STEVEN KUHN

THE PRAGMATICS OF TENSE[1]

INTRODUCTION

"I reject the contention that an important theoretical difference exists between formal and natural languages," wrote Montague in 1970,[2] and a growing legion of philosophers and linguists have since declared their allegiance to the same creed.

But natural languages do differ from formal languages in at least one obvious way: they are the product of a long evolution that has subjected them to a large number of diverse pressures. Natural languages must be used to communicate quickly and with a minimum of misunderstanding an enormous variety of ideas to audiences which differ in size, proximity and amount of prior knowledge: all this despite the users' limited ability to produce sounds and marks, their limited ability to discriminate among sounds and marks produced by others, their short and often faulty memory, and an innate laziness which makes it unlikely that they will fully exercise the meagre talents that they do possess.

These facts cause one to wonder how natural languages can exist at all, much less in a form that is amenable to the simple kind of description we use for formal languages. There is, however, an important fact that has not yet been mentioned. The users of a natural language are sentient beings sharing a common environment. They therefore have access to a common store of information. The size of this store may vary considerably among groups of language users. When a man talks to his wife he can generally count on more shared information than when he writes a column for readers of next week's *Chronicle*. Nevertheless, I believe that it is the accessibility of some store of shared information which makes communication possible, and that this fact must be taken seriously if Montague and his followers are to be vindicated. In this paper an attempt will be made to illustrate how this can be done. A treatment of the tenses of English will be given within a slightly modified version of Montague's framework. It will be argued that certain assumptions about the common impressions of speaker and hearer can explain (among other things) which tenses are appropriate and which tensed sentences are

Synthese 40 (1979) 231–263. 0039–7857/79/0402–0231 $03.30

true on a given occasion. The choice of English tenses as an example stems partly from the fact that I have written about the subject before ([10]) and partly from the fact that there is a substantial literature of others on which to draw. Little effort has been made to trace each idea to its sources in the literature, but a partial bibliography of relevant papers is included.[3] I believe that the kind of treatment given for tenses here is appropriate for many other features of language as well. In particular, I believe that some of what is said here about tense is relevant to problems involving pronouns, demonstratives, determiners, and ambiguity.

THE FRAMEWORK

The recent writings about English tense have come from two distinguishable traditions. On the one hand, there have been logicians, wanting to *generalize logic*; on the other, linguists wanting to *formalize English*. The logic generalizers (Prior, Kamp, Gabbay, Segerberg) have given us *formal systems* in which we can represent English inferences more directly than in the formal systems we were familiar with. The English formalizers (Chomsky, Ross, McCawley) have given us *fragments of English* which provide a simpler and more accurate description of grammaticality than the rules we learned in school. The formal systems are generally much simpler than the fragments of English. For example, the sentences of a typical formal system are built up from basic expressions of only two kinds: sentence letters (which are sentences as they stand) and operators (which apply to sentences to form new sentences); whereas the sentences of a fragment of English may be built up from basic expressions of a dozen or more categories. The relative simplicity of the formal systems is no accident. The logic generalizer is happy to *idealize* natural language in order to expose the few key features which interest him. If a linguist is told that he has included sentences which don't correspond to anything in English he will make adjustments, even at the expense of further complicating his fragment. The inventor of a formal system, however, is likely to reply 'So much the worse for English'. Being a logic-generalizer, he is more concerned with the logical properties of his system, properties like completeness and decidability.

In this paper we are more interested in linguistic matters than logical ones, so it is natural that we should turn to the tradition of formalizing English for

our inspiration. But we are particularly interested in how tense affects the *meaning* of a sentence and, until very recently, the English formalizers have neglected what has been called 'the first thing about the meaning of the English sentence',[4] namely, the conditions under which it would be true. Since the very recent literature has not contained very much about tense we shall have to use the logic generalizers' system as a starting point for this work in the succeeding sections. The recent literature does, however, provide a convenient framework within which this work can be carried out. The framework is what might be described as *categorial pragmatics*. In the remainder of this section we will give a brief description of it.[5]

'Pragmatics' is the label which Montague (following Bar-Hillel) gives to the study of expressions whose referents vary with context of use. In particular it includes the study of *sentences* whose *truth-values* vary with context of use. We take the information accessible to the language users as part of the context so for us pragmatics must be a central part of any treatment of natural language. 'Categorial' refers to a particularly simple kind of grammar invented by Ajdukiewicz applied to natural languages by Bar-Hillel. Our goal will be to construct a categorial grammar by which certain complex expressions are generated from simpler constituents and to provide rules of interpretation by which the meaning of a complex expression is obtained from the meaning of its constituents. We start with a fairly simple model which is able to generate and interpret only a small fragment. The model is then revised several times to accommodate more and more complex fragments. We try to minimize the readability problems that plague any such enterprise by consigning technical details to an appendix. The careful reader may wish to consult the appendix occasionally as he proceeds.

Grammar

To construct a categorial grammar we first select a set of strings of symbols which we intend to take as *basic expressions*. Basic expressions are assigned *syntactic categories* which will determine how they may be combined to form complex expressions. Syntactic categories may be regarded as refinements of traditional 'parts of speech'. The class of syntactic categories is given a structure which will facilitate the description of syntax. First, a few *primitive categories* are chosen and each is assigned to zero or more basic expressions. For example, we might choose the category CN and assign it to the expressions 'table' and 'chair'. *Derived categories* are obtained from applying the rule: 'If $c_0, \ldots, c_n$ are categories and m is a natural number, then $c_0/_m c_1, \ldots, c_n$ is also a category. (We usually write '$c_0/c_1, \ldots . c_n$', '$c_0//c, \ldots, c$' and '$c_0///c_1, \ldots, c_n$' for '$c_0/_1 c_1, \ldots, c_n$', '$c_0/_2 c_1, \ldots, c_n$' and '$c_0/_3 c_1, \ldots, c_n$', respectively.) The categories $c_0/_m c_1, \ldots, c_n$ are to be assigned to expressions which can be combined with expressions of categories $c_1, \ldots, c_n$ to form expressions of category c. For example, we might assign the category CN/CN to the basic expressions 'large' and 'brown' so that complex expressions like 'large chair' and 'brown table' fall under the category CN. The 'combination' we have in mind in this case is just prefixing, but not always. To complete the grammar we must spell out, in a list of *syntactic rules*, exactly what the combinations are. We try to choose the categories so that the syntactic rules apply uniformly to expressions of the same category. For example, if CN were assigned to 'table' and CN/CN to 'brown' we might have the following as a syntactic rule:

> If α is an expression of category CN/CN and β is an expression of category CN then the result of prefixing α to β is an expression of category CN.

Given that rule, however, we would not want to assign the category CN/CN to the expression 'which was owned by George Washington'. We can deal with this expression by assigning it a new category, say CN//CN and adding the following to our list of syntactic rules:

> If α is an expression of category CN//CN and β is an expression of category CN then the result of appending α to β is an expression of category CN.

In general, a syntactic rule always has the following form:

> If α is an expression of $c_0/c_1, \ldots, c_n$ and $\beta_1, \ldots, \beta_n$ are expressions of categories $c_1, \ldots, c_n$ respectively, then $F(\alpha, \beta_1, \ldots, \beta_n)$ is an expression of category c_0.

$F(\alpha, \beta_1, \ldots, \beta_n)$ might be formed by concatenating the constituents $\alpha, \beta_1, \ldots, \beta_n$ in some order (as in the previous examples) or by inserting new symbols among the constituents or even by deleting or changing constituents.[6]

It will often be convenient to define F by cases: If $\alpha, \beta_1, \ldots, c_n$ are of one form, $F(\alpha, \beta_1, \ldots, \beta_n)$ is one kind of combination; if they are of another form, it is another kind of combination. This sort of definition seems to conflict with our principle that syntactic rules should apply uniformly to expressions of the same category. But to do away with definition by cases we would have to turn cases into categories. This is a costly move, for if one category is split, then so are all the categories derived from it. How do we choose between simple rules and a simple category structure? There doesn't appear to be any precise and convincing answer to this question, but as a rough guide we allow definition by cases whenever there is some simple principle by which the cases can be distinguished. For example, if 'large' and 'which was owned by George Washington' were both in the category CN/CN we might allow a rule like:

> If α is an expression of category CN/CN and β is an expression of category CN then $F(\alpha, \beta)$ is an expression of category CN where $F(\alpha, \beta)$ is the result of appending α to β if α contains the expression 'which' and of prefixing α to β otherwise.

Of course, if our fragment were enlarged, the principle by which the cases are distinguished might have to be complicated. Eventually we might decide that 'large' and 'which was owned by George Washington' should be placed in separate categories.

Montague and other authors allow syntactic rules of other forms as well, but we believe it is simpler not to. Our austerity concerning rules, however, encourages a certain lenience concerning lexicon. We will use some basic expressions which the other authors probably wouldn't.

Sometimes we may wish to group together expressions which were originally placed in different syntactic categories. For example, in the fragment discussed in the following sections we distinguish initially between *simple sentences* (to which tense operators apply) and *complex sentences* (to which tense operators don't apply). But many of our syntactic rules apply uniformly to both kinds of expressions. For this reason it is convenient to introduce *combined categories* which are assigned to the expressions of several previously defined categories. New derived categories can be obtained from the combined categories these new categories can be combined, and the process can be repeated.

The *expressions* of a category c are the basic expressions to which c is assigned initially together with all the strings of category c which can be generated by the syntactic rules. For convenience we often identify a category with the set of its expressions. In our fragment (and perhaps in any fragment of a learnable language) there are only finitely many basic expressions and syntactic rules. In addition, each basic expression is assigned only one or two categories (and all the categories formed by combining these categories with others). It follows that there will be infinitely many categories containing no expressions at all.

Interpretation

We have now described the form our grammar is to take, but we have said very little about how we shall go about constructing it. There is a reason for this. Our choice of categories, basic expressions and syntactic rules will be determined partly by semantic considerations. We want our grammar to be such that it will be possible to give a procedure for building meanings that parallels the procedure for building expressions.

We don't attempt to handle everything that might be considered part of 'meaning', but restrict ourselves to a formal approximation which we call 'intension'.[7] Certain expressions, like 'the tallest building in France' and 'John Smith' are used to name or *refer to* things.[8] Frege has shown that the notion of reference can be generalized to apply to (declarative) sentences as well, the referents in this case being truth values. For expressions like these intensions are functions from contexts to referents. More specifically, the intension of such an expression is the function which assigns to each context of use the object to which the expression refers in that context. The intension of the 'tallest building in France', for example, assigns a French building to each context. We assign intensions to the remaining expressions by applying the principle that the intension of an expression is determined by the intensions of its parts. We choose the syntactic categories in such a way that all the expressions in the primitive categories are the kind which have referents (i.e., the kind for which 'intension' is already defined). If α is an expression in the *derived* category $c_0/_m c_1 \ldots, c_n$, we stipulate that the intension of α is the *n*-ary function which applies to intensions of expressions $\beta_1, \ldots, \beta_n$ of category $c_1, \ldots, c_n$, respectively, and yields the intension of

the expression $F(\alpha, \beta_1, \ldots, \beta_n)$ of category c_0 which is generated from α and $\beta_1, \ldots, \beta_n$ by a syntactic rule. (If there is no such expression, the function may be left undefined.) In this way we insure that the intension of $F(\alpha, \beta_1, \ldots, \beta_n)$ is determined by the intensions of its parts. To be precise the intension of $F(\alpha, \beta_1, \ldots, \beta_n)$ is $f(g_1, \ldots, g_n)$ where f is the intension of α and $g_1, \ldots, g_n$ are the intensions of $\beta_1, \ldots, \beta_n$. It follows that we can 'compute' the meaning of any expression step by step from the meanings of the expressions from which it was generated.

Of course, we have to start somewhere. Ideally, we would specify outright the intension of each basic expression. For example, if 'Mother' were a basic expression we might associate with it a function that assigns the speaker's mother to a large number of contexts and the listener's mother to a smaller number. But it would be difficult, and not particularly worthwile, to try to spell out exactly what this function is. We are willing to put off the question of what 'Mother' means in order to proceed with the more manageable question of how the meaning of 'Mother knows best' is related to the meaning of 'Mother'. So, instead of specifying any particular intension we merely state that 'Mother' is one of those expressions which always refer to people or, more broadly, one of those expressions which always refer to things. In general, we divide the basic expressions into semantic categories called *types* and specify an appropriate form for the intensions of all the expressions of each type. Since the intensions of expressions in derived categories are fixed once those in the primitive categories are, we really only need to divide the expressions in primitive categories.

From the description so far given it might seem desirable to create a large number of semantic categories in order to make the range of possible meanings of a given expression narrow. It turns out, however, to be more convenient to assign expressions from the same syntactic category to the same semantic category. Syntactic categories can then be named so that the intensions of their members are revealed.

The method of interpretation we have described can be illustrated by a simple example. Suppose 'nearby table' is an expression of the primitive category CN which is formed by combining the basic expression 'nearby' of category CN//CN with the basic expression 'table' of category CN. If CN contains only expressions like 'table', 'white horse' and 'doctor of medicine' we might place the members of CN into the semantic category of expressions which refer to sets of things (the referents of 'table' and 'white horse' being the class of all tables and the class of all white horses). The expressions in CN//CN would then have as intensions functions from 'CN-intensions' to CN-intensions. If f is the intension of 'nearby' and g is the intension of 'table' then the intension of 'nearby table' is $f(g)$. Notice that, although it is reasonable to suppose that g is a constant function, it is not reasonable to suppose $f(g)$ is.

We have been talking loosely about 'the intension of an expression'. This talk is misleading. We have not ruled out the possibility that a basic expression might belong to several different semantic categories, each associated with a different class of permissible intensions. So an intension isn't assigned to a basic expression alone, but to such an expression *relative to one of its categories*. Furthermore, a complex expression might be generated in several different ways. With the simple rules described above, for example, the expression 'brown chair which was owned by George Washington' can be obtained by combining 'brown' with the result of combining 'chair' with 'which was owned by George Washington', or by combining 'which was owned by George Washington' with the result of combining 'brown' with 'chair'. There is no guarantee that the resulting intensions will agree. So an intension is not assigned to a complex expression alone, but to such an expression *relative to one of its derivations.*

We have also been talking loosely about the *context* in which a sentence occurs. Actually we are not interested in everything that might be considered a part of context, but only in those features which affect the truth value of the sentences of our fragment. This information is summarized in n-tuples called *indices.* For example, an index suitable for a fragment containing sentences in the present perfect tense with the pronoun 'I' might be a pair (t,u) where t is the time at which a sentence is produced and u is the person who produces it. Some time-person pairs (like (George Washington, New Years 1977)) are obviously not the indices determined by any context, but it turns out to be convenient to call these tuples indices as well. To be precise, a set of indices is closed under the rule that if a and b are indices then so is the result of replacing any coordinate of a by the corresponding coordinate of b.[9]

Meaning postulates

We wanted a simple account of how the meaning of an expression is determined from the meaning of its constituents, and now we have one. But our achievement seems a little empty. It isn't very revealing, for example, to say that the word 'large' refers to some function from sets of things to sets of things. Surely, we can give a better account than that.

There are at least two ways we could try to build more content into our framework in response to this objection. First, we could allow the intensions of some complex expressions to be determined by some method other than functional application. Second, we could place more restrictions on the kinds of functions than can serve as the intensions of particular basic expressions.

In the literature both of these strategies are adopted. But in using the first we would be losing a great deal of the simplicity which we were so anxious to obtain. In our fragment, therefore, we stick to the function-and-argument approach to meaning. Meanings are specified more completely only by restricting the classes of possible interpretations of basic expressions. The restrictions are called 'meaning postulates'. For example, if I ('large', CN/CN) is the intension of 'large' with respect to CN/CN one meaning postulate might require that, for all N-intensions f and all contexts C,(I ('large', CN/CN) (f)) (C) $\subseteq f$(C). So a large chair must always be a chair; a large table, a table. Notice that there are still many possible intensions for 'large'. Sometimes a meaning postulate will be so restrictive that the intension of an expression can be uniquely determined. In our fragment, this will be true of the expressions 'and', 'or', 'not', 'PAST', 'FUT', 'NOW', 'PROG', 'PERF', 'whenever', 'when', 'after', 'before', 'tomorrow', 'yesterday', and 'today'.

TENSES AS OPERATORS

As an illustration of how linguistic data is to be fit within a framework like the one sketched above, Montague ([21]) discusses a fragment which contains sentences in the present, future and present perfect tenses. Tenses are viewed as *ways of building sentences.* There are three syntactical rules by which a sentence can be generated from a 'term' and an intransitive verb. The first generates a present tense sentence; the second, a future; and the third, a present perfect. This approach could obviously be extended to cover the more complicated tense constructions as well, but the result would be uneconomical and unilluminating. As many as twelve different sentence generating rules would be needed. These rules would not reveal, for example, the fact that the construction (and meaning) of the future perfect progressive is related to that of the present perfect progressive in exactly the same way as the construction (and meaning) of the simple future is related to that of the present.

A better approach is provided by tense logic. Tense logic generalizes the ordinary predicate calculus by taking sentences to be true or false *at a time* rather than simply true or false. Tenses (or their formal analogs) are seen as *operators* which apply to sentences to form new sentences. For example, if p is a sentence of tense logic then we can apply a 'past tense' operator to p. The resulting sentence is true at a time just in case p is true at some earlier time.

In the usual tense logics the 'tensed' sentences are formed by simply concatenating the operators and the original sentences, but this construction could easily be modified so that the sentences look more like English. Unfortunately, however, the interpretations these sentences get in tense logic are not very good approximations to their meanings in English.

Perhaps the most obvious discrepancy between tensed English sentences and formulas of tense logic is that the former may describe events which take place over a period of time, whereas the latter are always evaluated at points representing instants of time. The sentence 'John builds the house', for example, describes what happens during an interval that includes both the moments John spends laying the foundation and those he spends shingling the roof. To describe the state of affairs at a particular instant of this interval there is a special construction: 'John is building the house'.

An even more fundamental shortcoming of the traditional tense logics is that formulas are evaluated only relative to their *utterance times*. In natural languages the context in which a sentence is uttered often indicates that it should be evaluated relative to some other time. The formula representing 'Baltimore won the Pennant', for example, is true at time t if there is some time preceding t at which 'Baltimore wins the Pennant' is true. But a sentence like 'Baltimore won the Pennant' is usally uttered with a specific time in mind and is considered false unless the event described took place at that time. In other words, past tense sentences are generally taken to be making an implicit reference to a *specific* prior time.[10] To express the idea that there was *some* prior time at which the event occurred it is more natural to use the present perfect, e.g., 'Baltimore has won the Pennant'. In traditional tense logics, however, there is no way to distinguish between simple past and present perfect.

The first of these problems can be solved fairly easily. We simply divide the sentences of our fragment into two categories: interval-evaluated sentence ($t(\text{-})$) and instant-evaluated sentence ($t(\cdot)$). 'John builds the house' belongs to $t(\text{-})$ but there is another expression, 'PROG' of category $t(\cdot)/t(\text{-})$ which can be combined with it to form a new expression – 'John is building the house' – of category $t(\cdot)$. A meaning postulate guarantees that any combination of a sentence α with 'PROG' is true at an instant i if and only if there is some interval containing i at which α is true.[11]

Notice that this treatment can account for the fact that some sentences cannot be put into a progressive form. The present tense sentences 'John knows the cat' and 'The cat is on the mat' are already instant-evaluated, so PROG cannot be sensibly applied to them. Similarly, since the operation of forming the progressive tense always produces instant evaluated sentences, that operation cannot be iterated. (If it weren't for syntactic facts like these we could incorporate the distinction between interval-evaluated and instant-evaluated sentences in the meaning postulates without increasing the number of categories.) The fact that 'Baltimore wins' does have a progressive form is evidence that it should be evaluated at a game-long or season-long interval rather than at the end point of such an interval.

The second problem is a little more difficult to handle. We would like to say that a sentence like 'Baltimore won the Pennant' should be evaluated relative to some 'reference time'. which is determined by the context in which it is uttered. But we can't simply ignore the utterance time. For we do not want to accept the sentence as true unless the time referred to precedes the utterance time. Uttered today in a discussion about the events of 1980, the sentence is simply *inappropriate*. Our tentative solution is to evaluate sentences relative to two times, an utterance time and a reference time.[12] Then 'Baltimore won the Pennant' is true when uttered at time t with reference to i if i precedes t and 'Baltimore wins the pennant' is true at i. If i does not precede t the sentence is assigned no truth value, but is simply declared inappropriate. Similarly, 'Baltimore will win the Pennant' uttered at t with reference to i is true if 'Baltimore wins the Pennant' is true at i and t precedes i, false if 'Baltimore wins the Pennant' is false at i and t precedes i, and inappropriate otherwise.

Expressions which are 'inappropriate' in a context are to be regarded as having the same sort of status as expressions which are semantically ill-formed. Linguists have long advocated allowing the grammar to generate nonsense sentences like 'Colorless green ideas sleep furiously' and explaining their oddity semantically. We allow our grammar to generate expressions which don't make sense on some occasions of use and account for the nonsensical occasions semantically.[13]

To say that the time to which a past tense sentence refers is determined by context may seem a little underhanded. The determination of reference times must follow some regular laws, or we could not know whether 'Baltimore won the Pennant' is true or false in a given context. It might be felt that some description of these laws must be part of an adequate treatment for tenses. When the appropriate reference times for a sentence can be determined from the sentence itself I believe that this criticism is justified. Subsequent sections of this paper deal with some of the devices by which reference times can be fixed in English. In many cases, however, the reference time for a given utterance seems to depend on extra-linguistic facts known to speaker and hearer. For example, suppose Bob and Joe each know that the baseball season has just ended, that the other knows that fact, that the other knows that he knows it, and so on. Then when he hears Bob telling him 'Baltimore won the Pennant' Joe has a number of good reasons to believe Bob's remark refers to the current season. The season has just ended, Bob knows the season has just ended, Bob knows that he knows the season has just ended. Similarly, in directing his utterance at Joe, Bob has some good reasons to believe he was referring to the current season: the season has just ended, Joe knows the season has just ended, and Joe knows that he knows the season has just ended. This is just the kind of situation which (as David Lewis has argued in [11]) leads to convention-governed behavior. It seems more fruitful, therefore, to treat the reference times in these cases as 'given' with context than to try to include an account of how they are determined as part of our treatment of tenses. This should not be taken to mean that the time to which a speaker refers is always obvious from the context of his utterances. If speaker and hearer don't have enough of the appropriate knowledge a remark like 'Baltimore won the Pennant' will not be informative at all. When a past

tense sentence is informative, it is because the context does determine a reference time for speaker and hearer.

Our fragment, then, will contain three 'operator' expressions: 'PAST', 'FUT' and 'PROG'. Using these expressions we will be able to form sentences in the past, future and present progressive tenses with the truth conditions we have described. It remains to show how the other tenses are constructed. The present tense in English seems to have at least two different uses. The first, which we might call the 'tenseless' present, is captured by the simple sentences to which our operators apply. 'John builds the house', on this interpretation, means that the house is built during some past, future or partly past, partly future interval determined by context. When the present tense is used with instant-evaluated sentences, however, it is often used to describe the state of affair *at the moment of utterance.* For this reason we add another expression 'NOW' which, like 'PAST', 'FUT' and 'PROG', can be combined with sentences to form new sentences. When 'NOW' is combined with, say, 'The cat is on the mat' it forms the 'new' sentence, 'The cat is on the mat' which is true when uttered at t with reference to i if the tenseless sentence 'The cat is on the mat' is true when uttered at t with reference to t. The present tense also has uses which are not treated in our fragment. Some of these could be captured by applying operators which behave like the expressions 'occasionally', 'habitually', and 'it is feasible that' to the tenseless present sentences.

'PAST', 'FUT', 'NOW', and 'PROG' are like operators. They combine with sentences to form new sentences. But they are not all alike. The operations of forming the past and future tenses can be performed on progressive sentences to form the past progressive and future progressive tenses respectively. Both the form and the meaning of the new sentence will come out right. (See section V of the appendix). But neither of these operations can be performed on sentences already in the past or future tense, nor can the operation of forming the progressive be performed on a past or future tense sentence. For this reason we further divide the category of sentences. 'PAST', 'FUT', and 'NOW' combine with *untensed* sentences to form *tensed* sentences. The idea is that 'PAST', 'FUT' and 'NOW' are applied to a sentence to locate its reference time relative to the moment of utterance. This information obviously only needs to be supplied once. 'PROG' combines with interval-evaluated untensed sentences to form instant-evaluated untensed sentences.[14]

The additional complication may seem a high price to pay to prevent the unwanted constructions, but subsequent discussion will produce more evidence that the new distinctions are necessary.

To obtain the remaining tenses we add another expression 'PERF' which, like 'PROG', combines with untensed sentences and forms untensed sentences. When 'PERF' is combined with 'John builds a house' which is true when uttered at u with reference to *i* if there is some interval *i'* preceding *i* such that the original sentence is true with reference to that time. The perfect construction is not always construed in this way (as McCawley shows in [16]), but as in the case of the present, we have tried to deal with the most fundamental use. Notice that 'PERF' can be applied to sentences to which 'PROG' has already been applied. The results of such applications will be expressions like 'John has been building the house.' The operators cannot be applied in the reverse order, however, because any sentence formed by an application of 'PERF' is instant-evaluated. 'PAST', 'FUT', and 'NOW' can be combined with sentences built up using 'PERF' to obtain more complicated tense constructions. For example, the result of applying 'PROG', 'PERF' and then 'PAST' to the expression 'John builds the house' will be the past perfect progressive sentence 'John had been building the house.' A table showing all the tenses that can be built up in this way is included in the appendix. The truth-conditions of the resulting sentences appear to be good approximations to their everyday meanings. It should be pointed out that the categories of the tense operators allow one construction that is not often heard in English. The operation of forming perfect tenses can be iterated. It may be that perfect perfects aren't used because they aren't needed. If we assume that time is dense (as English speakers almost certainly do) then the truth conditions for iterated perfects will be the same as those for simple perfects.[15]

ADDING BOOLEAN CONNECTIVES

The account of tenses sketched in the preceding section will not do when our fragment is enlarged to include expressions like 'and', 'or', and 'not'. For if these 'Boolean' connectives are treated in the usual way, combinations of future and past tense sentences will always be ruled inappropriate. There are

circumstances, however, in which a sentence like 'Robinson missed batting practice and Baltimore will lose' seem perfectly intelligible.

Apparently, compound sentences can make implicit reference to *several* times. If we are to incorporate this feature in our fragment we must give some procedure for determining which time is relevant to which clause. One solution would be to evaluate a sentence with respect to a *sequence* of times, where the *i*'th time is understood to be that referred to by the *i*'th clause.[16] For example, 'Robinson missed batting practice and Baltimore lost' is true with respect to (i,j) if 'Robinson missed batting practice' is true with respect to *i* and 'Baltimore lost' is true with respect to *j*. This approach, however, is not very satisfactory. It seems unlikely that the context would really enable a listener to pick out a sequence of times by which he could evaluate the successive clauses in the speaker's utterance. Furthermore, the approach would mean that sentences which are intuitively equivalent like 'Baltimore will lose and Robinson missed practice' and 'Robinson missed practice and Baltimore will lose' could be assigned different truth values.[17]

A better approach, it seems to me, is to say that the context determines a *set* of possible reference times. We determine which time a clause refers to by noticing its tense. We *assume* the speaker's remarks are appropriate and true and we try to choose from among several possible alternatives a reference time which will verify this assumption. Accordingly, we say that the past tense of a sentence uttered at *u* with reference to the set R is true if there is *some* interval or instant in R preceding *u* at which the original statement is true. A conjunction uttered at *u* with reference to R is appropriate (true) if and only if each of its conjuncts is appropriate (true). For example suppose the context indicates that the only possible reference times are the intervals and instants of June 1, 1970. The sentence 'Robinson took batting practice and Baltimore will lose' uttered at gametime on June 1 is considered true if there is some interval of June 1 preceding gametime during which Robinson takes batting practice and there is some interval of June 1 after gametime at which Baltimore wins.

It might be felt that this view sanctions an excessively lenient standard of truth. Suppose, for example, that Baltimore happened to be playing a double-header on June 1. We would then be forced to accept the clause 'Baltimore will lose' as true if Baltimore will win the first game and lose the second. Surely, the critic might argue, 'Baltimore will lose' is false – or at best ambiguous – when uttered in this context. Our reply is that the critic may well be right in calling a particular utterance of 'Baltimore will lose' ambiguous. But it is ambiguous only because the possible reference times have not been made clear. Once the possible reference times *are* made clear we will certainly want to count the sentence true if it describes an event which occurs at any of these times. Suppose, for example, that our questionable clause had occurred in a paragraph beginning 'Next week will see many surprises in professional sports.' Surely we would then count our clause true if Baltimore should lose any game next week.

The changes in grammar needed to accommodate the Boolean connectives are more straightforward than the changes in semantics, but they still require some thought. It might seem natural to place 'and' and 'or' into a category of expressions which combine with pairs of sentences of the same category to form new sentences of that category. But this would allow the tense operators to apply to compound sentences. A sentence like 'Robinson takes batting practice and Baltimore loses' does not seem to have any past tense. The only plausible candidate is 'Robinson took practice and Baltimore lost'. If this were really the past tense of the conjunction both clauses would always refer to the same time. Obviously the sentence is better construed as the conjunction of two pasts. For this reason we include all compound sentences in the same category as the tensed ones. The category names 'untensed sentence' and 'tensed sentence' are replaced by the more appropriate ones, 'simple sentence' and 'complex sentence', 'And' and 'or' combine with all kinds of sentences, but the resulting sentence is always complex. Tenses apply only to simple sentences and produce only complex sentences.

Similar remarks apply to 'not'. What might appear to be tensed negated sentences actually are negated tensed sentences. (After 'Next week will see many surprises in sports', 'Baltimore will not win' is *not* equivalent to 'Baltimore will lose'.) The expression 'not', therefore, is permitted to combine with any sentence to form a complex sentence. This treatment is not entirely satisfactory, however, for it requires awkward rules for negating compound sentences. (See rule S12 in section II of the appendix.)

ADDING TEMPORAL MODIFIERS

The fragment can now easily be extended to include expressions like 'at three o'clock', 'today', and 'tomorrow'. By prefixing or suffixing such expressions to a sentence we narrow the range of times to which it can refer. 'The cat was on the mat yesterday' is true when uttered at u with reference to R if 'The cat was on the mat' is true when uttered at u with reference to the times that occupy the day preceding u. Similarly, 'The cat was on the mat at 3 o'clock' is true when uttered at u with reference to R if 'The cat was on the mat' is true when uttered at u with reference to the set that contains only the 3 o'clock instant. In order to explain the meaning of expressions like 'yesterday' and 'today' we must divide time into intervals representing days. In order to explain the meaning of expressions which mention dates and times we must be sure that the times are ordered like the real numbers.

Syntactically, temporal modifiers seem to be like the Boolean connectives. They apply to all kinds of sentences and produce sentences to which tense operators don't apply. But there is a complication. Temporal modifiers don't apply to negated sentences. For consider an apparent example to the contrary: 'John didn't come home yesterday'. If this were a temporal modification of a negated sentence it would say that there was some time yesterday at which John didn't come home. But the only plausible reading is that John didn't come home at *any* time yesterday, which is expressed by negating a modified sentence. The most obvious solution to this problem would be to introduce a new category for negated sentences and stipulate that temporal modifiers don't apply to the expression in this category. But since negated sentences are easily identifiable (by the presence of the word 'not') a neater solution is possible. We write our syntactic rules so that combinations of temporal modifiers and negated sentences are 'filtered out'. The result of combining 'yesterday' with 'John didn't come home' for example, is the empty string, which is no expression at all. These remarks do not apply to the other Boolean connectives. 'Yesterday John came home at 3 o'clock and Bob came home at 4 o'clock' is interpreted as the temporal modification of a conjunction. (The conjunction is evaluated at the set of yesterday's times.) The alternative interpretation is much less appealing.

Notice that many sentences built using temporal modifiers will be inappropriate in every context. For example, this is true of 'Yesterday John will come home at three o'clock and 'Tomorrow John comes home yesterday'.

'Yesterday John came home' and 'Yesterday John had come home' are both all right (and they don't have the same truth conditions) but 'yesterday John has come home' is always inappropriate. Notice also that the rules account for many ambiguities. Consider, for example, 'Tomorrow John will leave and Mary will come home at three o'clock'.

ADDING RELATIVE CLAUSES

Natural languages are equipped with another device for indicating the time to which a sentence refers. 'When', 'while', 'before', or 'after' can be prefixed to a sentence to form an expression which appears to be of the same status as those considered in the previous sections. 'Yesterday', for example, was treated as a way of signaling that the possible reference times are the intervals and instants of the day preceding the utterance. Similarly, 'When John came home' might be treated as a way of signaling that the possible reference times are the intervals at which John came home. But this isn't quite right. The sentence 'When John came home no one was there' would not be accepted merely because there was one occasion several years ago on which John came home and no one was there. The clause 'When John came home' seems to signal some *unique* time at which the remainder of the sentence must be evaluated.[18] To deal with this problem requires a further revision in our account. Instead of having the context determine merely a set of possible reference times, we require that it determine some kind of order on the set of times. The order represents something like the relative *salience* of the times. The most salient times are the ones that a sentence is most likely to refer to.[19] If α and β are sentences 'When' α β[20] will be true relative to an utterance time u and a salience order S if β holds at the most salient (i.e., S-maximal) time at which α holds. If β never holds or if there is not a unique 'most salient' time at which α holds, the sentence is inappropriate. Similarly, 'Before' α β is true if β is true at some time preceding the unique S-maximal time at which α holds.

'Before' clauses, being temporal modifiers, don't apply to negated sentences. Apparent examples to the contrary, like 'John didn't sleep before Mary came home' turn out to be negations of modified sentences.[21]

Our revision also enables us to refine the treatment of sentences without relative clauses. We count a sentence modified by 'yesterday' true if the unmodified sentence is true at any time which is maximally salient among the times that occupy the day before utterance. To put it another way, a sentence modified by 'yesterday' is true relative to a salience order if the original sentence is time relative to the salience order obtained by pushing all the times not occurring during the day before to the bottom of the original salience order. (See section III of the appendix.) Thus, temporal modifiers are viewed as devices for modifying the salience order determined by a context of utterance. Similarly, the past (future) tense of a sentence is true if the original sentence is true at a time which is maximally salient among the times which precede (follow) utterance. So past and future tense sentences are now always appropriate.

The salience order, like the reference time and the possible reference set which it supplants, is determined by extra-linguistic facts, probably by some sort of convention. In our treatment it is taken to be a part of the context. This is the kind of thing that was meant by the earlier remark that the knowledge and abilities of the language users would be taken seriously.

'WOULD' AND THE PROBLEM OF MEMORY

There is a curious assymmetry about English tenses. The perfect construction allows us to say that something happened sometime in the past, but there is no analogous construction which would allow us to say that something will happen sometime in the future. One explanation for this fact might be that we know so little about the future that in most contexts all future times are equally salient. Under these conditions we have no need for a special 'ferfect' construction – we can use the ordinary future tense to say the same thing.

Whether or not this explanation is correct, it is interesting to note that we do have a perfectly good construction that plays the role of *past* ferfect.[22] 'John would build a house' can be taken as meaning that there is a most salient past time i such that 'John builds a house' is true at some interval succeeding i. As we might expect, the past ferfect construction can also be applied to progressive and perfect sentences, resulting in past ferfect progressives and past ferfect perfects. The latter are hard to find among the counterfactual 'woulds', but one example might be an occurrence in a paragraph beginning 'It was 3 o'clock' of the sentence 'John would soon have built the house'.

Sentences containing the word 'would' feature prominently in writings of authors of the logic-generalizing tradition who are bothered by the problem of 'keeping track of' or 'remembering' reference times introduced by different clauses in a sentence. (See [6], [7], [9] and [32].) Consider for example, the sentence

(*) Abe said Bob thought Charles would leave.

In the framework of the traditional tense logics this can only be represented by something like

(**) $\mathscr{P}\boxed{A}\mathscr{P}\boxed{B}\mathscr{F}p$

where $\mathscr{P}$ and $\mathscr{F}$ are the usual tense operators and $\boxed{A}$ and $\boxed{B}$ are operators representing 'Abe said' and 'Bob thought', respectively. But (**) actually says that there is some time t which preceeds the present such that at t Abe says that at some time t' earlier than t Bob thinks that there is a time t'' later than t' at which Charles will leave. So on this interpretation. 'Charles would leave' must refer to an event following Bob's thinking. A little reflection, however, convinces us that (*) can also be construed so that Charles's leaving follows Abe's saying. The logically-minded writers consider the possibility of adding special operators which, when inserted between the $\boxed{B}$ and the $\mathscr{F}$ in (*) will direct the truth assessor to 'remember' the times used to evaluate some previous clause.

According to our account the appropriate time at which to evaluate a clause is determined by context. In some contexts (*) would mean that Charles leaves following some salient time *before* Bob's thinking. In other contexts the times of Bob's thinking and Abe's saying are maximally salient so Charles's leaving could be an event following either of these times. Notice, however, that for us Charles's leaving after (*) is uttered cannot be a part of the meaning of (*). This can only be expressed by the (unambiguous) sentence 'Abe said Bob thought Charlie *will* leave'.

FURTHER REFINEMENTS

Our original model has now been revised several times and will surely need to be revised again. There are two problems which seem especially important and difficult.

First, our treatment of the progressive makes 'John was building the house' true only if the house eventually gets built. This is unrealistic. The sentence might be uttered, for example, in reply to the question: 'What was going on when the earth was destroyed?' We could, of course, insist that this use of the progressive is wrong: the earthlings *thought* John was building the house, but they were proved wrong. In general, however, we should be wary of censuring usage which our theory doesn't accommodate. The 'unfinished' progressive certainty doesn't seem unnatural enough to be excluded. A proper solution might involve relaxing the requirement that time is linearly ordered, allowing each instant i to be followed by many possible future histories. (Such branching would probably be needed to handle the expression 'might' anyway.) Some of the paths through i (or perhaps initial segments of some of these paths) would be singled out as 'expected' or 'presumed' at i the idea being that at time i the language users don't take the other possibilities seriously. (The actual future history of i would probably need to be singled out as well.) The progressive tense of a sentence would be true at i if every expected path contained an interval including i at which the original sentence was true. I doubt that this treatment would be appropriate for all cases of the unfinished progressive, but perhaps something similar would.

Second, our treatment gives insufficient attention to the linguistic devices for fixing the salience order. We have argued that subordinate clauses may supply the salience order appropriate for evaluating a sentence. A similar role is often performed by previously produced sentences. For example, if 'The street was deserted' is immediately preceded by an utterance of 'John came home at 3 a.m. yesterday', we can be reasonably sure that 3 a.m. yesterday is a maximally salient time (and perhaps the only such). What is needed is a general account of how each new sentence modifies the salience order determined by the previous context. Of course, the new salience order cannot be completely determined by the old context and the new sentence – it may be affected by events silently observed by speaker and hearer. But some account of the role of previous sentences in determining salience orders is needed.

Georgetown University

NOTES

[1] This paper has benefited from the criticism of Elizabet Engdahl, David Lewis, Barbara Hall Partee, Anthony Ungar and the referee. It is based in part on material in the author's dissertation, written under the direction of Kit Fine.

[2] See [18]

[3] A much more comprehensive bibliography is Rainer Bäuerle's *Tempus Zeitreferenz und Temporale Logik: Eine Bibliographie 1940–1976*; published as *Linguistische Berichte* 49 (1977), Fachbereich Sprachwissenschaft, Universität Konstanz.

[4] See [13].

[5] Our framework is basically the same as that described by Montague in [19], [20], and [21]. The forms of syntactic and semantic rules are more restricted than in these papers, however, and this necessitates including in the lexicon expressions which Montague would probably consider syncategorematic. In addition, interpretations are assigned to expressions directly as in [19] and not induced by a translation into intensional logic as in [20] and [21]. The interpretation-by-translation approach seems at first glance an attractive synthesis of the logic generalizing and the English-formalizing traditions. If there were a simple formal system into which any fragment could be translated in a natural way, it would simplify semantical treatments considerably. Unfortunately, it isn't clear that such a 'universal' system has ever been described. We could not translate our fragment into Montague's intensional logic, for example, in the same straightforward way that Montague translates his. (Though we probably could do it by treating times and truth values as special kinds of individuals and by translating sentences of the fragment by names of intensions of individual constants – see [15] for a discussion of this kind of 'unnatural' interpretation.) For this reason it seemed better to deal with the expressions of our fragment directly.

[6] In formal languages complex expressions are usually built up from shorter ones, making it possible to demonstrate easily that the question of whether a string is an expression is effectively decidable. Since $F(\alpha, \beta_1, \ldots, \beta_n)$ may be shorter than its arguments, however, no such demonstration is possible here.

[7] For an attempt to give a fuller characterization of meaning along these lines see [13].

[8] Readers familiar with [21] may object that if this group is to include expressions like 'every man' which seem to fit there grammatically we will have to take its members as referring to sets of properties rather than to things. For simplicity, however, we shall ignore quantifier expression in our treatment.

[9] Since writing this paper I have had the opportunity to read David Kaplan's very persuasive treatise on demonstratives (*Demonstratives*, mimeoed, U.C.L.A.). Kaplan distinguishes between the *context* in which a sentence is uttered and the *circumstances* under which the thing expressed by an utterance might be evaluated. The sentence 'I am alive' is true in any context of utterance because dead people don't speak; but, for any utterance of the sentence by a mortal, there are circumstances in which what is said would be false. My 'indices' can be regarded as summarizing relevant information from both context and circumstance. On a more thorough account, it might be desirable to separate the roles played by each kind of information.

[10] This view will be modified in subsequent sections. Attempts to accommodate Boolean connectives will lead to the idea that past tense sentences make implicit reference to a set of possible reference times. Attempts to accommodate relative clauses will lead to the idea that they make implicit reference to the maximal elements in an ordering that is determined by context.

[11] The wording here is not quite accurate. We will not define truth at an instant i or truth at an interval i, but rather truth at an index in which i plays some special role. (See Appendix.)

[12] We use 'time' to mean either instant of time or interval of time. The utterance time is always an instant, but the reference time may be either.

[13] Tensed sentences are, in this respect, like sentences containing demonstratives. On a plausible account of demonstratives, the sentence 'That man standing in the street is a detective', uttered while pointing toward an empty street, lacks 'content' – it doesn't *say* anything. The sentence is not really gibberish, because we know what it *would* have said uttered in other contexts. Similarly the question of what, if anything, is said by an utterance of 'Baltimore won the Pennant' depends on the context of that utterance. Furthermore, tensed sentences are like sentences containing demonstratives – and unlike sentences of tense logic – in that 'context' must include information about audience as well as speaker.

[14] When logicians want to translate expressions with iterated tense operators into English they use the locution 'it is the case that . . .' This seems to be an expression which changes tensed sentences into untensed ones, i.e., a member of $t(\cdot)/t^*$.

[15] Since this section was written I have come to believe that PERF should *not* be an operator-like expression, but rather an expression which takes intransitive verbs to intransitive verbs. This would make it possible to account for the 'ampliation' properties noted, for example, in [16]. The sentences below illustrate the fact that present perfect sentences, unlike past sentences, seem to be appropriate only when the subject exists at utterance time

(1) Einstein visited Princeton.
(2) Princeton has been visited by Einstein.
*(3) Einstein has visited Princeton.

If PERF applies only to the verb 'visits Princeton', then the inappropriateness of recent utterances can be explained on the same grounds as the inappropriateness of recent utterances of

(4) Einstein plays the violin.

Changing the category of PERF would have no substantial effect on the discussion in the rest of the paper.

[16] This is essentially the suggestion which Lewis attributes to Kaplan in [13]. (The discussion there concerns an analogous problem involving pronouns.)

[17] Some authors have argued that the English 'and' and 'or' are *not* commutative in this sense. The non-commutative connectives they have in mind ('and then' and 'or then') can easily be interpreted by adding a clause to our interpretation of 'and' and 'or'. Our interpretations are appropriate as they stand, however, in many contexts.

[18] As Partee points out in [25], 'when' is also used to mean 'whenever'. This kind of construction however, is easily handled in our framework. (See Appendix.) A more difficult problem is presented by non-temporal uses of 'when'. (For example, 'When p and q are relatively prime the sum of their product and sum is odd.') We don't treat these cases here, but see [14].

[19] A similar device was proposed in [12] as a way of determining the referents of English definite descriptions.
[20] Actually the tenses of α and β may have to be changed. (See rule S9 in section II of Appendix.)
[21] It is worth noting that some expressions which seem to behave grammatically like 'before' and 'after' clauses do apply to negated sentences. Consider, for example, 'John didn't sleep until Mary came home'.
[22] We also have a not-so-good construction that plays the role of future ferfect: 'John will be going to build 'a house'.

BIBLIOGRAPHY

[1] John Clifford, *Tense and Tense Logic, Janua Linguarium, Series Minor*, 215, The Hague, 1975.
[2] M. J. Cresswell, *Logics and Languages*, London, 1973.
[3] M. J. Cresswell 'Interval Semantics and Logical Words', forthcoming.
[4] David Dowty, *Studies in the Logic of Verb Aspect and Time Reference in English*, Ph.D dissertation, University of Texas at Austin, 1972.
[5] R. W. Fiengo, *On the Semantic Interpretation of Tense and Aspect*, Ph.D dissertation, Massachussetts Institute of Technology, 1971.
[6] Dov Gabbay, 'Tense Logics and the Tenses of English', in J. M. E. Moravcsik (ed.), *Logic and Philosophy for Linguists*, The Hague, 1974.
[7] Dov Gabbay, 'Two Dimensional Propositional Tense Logics', in A. Kasher (ed.), *Language in Focus: Foundations, Methods and System – Essays in Memory of Yehoshua Bar-Hillel*, Dordrecht, 1976.
[8] Otto Jesperson, *A Modern English Grammar on Historical Principles*, vol. 4. Heidelberg, 1931.
[9] Hans Kamp, 'Formal Properties of "Now"', *Theoria* 7 (1971).
[10] Steven Kuhn, *Many-sorted Modal Logics*, vols I and II. Number 29 of *Philosophical Studies*, Philosophical Society and Department of Philosophy, University of Uppsala, Sweden.
[11] David Lewis, *Convention: A Philosophical Study*, Cambridge, Mass., 1969.
[12] David Lewis, *Counterfactuals*, Oxford, 1973.
[13] David Lewis, 'General Semantics', in D. Davidson and G. Harman (eds.), *Semantics of Natural Language*, Dordrecht, 1973. Reprinted in [23];
[14] David Lewis, 'Adverbs of Quantification', in E. Keenan (ed.), *Formal Semantics of Natural Language*, Cambridge, 1975.
[15] David Lewis, 'Tensions', in M. K. Munitz and P. Unger (eds.), *Semantics and Philosophy*, New York (forthcoming).
[16] James McCawley, 'Tense and Time Reference in English', in C. Fillmore and D. T. Langendoen (eds.), *Studies in Linguistic Semantics*, New York, 1971.
[17] Richard Montague, 'Pragmatics', in R. Klibansky (ed.), *Contemporary Philosophy: A Survey*, Florence, 1968. Reprinted in [20].
[18] Richard Montague, 'Pragmatics and Intensional Logic', *Synthese* **22** (1970). Reprinted in [20].
[19] Richard Montague 'English as a Formal Language', in B. Visentini et al. (eds.), *Linguaggi Nella Società e Nella Tecnica*, Milan, 1970. Reprinted in [20].

[20] Richard Montague, 'Universal Grammar', *Theoria* **36** (1970). Reprinted in [20].
[21] Richard Montague, 'The Proper Treatment of Quantification in Ordinary English', in J. Hintikka et al. (eds.), *Approaches to Natural Language*, Dordrecht, 1973. Reprinted in [20].
[22] Richard Montague, *Formal Philosophy: Selected Papers of Richard Montague*, ed. by Richmond Thomason, New Haven, 1974.
[23] Peter Mott, 'Dates, Tenseless Verbs and Token-Reflexivity', *Mind* **82** (1973).
[24] Paul Needham, *Temporal Perspective: A Logical Analysis of Temporal Reference in English* (*Philosophical Studies*, No. 25), Uppsala, 1975.
[25] Barbara Hall Partee, 'Some Structural Analogies Between Tenses and Pronouns in English', *Journal of Philosophy* 18 (1973).
[26] Barbara Hall Partee, (ed.), *Montague Grammar*, New York, 1976.
[27] Arthur Prior, *Time and Modality*, London, 1957.
[28] Arthur Prior, *Past, Present and Future*, Oxford, 1957.
[29] Arthur Prior, *Papers on Time and Tense*, London, 1968.
[30] Hans Reichenbach, *Elements of Symbolic Logic*, London, 1947, reprinted New York, 1966.
[31] Nicolas Rescher, 'On the Logic of Chronological Propositions', *Mind* **75** (1966).
[32] Esa Saarinen, 'Bachwards-looking Operators in Tense Logic and in Natural Language', in J. Hintikka. I. Niiniluoto and E. Saarinen (eds.), *Essays in Mathematical and Philosophical Logic*, Dordrecht, 1978.
[33] Dana Scott, 'Advice on Modal Logic', in K. Lambert (ed.), *Philosophical Problems in Logic*, Dordrecht, 1970.
[34] Richmond Thomason, 'Indeterminist Time and Truth Value Gaps', *Theoria* **36** (1970).
[35] Zeno Vendler, 'Verbs and Times', *Philosophical Review* **66** (1957).

APPENDIX: A FRAGMENT OF ENGLISH

I. *Syntactic categories*

Category	*Informal name*	*Abbreviation*	*Basic expressions*
$t(\cdot)$	instant-evaluated sentence	—	—
$t(-)$	interval-evaluated sentence	—	—
t^*	complex sentence	—	—
e	term	—	Baltimore, Robinson, the cat, the Pennant, John, the house
$t(\cdot) \cup t(-)$	simple sentence	SS	—
$t^* \cup SS$	sentence	S	—
$t(\cdot)/e$	intransitive instant verb	IV(·)	is on the mat, knows, is
$t(-)/e$	intransitive interval verb	IV(−)	wins, smiles
IV(·)/e	transitive instant verb	TV(·)	loves, knows, owns, has
IV(−)/e	transitive interval verb	TV(−)	builds, wins

t^*/S	temporal modifier	TM	tomorrow, yesterday, today, at 3 o'clock
TM/TM	temporal modifier modifier	TMM	at 3 o'clock, early
TM/S	relativizer	—	when, before, after
t^*/S	one-place connective	—	not
t^*/S, S	two-place connective	—	and, or, whenever, sometimes when
t^*/SS	tense operator	—	PAST, FUT, NOW, PAST PERF
$t(\cdot)/t(-)$	—	—	PROG
$t(\cdot)$/SS	—	—	PERF
IV(·)∪IV(−)	intransitive verb	IV	is on the mat, knows, is, wins smiles
TV(·)∪TV(−)	transitive verb	TV	loves, knows, owns, has, builds wins
IV∪TV	verb	V	is on the mat, knows, is, wins
		R	smiles, loves, owns, has, builds

II. *Syntactic rules*

Forms of the Basic Verbs

Verb	*Progressive*	*Perfect*	*Past*	*Future*	*Root*
is	—	has been	was	will be	be
knows	—	has known	knew	will know	know
wins	is winning	has won	won	will win	win
smiles	is smiling	has smiled	smiled	will smile	smile
loves	—	has loved	loved	will love	love
owns	—	has owned	owned	will own	own
builds	is building	has built	built	will build	build
has	is having	has had	had	will have	have

The *would*, *does*, and *did* forms of a verb are the results of prefixing 'would' 'does' and 'did', respectively, to the root form.

Subjects and Predicates

(S1) If $\alpha \in t)$–)/e and $\beta \in$ e then $\alpha\beta \in t(-)$

(S2) If $\alpha \in$ t(·)/e and $\beta \in$ e then $\alpha\beta \in t(\cdot)$

(S3) If $\alpha \in$ IV(·)/e and $\beta \in$ e then $\alpha\beta \in$ IV(·)

(S4) If $\alpha \in$ IV(–)/e and $\beta \in$ e then $\alpha\beta \in$ IV(–)

Tenses

(S5) If $\alpha \in t(\cdot)/t(-)$ and $\beta \in t(-)$ then $\mathscr{P}\!rg(\beta) \in t(\cdot)$ where $\mathscr{P}\!rg(\beta)$ is the result of replacing the leftmost basic verb in β by its progressive form.

(S6) If $\alpha \in t(\cdot)$/SS and $\beta \in$ SS then $\mathscr{P}\!erf(\beta) \in t(\cdot)$ where $\mathscr{P}\!erf(\beta)$ is the result of replacing the leftmost basic verb in β by its perfect form.

(S7) If αt^*/SS and $\beta \in$ SS then $\mathscr{T}\!ense(\alpha, \beta) \in t^*$ where $\mathscr{T}\!ense(\alpha, \beta)$ is the result of replacing the leftmost basic verb in β by its future form if α = 'FUT', by its past form if α = 'PAST' and by its would form if α = 'PASTPERF'.

Temporal Modifiers

(S8) If $\alpha \in t^*$/S and $\beta \in$ S then $\mathscr{M}\!od_1(\alpha, \beta)\ t^*$ and $\mathscr{M}\!od_2(\alpha, \beta) \in t^*$ where $\mathscr{M}\!od_1(\alpha, \beta)$ is the empty sequence if 'not' occurs in β and αll otherwise and $\mathscr{M}\!od_2(\alpha, \beta)$ is the empty sequence if 'not' occurs in β and $\beta\alpha$ otherwise.

(S9) If $\alpha \in$ TM/S and $\beta \in$ S then $\alpha\beta'$ TM where β' is the result of replacing each occurrence in β of a verb in future form by that verb's present form.

(S10) If $\alpha \in$ TM/TM and $\beta \in$ TM then $\alpha\beta \in$ TM.

Connectives

(S11) If $\alpha \in t^*$/S, S $\beta \in$ S and $\gamma \in$ S then $\mathscr{C}\!on(\alpha, \beta, \gamma) \in t^*$ where $\mathscr{C}\!on(\alpha, \beta, \gamma)$ is defined as follows: If α is 'and' or 'or' $\mathscr{C}\!on(\alpha, \beta, \gamma)$. If α is 'whenever' then $\mathscr{C}\!on(\alpha, \beta, \gamma)$ is $\alpha\beta'\gamma'$ where β' is as in S9 and γ' is the result of replacing each occurrence of a verb in past form by that verb's would form.

The scope of an occurrence of an expression in a longer expression is the longest string following that occurrence which is a sentence. For example, the scope of 'when' in 'When John won and Mary built the house Robinson smiled' is 'John won and Mary built the house'. An expression which is not in the scope of any occurrence of 'when'. 'before', 'after', or 'whenever' is *unscoped*.

(S12) If $\alpha \in t^*/S$ and $\beta \in S$ then $\mathscr{Neg}(\beta) \in t^*$ where $\mathscr{Neg}(\beta)$ is the expression obtained by applying the following rules to β:

(a) Change each unscoped verb which is not a form of 'is' or 'has' to its does form, unless it is preceded by 'not'. Change each unscoped past form of a verb other than 'was' and 'had' to its did form unless it is preceded by 'has' or 'not'.

(b) Simultaneously change each unscoped 'and' to 'or' and each unscoped 'or' to 'and'.

(c) Simultaneously change each unscoped 'whenever' and 'sometimes when' to 'sometimes when' and 'whenever', respectively.

(d) After every unscoped occurrence of 'will', 'has', 'had', 'is', place a 'not' if there isn't one already and remove the 'not' otherwise.

An analysis tree for the expression α is a finite tree with the following properties:

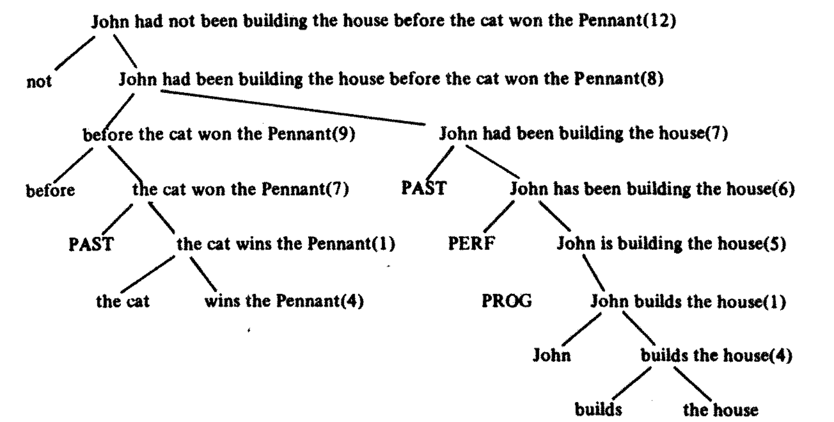
(1) Each terminal node is labeled by a basic expression.
(2) Each non-terminal node is labeled by the expression obtained by applying one of the syntactic rules to the labels of its immediate successors.
(3) The initial node is labeled by α.

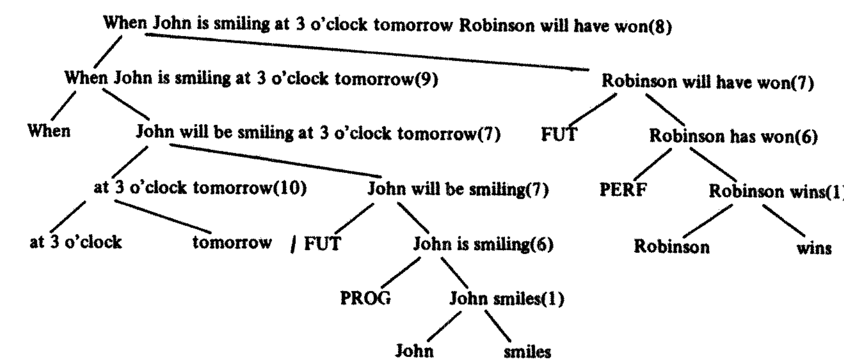
Examples

Shown below are analysis trees for two sentences of our fragment. Numbers shown in parentheses after the labels of non-terminal nodes are the syntactic rules by which these labels are formed.

III. *Interpretation*

Real numbers and intervals of reals are called *times.* The usual ordering of the reals is extended to an ordering $\dashv$ of the set of all times: $u \dashv v$ if and only if u lies entirely to the left of v on the real line. An *index* is a pair (u, S) where u is a real number (the *utterance* time) and S is a simple ordering of the set of all times (the *salience* ordering). A function from the reals into $\{0, 1\}$ is an





instant-marker and a function from the intervals of reals into $\{0, 1\}$ is an *interval-marker.* 'I' is used to denote the set of all indices.

Let A be a non-empty set and c a syntactic category. The set $\text{Int}_A(c)$ of possible intensions of expressions of category c relative to the set A of individuals is defined as follows:

(1) If c is $t(\cdot)$ $(t(-))$ then $\text{Int}_A(c)$ is the set of all f in $\{0, 1, U\}^I$ such that for some instant-marker (interval-marker) g and all indices i with salience order S

$$f(i) = \begin{cases} 1 \text{ if S has a unique maximum } t \text{ and } g(t) = 1 \\ 0 \text{ if S has a unique maximum } t \text{ and } g(t) = 0 \\ \text{U otherwise} \end{cases}$$

(2) If c is t^* then $\text{Int}_A(c) = \{0, 1, U\}^I$

(3) If c is e, $\text{Int}_A(c) = A^I$

(4) If $c = c_0 \cup c_1$, $\text{Int}_A(c) = \text{Int}_A(c_0) \cup \text{Int}_A(c_1)$

(5) If $c = c_0/c_1, \ldots, c_n$, $\text{Int}_A(c) = \text{Int}_A(c_0)^{\text{Int}_A(c_1) \times \ldots \times \text{Int}_A(c_n))}$

A *meaning assignment* (relative to A) is a function V such that for all basic expressions α of category $c\text{V}(\alpha, c) \in \text{Int}_A(c)$. A meaning assignment is *proper* if it satisfies the meaning postulates M1 – M12 listed in the next section. If V is a meaning assignment and T is an analysis tree for the expression α of category c then the intension of α under V relative to T and c is defined in the obvious way.

IV. *Meaning Postulates*

The possible intensions of sentences (i.e., the members of $\{0, 1, U\}^I$) are *propositions*. Functions from propositions to propositions are *propositional operators*. Rationals and intervals of rationals are *times* and functions from contexts to times are *time specifiers*. If $i = (u, S)$ is an index and X is a set of times then the *X-dominated version of i* (written: i^X) is the index obtained by 'hiding' the times not in X. More precisely $i^X = (u, S^X)$ where $w\ S^X\ v$ if and only if either $w \in X$ and $v \in X$ or $w \in X$, $v \in X$ and wSv. If T is a time specifier than the propositional operator determined by T is the propositional operator F such that for all indices i and all propositions p, $(F(p))(i) = p(i^X)$. The *occurrence set* of a proposition p relative to an index $i = (u, S)$ (written: $/p/_i$) is the set of all times t such that $p((u, S^t)) = 1$.

(M1) V('PAST', t^*/SS) is the propositional operator F such that for each proposition p and each index $i = (u, S)$

$$(F(p))(i) = \begin{cases} 1 \text{ if there is a time } t \text{ which is an S-maximal member of the times preceding } u \text{ such that } p(C^{\{t\}}) = 1 \\ 0 \text{ otherwise} \end{cases}$$

(M2) V('FUT', t^*/SS) is the propositional operator F such that for each proposition p and each index $i = (u, S)$

$$(F(p))(i) = \begin{cases} 1 \text{ if there is a time } t \text{ which is an S-maximal member of the set of times succeeding } u \text{ such that } p(i^{\{t\}}) = 1 \\ 0 \text{ otherwise} \end{cases}$$

(M3) V('NOW', t^*/SS) is the function F such that for all propositions p and all indices $i = (u, S)$

$$(F(p))(i) = \begin{cases} 1 \text{ if } p(i^{\{u\}}) = 1 \\ 0 \text{ if } p(i^{\{u\}}) = 0 \\ U \text{ otherwise} \end{cases}$$

(M4) V('PROG', $t(\cdot)/t(-)$) is the propositional operator F such that for all propositions p and all indices $i = (u, S)$

$$(F(p))(i) = \begin{cases} 1 \text{ if there is a unique S-maximal time } t, t \text{ is an instant and, for some interval } x \text{ containing } t, p(i^{\{t\}}) = 0 \\ 0 \text{ if there is a unique S-maximal time } t, t \text{ is an instant and, for all intervals } x \text{ containing } t, p(i^{\{t\}}) = 0 \\ U \text{ otherwise} \end{cases}$$

(M5) V('PERF', $t(\cdot)$/SS) is the propositional operator F such that for all propositions p and all indices $i = (u, S)$

$$(F(p))(i) = \begin{cases} 1 \text{ if there is a unique S-maximal time } t, t \text{ is an instant and, for some time } s \text{ which precedes } t, p(i^{\{s\}}) = 1 \\ 0 \text{ if there is a unique S-maximal time } t, t \text{ is an instant and, there is no time } s \text{ preceding } t \text{ for which } p(i^{\{s\}}) = 0 \\ U \text{ otherwise} \end{cases}$$

(M6) V('not', t^*/S) is the propositional operator such that for all propositions p and all indices i

$$(F(p))(i) = \begin{cases} 1 \text{ if } p(i) = 0 \\ 0 \text{ if } p(i) = 1 \\ U \text{ otherwise} \end{cases}$$

(M7) V('and', t^*/S, S) is the function F in Int_A(S/S, S) such that for all propositions p, q and all indices i

$$(F(p, q))(i) = \begin{cases} U \text{ if } p(i) = U \text{ or } q(i) = U \\ 1 \text{ if } p(i) = 1 \text{ and } q(i) = 1 \\ 0 \text{ otherwise} \end{cases}$$

(M8) V('or', t^*/S, S) is the function F in Int_A(S/S, S) such that for all propositions p, q and all indices i

$$(F(p, q))(i) = \begin{cases} U \text{ if } p(i) = U \text{ or } q(i) = U \\ 0 \text{ if } p(i) = 0 \text{ and } q(i) = 0 \\ 1 \text{ otherwise} \end{cases}$$

(M9) V('whenever', t^*/S, S) is the function F such that for all propositions p, q and all indices i

$$(F(p,q))(i) = \begin{cases} 1 \text{ if } |p|_i \text{ is non-empty and for all t in } |p|_i \; q(i^{\{t\}}) = 1 \\ 0 \text{ if there is a time } t \text{ in } |p|_i \text{ such that } q(i^{\{t\}}) = 0 \\ U \text{ otherwise} \end{cases}$$

(M10) V('sometimes when', t^*/S, S) is the function F in Int_A(S/S, S) such that for all propositions p, q and all indices i

$$(F(p,q))(i) = \begin{cases} 1 \text{ if there is a time } t \text{ in } |p|_i \text{ such that } q(i^{\{t\}}) = 1 \\ 0 \text{ if } |p|_i \text{ is non-empty and for all } t \text{ in } |p|_i \; q(i^{\{t\}}) = 0 \\ U \text{ otherwise} \end{cases}$$

(M11) If α is a basic expression of category TM then there is a time specifier $\mathscr{T}$ such that V(α, TM) is the propositional operator determined by $\mathscr{T}$. Furthermore if α is 'yesterday' and i is an index with utterance time u then $\mathscr{T}(i)$ is the set of all times lying between $[u] - 1$ and $[u]$ (where $[x]$ is the greatest integer less than x). Similarly if α is 'today' $\mathscr{T}(i)$ is the times between $[u]$ and $[u] + 1$; and if α is 'tomorrow', those between $[u] + 1$ and $[u] + 2$.

(M12) If α is a basic expression of category TM/S then for all propositions p, q and all indices i, $((V(\alpha, \text{TM/S})(p))(q))(i) = U$ if $/p/_i$ has no unique maximal element. Furthermore, if $/p/_i$ does have a unique maximal element t then V('when', TM/S) (p) is the propositional operator determined by t, V('before', TM/S)(p) is the propositional operator determined by $\{x: x<t\}$ and V('after', TM/S)(p) is the propositional operator determined by $\{x: x>t\}$.

(M13) V('PASTFERF', t^*/S) is the function F such that for all propositions p and all indices $i = (u, S)$

$$(F(p,q))(i) = \begin{cases} 1 \text{ if there is a time } t \text{ which is an S-maximal member of the times preceding } u \text{ such that for some } v \text{ succeeding } u \; p(i^{\{v\}}) = 1 \\ 0 \text{ otherwise} \end{cases}$$

V. *The Tenses of English*

Tense	Sentence	Operator Constituents (In reverse order of application)	Conditions for truth at index (u, S) where P and F consist of the S-maximal elements or the set of times preceding u and following u, respectively, and X and Y are the occurrence sets of 'John builds the house' and 'The cat is on the mat'.
simple present	John builds the house. The cat is on the mat.	NOW (or none)	$M = \{s\}$ for some $s \in X$ $M = \{t\}$ for some $t \in Y$ (or $u \in Y$)
simple past	John built the house. The cat was on the mat.	PAST	$\exists s \in P(s \in X)$ $\exists t \in P(t \in Y)$
simple future	John will build the house. The cat will be on the mat.	FUT	$\exists s \in F(s \in X)$ $\exists t \in F(t \in Y)$
present progressive	John is building the house.	NOW, PROG	$\exists s$ ($u \in$ Interior(s), $s \in X$)
past progressive	John was building the house.	PAST, PROG	$\exists t \in P \; \exists s$ ($t \in$ Interior(s), $s \in X$)
future progressive	John will be building the house.	FUT, PROG	$\exists t \in F \; \exists s$ ($t \in$ Interior(s), $s \in X$)
present perfect	John has built the house. The cat has been on the mat.	NOW, PERF	$\exists s$ ($s < u$, $s \in X$) $\exists t$ ($t < u$, $t \in Y$)
past perfect	John had built the house. The cat had been on the mat.	PAST, PERF	$\exists t \in P \; \exists s$ ($s < t$, $s \in X$) $\exists t \in P \; \exists t'$ ($t' < t$, $t' \in Y$)
future perfect	John will have built the house. The cat will have been on the mat.	FUT, PERF	$\exists t \in F \; \exists s$ ($s < t$, $s \in X$) $\exists t \in F \; \exists t'$ ($t' < t$, $t' \in Y$)
present perfect progressive	John has been building the house.	NOW, PERF, PROG	$\exists t \; \exists s$ ($t < u$, $t \in$ Interior(s), $s \in X$)
past perfect progressive	John had been building the house.	PAST, PERF, PROG	$\exists t \in P \; \exists t' \; \exists s$ ($t' < t$, $t' \in$ Interior(s), $s \in X$)
future perfect progressive	John will have been building the house.	FUT, PERF, PROG	$\exists t \in F \; \exists t' \; \exists s$ ($t' < t$, $t' \in$ Interior(s), $s \in X$)
past ferfect	John would build the house. The cat would be on the mat.	PASTFERFF	$\exists t \in P \; \exists s$ ($t < s$, $s \in X$) $\exists t \in P \; \exists t'$ ($t < t'$, $t' \in Y$)

('t' and 't'' range over the reals; 's', over intervals of reals.)