these as naming instants and calls his systems "nominal tense logics," but they are more accurately viewed as "dating sentences", asserting, for example *It is now three pm on July 1, 1995*. Tense logical systems in this language can be characterized by adding to the usual tense logical axioms the schema

$n \wedge E(n \wedge A) \rightarrow A$

where n is a dating sentence and $\mathcal{E}$ is any string of $\mathcal{P}$'s and $\mathcal{F}$'s. In place of (50), we can now write:

(50b) $A\wedge\mathcal{F}(B\wedge\mathbf{i}\wedge\mathcal{P}(C\wedge\mathbf{j}\wedge\mathcal{F}D))\wedge\mathcal{P}\mathcal{F}(i\wedge E)\wedge\mathcal{P}\mathcal{F}(\mathbf{j}\wedge F)$.

Here **i** and **j** "date" the relevant times at which B and C are true, so that the truth of **i**∧E and **j**∧**F** requires the truth of E and F at those same times.

3. Generalization of $\mathcal{N}$-$\mathcal{I}$ (Vlach [1973] appendix).

To the language of Priorean tense logic, add connectives $\mathcal{N}_i$ and $\mathcal{I}_i$ for all non-negative integers i. Let formulas be evaluated at pairs (**s**,i) where **s**=$(s_0,s_1,...)$ is an infinite sequence of times and i is a non-negative integer, specifying the coordinate of **s** relevant to the evaluation. $\mathcal{N}_iA$ indicates that *A* is to be evaluated at the time referred to when $\mathcal{I}_i$ was encountered. More precisely,

$(\mathbf{s},i)\models\mathcal{P}A$ iff $\exists t<s_i((s_0,...,s_{i-1},t,s_{i+1},...),i)\models A$

$(\mathbf{s},i)\models\mathcal{F}A$ iff $\exists t>s_i((s_0,...,s_{i-1},t,s_{i+1},...),i)\models A$

$(\mathbf{s},i)\models\mathcal{I}_jA$ iff $(s_0,...,s_{j-1},s_i,s_{j+1},...),i)\models A$

$(\mathbf{s},i)\models\mathcal{N}_jA$ iff $(\mathbf{s},j)\models A$

The truth of sentence letters at (**s**,i) depend only on s_i and formulas are to be considered valid in a model if they are true at all pairs ((t,t,...),0). In this language (50) can be expressed

(50c) $A\wedge\mathcal{F}\mathcal{I}_1(B\wedge\mathcal{P}\mathcal{I}_2(C\wedge\mathcal{F}(D\wedge\mathcal{N}_2E\wedge\mathcal{N}_1F)))$.

Here $\mathcal{I}_1$ and $\mathcal{I}_2$ "store" in s_1 and s_2 the times at which B and C are evaluated and $\mathcal{N}_2$ and $\mathcal{N}_1$ shift the evaluation to s_2 and s_1, causing F and E to be evaluated at times there stored.

4. The backspace operator (Vlach [1973] appendix).

Add to the language of Priorean tense logic a single unary connective **B**. Let formulas be evaluated at finite (nonempty) sequences of times according to the conditions:

$(t_1,...,t_n) \models \mathsf{P}A$ iff $\exists t_{n+1} < t_n ((t_1,...,t_{n+1}) \models A)$

$(t_1,...,t_n) \models \mathsf{F}A$ iff $\exists t_{n+1} > t_n ((t_1,...,t_{n+1}) \models A)$

$(t_1,...,t_{n+1}) \models \mathbf{B}A$ iff $(t_1,...,t_n) \models A$ (and, if n=0, $(t_1) \models \mathbf{B}A$ iff $(t_1) \models A$)

The truth value of sentence letters depends only on the last time in the sequence, and formulas are considered valid in a model when they are true at all length-one sequences. (50) is now represented

(50d) $A \wedge \mathsf{F}(B \wedge \mathsf{P}(C \wedge \mathsf{F}(D \wedge \mathbf{B}E \wedge \mathbf{BB}F))$.

The indices of evaluation here form a stack. In the course of evaluating a formula new time is pushed onto the stack whenever a Priorean tense connective is encountered and it is popped off whenever a **B** is encountered. Thus, **B** is a "backspace" operator, which causes its argument to be evaluated at the time that had been considered in the immediately preceding stage of evaluation. In terms of this metaphor, Kamp's original "now" connective was, in contrast, a "return" operator, causing its argument to be evaluated at the time that was given at the initial moment of evaluation.

5. Generalization of N-I (Cresswell [1990]).

Generalize the language of Vlach's N-I system just as in solution 3. Let formulas be evaluated at infinite sequences of times and let the truth definition contain the following clauses:

$(s_0,s_1,s_2,...) \models \mathsf{P}A$ iff $\exists s < s_0 ((s,s_1,s_2,...) \models A)$

$(s_0,s_1,s_2,...) \models \mathsf{F}A$ iff $\exists s > s_0((s,s_1,s_2,...) \models A)$

$(s_0,s_1,...,s_i,...) \models \mathsf{I}_i A$ iff $(s_0,s_1,...,s_{i-1},s_0,s_{i+1},...) \models A$

$(s_0,s_1,...,s_i,...) \models \mathsf{N}_i A$ iff $(s_i,s_1,s_2,...) \models A$

A formula is considered valid if it is true at all constant sequences (s,s,....). Then we can express (50) above as:

(50e) $A \wedge \mathsf{F}\mathsf{I}_1(B \wedge \mathsf{P}\mathsf{I}_2(C \wedge \mathsf{F}(D \wedge \mathsf{N}_2 E \wedge \mathsf{N}_1 F)))$.

As in solution 3, I_1 and I_2 store in s_1 and s_2 the times at which B and C are evaluated. Subsequent occurrences of N_2 and N_1 restore those times to s_0 so that E and F can be evaluated at with respect to them.

Each of the systems described in 1-5 has a certain appeal, and we believe that none of them has been investigated as thoroughly as it deserves. We confine ourselves here to a few remarks about their expressive powers and their suitability to represent tense constructions of natural language. Of the five systems, only Cresswell's N-I generalization permits atomic formulas to depend on more than one time. This makes it possible, for example, to represent *Johnson ran faster than Lewis,* meaning that Johnson ran faster in the 1996 Olympics than Lewis did in the 1992 Olympics, by Rmn. We understand R to be a predicate (*runs faster than*) which, at every pair of times, is true or false of pairs of individuals. Since the issues involved in these representations are somewhat removed from the ones discussed here, and since the other systems could be generalized in this way if desired, this difference is not significant. If we stipulate that the truth value of a sentence letter at **s** in Cresswell's system depends only on s_0 then, for each of

the systems, there is a translation of formulas into the classical first order language with identity and a countable collection of temporally monadic predicates and a single temporally dyadic predicate < (and, in the case of nominal tense logic, a countable collection of temporal constants). We say "temporally" monadic and dyadic because, if the base language of these systems is the language of predicate logic, it will already contain polyadic predicates that apply to tuples of *individuals*. The translation maps these to predicates with an additional temporal argument, and it maps tense formulas with free individual variables into classical formulas with those same free variables and additional free temporal variables. The sentential version of Cresswell's **N-I** provides an example. Associate with each sentence letter p a unary predicate letter p^{τ} and fix two (disjoint) sequences of variables $x_0,x_1,...$ and $y_0,y_1,...$. A translation τ from Cresswell-formulas into classical formulas is defined by the following clauses (where $A^x/_y$ is the result of replacing all free occurrences of y in A by x):

i)$\tau p = p^{\tau}x_0$

ii)$\tau PA = \exists y{<}x_0\ (\tau A)^y/_{x0}$, where y is the first y_i that does not occur in τA

iii)$\tau FA = \exists y{>}x_0\ (\tau A)^y/_{x0}$, where y is as above

iv)$\tau I_jA = (\tau A)^{x0}/_{xj}$

v)$\tau N_jA = (\tau A)^{xj}/_{x0}$

To every model M for Cresswell's language there corresponds a classical model M' with the same domain which assigns to each predicate letter p^{τ} the set of times at which p is true in M. τA expresses A in the sense that $(s_0,s_1,...)\models_M A$ iff τA is true in M' under the assignment that assigns s_i to x_i for i=0,1,.... . Viewing M and M' as the same model, we can say that a tense-logical formula expresses a classical one when the two formulas are true in the same models. (Of

course in defining a tense-logical system, we may restrict the class of appropriate models. By "true in the same models" we mean true in the same models appropriate for the tense logic.) A formula with one free variable in the first order language with unary predicates and < might be called a "classical tense". From the translation above we may observe that every Cresswell formula in which each occurrence of a connective N_j lies within the scope of an occurrence of l_j expresses a classical tense. If every classical tense is expressible in tense-logical system, the system is said to be temporally complete.

An argument in Chapter IV of Cresswell establishes that, as long as < is assumed to be connected (so that quantification over times can be expressed in the tense language), every classical tense without < can be expressed in his generalization of the N-l language. It is not difficult to see that this holds as well for Vlach's generalization. For consider the following translation τ mapping Cresswell's system into Vlach's:

$\tau A = N_0 A$ if A is a sentence letter,

$\tau PA = P\tau A$,

$\tau FA = F\tau A$,

$\tau l_i = l_i \tau A$,

$\tau N_i,A = l_x l_{x+1} \ldots l_{2x} N_i l_{x-i} N_{x-i} \tau A$ where x is the successor of the least integer greater than every subscript that occurs in N_i,A.

Then, using the subscripts C and V for Vlach's system and Cresswell's, $\mathbf{s} \models_C A$ iff $(\mathbf{s},0) \models_V \tau A$. So, if A is a classical tense without <, there is a formula A_C that expresses A in Cresswell's system, and τA_C will express A in Vlach's system.

The question of whether every classical tense is expressible is more difficult. As we saw with Kamp's N, questions about expressive power are sensitive to the underlying language. N adds nothing to the expressive power of sentential tense logic, but it does add to the expressive power of predicate tense logic. The examples suggest that the same is true of the backwards-looking and backspace operators. A well known result of Kamp (see Burgess [19**]) states that, if time is like the reals, every tense can be expressed with the connectives U (*until*) and S (*since*) with truth conditions U(A,B) iff $\exists t{>}t_0(t{\vDash}A \wedge \forall s(t_0{<}s{<}t{\rightarrow}s{\vDash}B)$ and S(A,B) iff $\exists t{<}t_0(t{\vDash}A \wedge \forall s(t{<}s{<}t_0{\rightarrow}s{\vDash}B)$. By constructing a pair of models that can be discriminated by formulas with U and S but not by any Priorean formulas, one can show that Priorean tense logic is not temporally complete. A reduction of the sentential backwards-looking and backspace systems to the ordinary ones, therefore, would imply their temporal incompleteness. From the pairs of ordinary models that are indistinguishable by Priorean formulas, we can easily construct pairs that are indistinguishable in the language of Blackburn's dating sentences. (pick corresponding times t and t' in the two models and require that every dating sentence be true exactly at t in the first model and exactly at t' in the second.). So that system also fails to be temporally complete.[16]

For a number of reasons, the suitability of a system of tense logic for natural language should not be identified with its expressive power, and the observation that the formulas in the five systems described here are all expressible as classical tenses does not imply that the language of classical tenses is itself a suitable tense logical system. Although we can express all the classical tenses in English, it is not the tense mechanism that allows us to do so. English sentences like *For every instant t, if t succeeds t_0 there is an instant t', such that t' succeeds t and t succeeds t_0 and John is asleep at t'*, however useful in explaining the meaning of first order

formulas, are not the sort of sentences for which one would expect to find a phrase-by-phrase representatives in an idealized language isolating the tense-and-aspect features of English. One can object to Saarinen's **D**, Blackburn's dating sentences, Vlach's **B**, and Vlach and Cresswell's I_j's and N_j's on similar grounds. It is possible, of course, that some of these systems make particularly good intermediaries between tense constructions of natural language and truth conditions, or that there is some other sense in which they are especially suitable as tense logics for natural language, but such claims need arguments beyond demonstrations of expressive capacity. Indeed the fact that we can express very simply in these languages ideas that in English require complex constructions (perhaps involving quantifier phrases variable expressions) suggests that they are unsuitable on some conceptions of tense logic. On the other hand, if there are ideas we can express simply and uniformly in English, the mere observation that a tense-logical system has sufficient expressive power to somehow express them, may not be evidence in favor of the system. For example, the fact that prefixing a sufficiently long string of backspace operators to an embedded formula causes it to be evaluated at the moment of utterance does not mean that the backspace system is a good model of the English *now*.

Part of the difficulty in judging the adequacy of tense logical systems for natural language is discerning the linguistic data itself. It is not clear, for example, whether *John said he would come* does have the reading indicated in 46a implying that he said he would come *by now*, or whether that inference, when legitimate, is based on (extralinguistic) contextual cues. Similarly, the observation that *Joe said that a child had been born who would become ruler of the world* is consistent with two possible utterances by Joe does not establish that 48 is ambiguous between 48a and 48b. Saarinen maintains that a sentence of the form *A reported that B believed that C*

said John would go has at least four readings, according to whether John's alleged departure occurs in the future of C's saying, B's believing, A's reporting, or the utterance time. Since the first of these readings is true if any of the others is, one can't expect to find a case which *requires* readings other than the first. The plausibility of there being such readings is undermined by observation that a similar ambiguity does not occur when the *would* is in the scope of future operators. *A will report (next week) that B said (the previous day) that C would go* is not made true by A's reporting next week that B said "C went yesterday," as it would if "C would go" could refer to a time future to the utterance moment. While an adequate logic for the tenses of natural language may require greater "time-tracking" capabilities than Priorean tense logic, there is not strong evidence for the thesis that it be able to "remember" at each stage in the evaluation times at which previous clauses were evaluated.

D. Galton's Logic of Aspects and Events

English discourse presumes a universe of events and states with internal structure as well as temporal location. The language of Priorean tense logic is built solely from formulas, boolean connectives, and operators of temporal location. It is reasonable to try to enrich the language so that more of the internal structure of events can be described. In recent years there has been a proliferation of work in this area motivated by concerns in deontic logic and action theory. (See, for example, Jones and Sergot and the references therein.) For the most part, however, that work has not focussed on temporal or natural language considerations. There is a large and growing semantics literature on events and aspect, but much of it is too detailed to be considered part of a "logic" of tense. In this section we sketch some ideas in the spirit of Galton ([1984] and [1987a],

which seem to strike a good balance between simplicity and fidelity to "surface" phenomena of English.

The idea that sentences in the future and present perfect can be represented by attaching **F** and **P** to some more basic sentence is plausible for sentences describing states but not those describing events. *The cat has been on the mat* is true now if *the cat is on the mat* was true before, but to say that *John has built a house* is true now if *John builds a house* was true before is confusing, since we don't normally use the present tense to indicate that an event is true at the present time. (Indeed, since events like house building occur over extended intervals, it is not clear what the "present" time would be in this case.) Let us instead add a class of *event letters* $E_1, E_2, \ldots$ to the language along with two *e-f aspect operators* **Perf** and **Pros**, which attach to event letters to produce formulas[17]. (The tense operators **P** and **F** and the boolean operators, as usual, apply to formulas to form formulas.) Let us provisionally say that an interpretation assigns to each event letter a set I(E) of *occurrence intervals*. **Pros**E is true at t if t precedes (all of) some interval in I(E); **Perf**E, if t succeeds (all of) some interval in I(E). One may wonder what hinges on the distinction between an event's occurring at a time and a formulas's being true at a time. Granting that we don't normally say that *John builds a house* is true, say, in the Spring of 1995, we might find it convenient to stipulate that it be true then if one of John's house buildings occurs at that time. One advantage of not doing so is that the event/formula provides a sorting that blocks inappropriate iterations of aspect operators. Another is that the distinction makes it possible to retain the Priorean notion that all formulas are to be evaluated at instants even when the events they describe occupy extended intervals. The tense logical systems that result from

this language so interpreted will contain the usual tense logical principles, like FA→FPA as well as event analogs of some of these, like ProsE →FPerf E. Some tense theorems logic lack event analogs. For example, FPA→(FA∨PA∨A) is valid when time does not branch towards the past, but FPerfE→PerfE∨ProsE is not (because E may occur only at intervals containing the present moment).

We may add to this logic another e-f operator Prog such that Prog E is true at t iff t belongs to an interval at which E occurs. Thus ProgE asserts that event E is in progress. In view of the discussion in section III D above, it should be obvious that Prog is a poor representation of the English progressive. It can perhaps be viewed as an idealization of that construction which comes as close to its meaning as is possible with a purely temporal truth condition. (Analogous justifications are sometimes given for claims that the material conditional represents the English "if...then" construction.) The new connective allows us to express the principle that eluded us above: FPerfE→PerfE∨ProsE∨ProgE.

Since Zeno of Elea posed his famous paradoxes in the fifth century BC, accounts of events and time have been tested by a number of puzzles. One Zeno-like puzzle, discussed in Hamblin ([1971], [1971a]), Humberstone, and Galton ([1984],[1987a]), is expressed by the following question. "At the instant a car starts to move, is it moving or at rest?" To choose one alternative would seem to distort the meaning of *starting to move*, to choose both or neither would seem to violate the laws of non-contradiction or excluded middle. Such considerations lead Galton to a slightly more complicated interpretation for event logic. Events are not assigned sets of occurrence intervals, but rather sets of interval pairs (B,A), where B and A represent the

times before the event and the times after the event (so that, if time is linear, B and A are disjoint initial and final segments of the set of times.) The clauses in the truth definition are modified appropriately. For example, **Prog**E is true at t if, for some (B,A)∈I(E), t∈-B∩-A, where -Aand -B are those times of the model that do not belong to A and B. **Perf**E is true at t if, for some (B,A)∈I(E), t∈B. For an event like the car's starting to move, any (B,A) in the occurrence set will be exhaustive, i.e., B∪A will contain all times. Such events are said to be *punctual* (although we must distinguish these from events that occupy a "point" in the sense that B∪A always omits a single time). A punctual event does not really occur "at" a time, nor is it ever in the process of occurring. Instead, it marks a boundary between two states, like the states of rest and motion. When E is punctual, **Prog**E is always false, and so the principle **FPerf**E→**Perf**E∨**Pros**E∨**Prog**E reduces to **FPerf**E→**Perf**E∨**Pros**E, which we have observed not to be valid without the stipulation that E is punctual.

We may also wish to add *f-e* aspect operators that apply to formulas to form event-expressions. Galton suggests the "ingressive" operator **Ingr** and the "pofective" operator **Po**, where, for any formula A, **Ingr**A is the event of A's *beginning* to be true, and **Po**A is the event (or state) of A's being *true for a time*. In the "before-after" semantics, these operators can be interpreted by the clauses below:

I(**Ingr**A) = {(B,-B): A is true throughout a non-empty initial segment of -B, and false throughout a nonempty final segment of B}

I(**Po**A) = {(B,C): -B∩-C is not empty, A is true throughout -B∩-C and A is false at some point in every interval that properly contains -B∩-C}

Thus, **Ingr**A is always punctual, and **Po**A is never punctual. Notice that -B∩-C can be a singleton, so that being true for "a time," on this interpretation, includes being true for an instant. We get principles like **Pros Ingr** A→ (¬A∧FA)∨F (¬A∧FA), **PerfIngrPerf** E → **Perf** E, and **ProgPo** A → P¬A∧A∧F¬A. It is instructive to consider the converses of these principles. If A is true and false at everywhere dense subsets of the times, (for example if time is the reals and A is false at all rationals and true at all irrationals) then at the times A is false ¬A∧FA is true, but **Ingr**A has no occurrence pairs, and so **ProsIngr**A is false. Thus the converse of the first principle fails. Likewise, if E occurs repeatedly throughout the past (for example, if time is the reals and I(E)={(-∞,n][n+1,∞)}) then **Perf**E is true at all times, which implies that **IngrPerf**E has an empty occurrence set, **PerfIngrPerf**E is everywhere false, and the converse to the second principle fails. The converse to the third principle is valid, for if P¬A∧A∧F¬A is true at t, then, letting ∩S be the intersection of all intervals S such that t∈S and A is true throughout S, the occurrence set of **Po**A includes the pair ({x:∀y∈∩S, x<y}, {x:∀y∈∩S,x>y}) and **ProgPo**A is true at t. (The principle would fail, however, if we took **Po**A to require that A be true throughout an *extended* period.) As a final exercise in Galtonian event logic, we observe that it provides a relatively straightforward expression of Dedekind continuity (see Burgess [1997]). The formula **PerfIngrPerf**E → P(**Perf**E∧¬P**Perf**E)∨P(¬**Perf**E∧¬F¬**Perf**E) states that, if there was a cut between times at which **Perf**E was false and times at which it was true, then either there was a first time when it was true or a last time when it was false. It corresponds to Dedekind continuity in the sense that a dense frame verifies the formula if and only if the frame is Dedekind continuous.

The view represented by the "before-after" semantics suggests that events of the form

IngrA and other punctual events are never in the process of occurring, but somehow occur "between" times. However plausible as a metaphysical theory, this idea seems not to be reflected in ordinary language. We sometimes accept as true sentences like *the car is starting to move*, which would seem to be of the form **Prog**Ingr**A**. To accommodate these ordinary-language intuitions, we might wish to revert to the simpler occurrence-set semantics. **Ingr**A can be assigned short intervals, each consisting of an initial segment during which A is false and a final segment at which A is true. On this view, **Ingr**A exhibits *vagueness*. In a particular context, the length of the interval (or a range of permissible lengths) is understood. When the driver engages the gear as the car starts to move he invokes one standard, when the engineer starts the timer as the car starts to move she invokes a stricter one. As in Galton's account, the Zeno-like puzzle is dissolved by denying that there is an instant at which the car starts to move. The modified account concedes, however, that there are instants at which the car is starting to move while moving and other instants at which it is starting to move while not moving.

Leaving aside particular issues like the semantics of punctual events and the distinction between event-letters and sentence-letters, Galton's framework suggests general tense-logical questions. The f-e aspect operators, like **Ingr** and **Po** can be viewed as operations transforming instant-evaluated expressions into interval-evaluated (or interval-occupying?) expressions, and the e-f aspect operators, like **Perf** and **Prog**, as operations of the opposite kind. We might say that traditional tense logic has investigated general questions about instant/instant operations and that interval tense logic has investigated general questions about operations taking intervals (or pairs of intervals) to intervals. A general logic of aspect would investigate questions about operations

between instants and intervals. Which such operations can be defined with particular metalinguistic resources? Is there anything logically special about those (or the set of all those) that approximate aspects of natural language? The logic of events and aspect would seem to be a fertile ground for further investigation.

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Notes

1. A portion of this paper was written while Portner was supported by a Georgetown University Graduate School Academic Research Grant. Helpful comments on an earlier draft were provided by Antony Galton. Some material is taken from Kuhn [1984] (in the earlier edition of this *Handbook*), which benefitted from the help of Rainer Bäuerle, Franz Guenthner, and Frank Vlach, and the financial assistance of the Alexander von Humboldt foundation.

2. By "ours" I mean those of the authors discussed in the remainder of the article. Some recent work, including that of F. Palmer and R. Huddleston, say, is more in the tradition of Jespersen than this.

3. A similar claim is made in Vlach [1981]. For the most part, however, the history of English is ignored in contemporary semantics.

4. Many of the older grammars have been reprinted in the series *English Linguistics: 1500-1800 (A Collection of Facsimile Reprints)* edited by R.C. Alston and published by Scholar Press Limited, Menston, England in 1967.

5. From the contemporary perspective we would probably prefer to say here that *had arrived* is a subjunctive preterit which happens to have the same form as a pluperfect.

6. There are actually only six English tense constructions on Reichenbach's count, because two tenses are realized by one construction. The simple future is ambiguous between S,R_E, as in *Now I shall go* or S_R,E, as in *I shall go tomorrow*. Reichenbach suggests that, in French the two tenses may be expressed by different constructions: *je vais voir* and *je verrai*.

7. Unlike ordinary indexicals, verbs do not refer to the locations which they pick out. The verb *loved* still denotes the relation **love**.

8. This is true, for example, of Bennett and Partee. But there is no consensus here. Kuhn [1983], for example, argues that past, present, and future should be taken as (equally fundamental) modes of combination of noun phrases and verb phrases.

9. Many authors restrict the use of the term 'reportive' to event sentences.

10. The proposal is made in these terms in Kuhn [1979]. In Bennett-Partee the idea is rather that the reference time is an interval over whose subintervals the past tense quantifies. Thus the main difference between these accounts has to do with whether the reference time (or range of reference times) can be discontinuous. One argument for allowing it to be is the apparent reference to such times in sentences like *John came on a Saturday*. Another such argument

might be based on the contention Kuhn [1979] that the possible reference times are merely the times that happen to be maximally *salient* for speaker and audience. Vlach [1980] goes Partee-Bennett one further by allowing the past to indicate what obtains *in, at,* or *for* the reference interval.

11. On the theory of focus, see for example Jackendoff, Rooth ([1985], [1992]), and Cresswell and von Stechow. On the nature of presupposition and factivity more generally, Levinson provides a good overview.

12. This argument is not completely decisive. It would seem quite natural to tell a friend one meets at the popcorn counter *I am sitting in the front row.* On the other hand, if one is prepared to accept *I am not sitting in the front row* at popcorn buying time, then perhaps one should be prepared to accept *I sat in the front row before I bought the popcorn* ***and again*** *after.* This would suggest the process went on *twice* during the long interval rather than once.

13. Bennett attributes the idea behind his proposal to Glen Helman.

14. Dowty attributes this idea to David Lewis.

15. They hold that requirement in (45a) that t_2 precede t_0 is not part of the truth conditions for (45) (though it may be implicated). Similarly, they hold that (48a) is the sole reading of III.D.8.

16. There is a weaker sense in which U and S can be expressed with dating sentences. Let U(**i**,A,B) be i/\F(A/\¬P¬(Fi/\i/\B)) and S(**i,**A,B) be i/\P(A/\¬F¬(Pi/\i/\B)). Then U(i,A,B) is satisfiable in Blackburn's system iff U(A,B) is satisfiable in the since-until system and S(i,A,B) is satisfiable iff S(A,B) is.

17. Galton uses the label 'imperfective' in place of 'e-f', and the label 'perfective' in place of our f-e.