Reference to Past Time

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1 PRELIMINARIES

1.1 Introduction

Lyons (1977, p. 637) has defined deixis as 'the location and identification of persons, objects, events, processes and activities being talked about, or referred to, in relation to the spatiotemporal context created and sustained by the act of utterance . . .'. The present paper examines the linguistic apparatus of tense and other related categories which is used to accomplish such deixis to events and states of affairs in the past. In particular, it is concerned with the precise way in which such adjuncts as when clauses do sustain, and indeed change, the spatiotemporal context to which these categories refer.

The problem in formulating the semantics of time reference has always been the extraordinary ambiguity or non-specificity apparent in the linguistic categories that are involved. It seems as if a wide variety of different meanings are distributed rather haphazardly among a handful of linguistic devices. For example, a simple English clause in the past tense, such as

(1) John played 'Cherokee'

may refer to a single occasion of playing, either incomplete or completed, or to a period of repeated playing of the tune. It may also refer to a rather more indefinitely extended period of habitual playing of the tune, or even to the instant with which its playing began. These various meanings may be brought out by the inclusion of different time adverbials, such as for a few minutes, in a few minutes, for ten hours, in those days, and at half past nine, respectively. (Temporal description is of course only one class of meaning carried by past tense. Others are oratio obliqua and counterfactuality. Only the purely temporal meanings will be considered here.) The meanings of time adverbials and subordinate clauses such as when and while clauses, which will be termed 'time adjuncts', are themselves also typically ambiguous. For example, two events related by a complex sentence involving a when clause may either be
simultaneous, or sequential, as in

(2a) When she took my queen, she gave me check.
(2b) When she took my queen, I took hers.

Of course, such protean shifts of temporal description as those ascribed to (1) may also occur in the complex sentences typified by (2). In the following sentence the main clause tends to undergo a change in character from the basic stative meaning of clauses involving the verb to know, to refer to the instantaneous event with which the state of knowing begins.

(3) When he left the party, I knew something was wrong.

Such context-dependent shifts in temporal descriptive meaning occur with great facility, and make the semantics of tense, mood, the auxiliaries, and the time adjuncts particularly hard to capture. They also mean that the literature of this area is unusually fraught with examples of unnoticed ambiguities, and of conflicting and uncertain intuitions. Moreover, while this vast literature describes the varieties of meaning that each category may convey, it has generally proved more difficult to show why just those particular functions rather than some other arbitrary collection, should have been brought

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Figure 1 Various temporal relations that can be conveyed by complex sentence including when clauses depend upon the verbs and auxiliaries of the two clauses
together under a single linguistic roof. As Bennett (1975) has pointed out, it
is essential for a semantic theory to meet this latter criterion.

In this paper, it is proposed that certain apparent ambiguities of tense, the
progressive and perfect auxiliaries, and when and while time adjuncts in
English can best be understood as ambiguities of the process of reference,
rather than of sense or semantics, and that, given an appropriate account
of the mechanism of reference, some apparently diverse meanings con-
veyed by these categories can be seen to be derived from a single sense.

Some impression of the complexity of the interactions of these categories
can be gained from Figures 1 and 2, where tables are presented showing
temporal relations typically expressed by while and when in complex sen-
tences. In each cell of the tables, the temporal extent defined by the subordi-
nate clause appears above a line representing the dimension of time. The
temporal extent defined by the main clause appears below. Where the rela-
tion is unspecific, an arrow represents the direction of variability. Where the
sentences in a cell are odd or anomalous, the anomaly is indicated by one or
more question-marks.

1.2 Reference

It has often been pointed out that tense is anaphorically and deictically
referential in character (McCawley, 1971; Partee, 1973; Isard, 1974; Lyons,
1977). That is, just as the anaphoric pronoun he demands an antecedent in
the preceding conversation, so, as McCawley points out, sentences like (1) must have an antecedent past time for their tense to refer to. If no such reference time has been established in the preceding conversation, say by a when clause such as When I was at Jim’s last night, . . . , then (1) will be unacceptable.

It is arguable that the most successful theories of reference to date are those theories which have been expressed as or exemplified by computer programs of which Winograd’s (1972) was an early example. Winograd’s program could carry on a ‘conversation’ with a human operator concerning states of affairs in a simulated universe of discourse representing a table-top upon which a number of child’s blocks were to be found. The program’s principal capabilities were to obey orders concerning this ‘Blocks World’, and to answer questions both about its current state, and about past situations that had occurred in the course of the conversation. The orders and questions could involve a wide range of expressions referring to objects in the world, including quantified expressions, such as the box, a big red pyramid, all blocks, any cube, and so on. Some of these references could be anaphoric in nature. For example, an expression like the block, in the context of a simulated world containing several blocks, achieves its reference by causing the recent conversation to be examined for mention of a suitable object, as do more purely anaphoric expressions such as it and that.

Winograd’s program also allows a simple kind of reference to events that have taken place during the conversation. For example, it can answer questions such as

(4) Did you pick up anything red while you were building the steeple?

As an account of time reference, it is greatly simplified with respect to the problems outlined in the introduction to this paper, and his way of handling questions like (4) is rather different to the procedures that will be suggested here. However, the present theory shares the feature of being embodied in a computer program, and also exploits the clear relation that such programs express between the semantics of an expression and the context in which it is used, in order to express both the sense and the reference of tense, the progressive and perfect auxiliaries, and the time adjuncts.

1.3 The nature of temporal descriptions in English

It has frequently been noted that many languages embody a parallel between concepts of space and of time. In English, nearly all locative prepositions are also temporal prepositions, and the concept of deixis has been applied to time as well as to space. In particular, tense is a quasi-spatial, deictic category (cf. Lyons, 1977; Miller & Johnson-Laird, 1976).

The classic localist account of the nature of tense and time reference is that
of Reichenbach (1947). According to his scheme, the distinctions of tense are
distinctions between the relationships of three points along a time-line. These
three points are the utterance time, or time of speaking (U), the reference
time (R), and the event time (E). For example, the past perfect in sentence
(5) is held to describe the event of John’s winning as being in the past with
respect to a reference time which is itself in the past with respect to the time of
utterance:

(5) John had won.

By contrast, a simple past tense conveys an event time simultaneous with
the reference time, both being in the past with respect to the utterance time.
Such relationships are conveniently represented pictorially, as in (6):

(6) \[ \begin{array}{ccc}
E & R & U \\
\cdots & \cdots & \cdots & \cdots \\
\text{past perfect} & \text{simple past}
\end{array} \]

Reichenbach’s scheme was intended, in part, to explicate the meaning of
time connectives, such as when. For example, the meaning of

(7) When Fred arrived, John had won

depends on the identity of the reference points in the two clauses, and may be
represented diagrammatically as follows, where \( E_1 \) represents Fred’s arrival
and \( E_2 \) John’s winning:

(8) \[ \begin{array}{ccc}
E_1, R & U \\
\cdots & \cdots & \cdots & \cdots \\
E_2
\end{array} \]

Reichenbach (1947) embodied this behaviour of when clauses in the principle
of the ‘positional use of the reference point’.

Reichenbach’s scheme neatly expresses the quasi-spatial and deictic nature
of tense and time reference and many subsequent theories of tense and the
auxiliary system have built upon its foundation (e.g. Bull, 1963; Isard &
Longuet-Higgins, 1971; Smith, 1975, 1978; Hornstein, 1977). In particular,
Isard (1974) considerably extended the idea to encompass the semantics of
conditionals and counterfactual conditionals, of modal verbs, and of when
relative clauses. The current paper stems directly from his work on the last of
these categories.

1.4 Tense and time reference

The task for Isard’s (1974) program was to answer questions, posed in type-
written English, concerning the moves in a game of tic-tac-toe, or noughts-
and-crosses, which it played with its operator. Typical questions were

(9a) Could you have taken square four when I took square five?
(9b) If I had taken square four when I took square five, what would you have done?

The *when* clause in such questions was evaluated first, to yield a new referent for the past tense marker—in the above cases, by searching for that situation in the game’s history at which the operator took square five, or for the situation immediately following. (Counterfactual conditionals and moda verbs were handled using simulated possible states of play, in addition to the single Reichenbach line of factual time.) Once this had been done the main clause could be evaluated solely by examination of the situation that had been identified by the *when* clause. Where there was no *when* clause in a question for example

(10) Could you have won?

the program would take the reference time to be the one most recently established.

In expressing the role that *when* clauses play in setting up a tempora referent, Isard’s account goes considerably beyond Reichenbach’s. It is no enough to say, as he did, that the reference times of main and subordinate clauses must coincide. The *order* in which subordinate and main clause are evaluated is crucial for the language understander, since natural language expressions are typically extremely ambiguous with respect to the events to which they refer. For example, consider the following question, asked about an party at which the hearer was present:

(11) When the band played ‘Autumn Leaves’, did Arthur dance with Alison?

There may have been many occasions on which Arthur danced with Alison. In answering the question, the order in which the two events are considered makes no difference, *once the particular events in question have been identified*. But in order to identify the particular instance in question of Arthur’s dancing with Alison, it is essential to first identify the period of the band’s playing the tune in question, and only then to search for an instance of the main clause event in that temporal vicinity. (This will be necessary if further questions about this *particular* instance are to be answered, for example.) It is in explicating these pragmatic aspects of *when* clauses that the computational account can be claimed to add something to the logic-based accounts of Reichenbach and his direct descendants.³

It was a virtue of Isard’s program that its extremely circumscribed universe of discourse allowed him to tackle several difficult problems in the semantics of tense, mood, and aspect. Nevertheless, it is inevitable that certain idiosyn-
cracies of the world of tic-tac-toe games makes his account less than general. In particular, the fact that the only events that can be discussed are instantaneous moves of the game, and the fact that only one of these events can occur at a time, mean that a great deal of the semantics of connectives like when and of sentences in the perfect, and all of the semantics of while and of progressive sentences, cannot be illustrated. Moreover, as he pointed out himself, his method of resolving the ambiguity of when clauses, as between the ‘simultaneous’ and ‘sequential’ meaning, exemplified by sentences (9a) and (9b), was ad hoc.

1.5 ‘Events’ and ‘situations’

The distinction between instantaneous events and those which occupy a period of time is only the most obvious of those which are made more or less explicit in natural languages. Many linguists and philosophers have been concerned to enumerate the varieties of temporal or ‘aspectual’ event-descriptions that are distinguished in English, some of which were mentioned in passing in the introduction to this paper. In particular, Vendler (1967), working in a philosophical tradition that includes Ryle (1949) and Kenny (1963), classified English verb-groups into four temporal categories. He derived his classification by observing restrictions upon the co-occurrence of the verb-groups with time-adverbial phrases, such as in an hour and for an hour. More recently, Verkuyl (1972), Dowty (1972, 1977, 1979), Heinamaki (1974), Bennett (1975), Comrie (1976), Steedman (1977), and Ritchie (1979) have elaborated this basic scheme.

Many of these authors have pointed out that few verbs fit neatly into a single one of these temporal categories. Indeed, most verbs, whatever their ‘core’ or basic temporal category, can be made to take on any temporal category by an appropriate choice of auxiliary or adverbial, as in example (1). Hence, as Verkuyl (1972) argued, these categories should be regarded as classifications of whole propositions, rather than of verbs. It will therefore be important to bear in mind throughout the discussion below that the temporal character of a proposition whose verb we regard as bearing a certain core temporal category may without warning take on a quite different character. While many of the distinctions drawn by Vendler and his followers, such as that between periods with and without conclusions, will not be treated here (but cf. Steedman, 1977), the way that instants can become periods of intermittent repetition of the core instant will be treated. One basic distinction of temporal character will be very frequently drawn upon. A distinction will be drawn between ‘events’ and ‘situations’. The former category includes all definite instants and periods of activity, subsuming in particular Vendler’s categories of ‘achievements’, ‘activities’, and ‘accomplishments’. The latter category includes Vendler’s ‘states’, but also includes sentences bearing progressive and perfect auxiliaries. (McCawley (1971) and Longuet-Higgins
(1973) have pointed out the similarities between such verb groups and statives.) The distinction is related (but not identical) to the durative/non-

1.6 Representing episodes and events

A computer program is being developed that is to answer a wide variety of questions involving the categories discussed above. Its universe of discourse is the changing state of affairs on a computer ‘operating system’. An operating system is itself a program which has the role of overseeing the simultaneous use of a large computer by a number of human users. The users share certain resources, such as printers and paper-tape readers. Apart from the fact that only one person can use such a resource at a time, the users are free to pursue their activities, such as editing and running their programs, at the same time. It should be stressed, however, that the present program uses a simplified simulation of the passage of events in such a system.

The program is to answer questions involving tense, the progressive and perfect auxiliaries, time adverbials and time adjuncts, concerning the course of events on an operating system, much as a witness in a courtroom or in the closing chapter of a detective story might be questioned in detail concerning the precise relation in time of events at the scene of a crime. Such a universe of discourse is considerably more complex than both the Blocks World and the tic-tac-toe world of Winograd and Isard. At the time of writing only the semantic and referential mechanisms have been developed. The syntactic problem of producing the semantic representations from questions posed in English will not be treated here.

The first problem that must be solved in constructing such a program is that of selecting a suitable representation for the history of the universe of discourse. There is no doubt that a simple predicate logic can express the state of each element of the operating system world at each instant of its history, and be used to infer the truth of temporal relations between events in that history. The program employs what amounts to such a logic, embedded in a subset of the POPLER programming language (Davies, 1973) which is itself a descendant of Hewitt’s (1969) PLANNER. PLANNER and its descendants can be regarded as theorem provers in which the number of axioms has been reduced at the expense of increasing the number of inference rules (Davies and Isard, 1972).

However, there is still a serious problem with such a representation of episodes in the operating system world—that is, a logic (albeit one of a rather unfamiliar kind) representing the history of the operating system world in a body of formulae and a number of inference rules. The problem arises from the fact that a body of formulae in a logic is essentially unordered and unstruc-
tured. That is to say that if you are searching for a particular one, you simply have to go through the lot until you find the one you want, or until there are none left. Everything that is known about ‘episodic memory’, or memory for events, including our intuitions about what happens when we answer questions involving when clauses and the like, suggests that our memory of events is very highly structured, and that it is in fact linearly ordered, by analogy with the temporal sequence that it represents. Moreover, it has already been remarked, in considering Isard’s model, that it is of the essence of complex sentences involving when clauses that the when clause be considered first, and that the tense of the main clause be interpreted in anaphoric relation to the referent thus established. However, this obvious intuition about the process of answering questions about episodes is not captured by the kind of model that we have considered so far. Consider, for example, the question

(12) When your son was born, was it snowing?

Having identified the reference time when the child was born, we would still have to examine every formula, including those referring to all occasions on which it was snowing, even though most of these can immediately be rejected as not referring to the reference instant in question. Since we have to examine them, we might as well have found all occasions on which it was snowing first, and then found the reference time. Simply on grounds of efficiency, it would be sensible to go for a different kind of representation, in which the establishment of the reference time restricts the search to some particular subset of the formulae.

Such a representation can be achieved by structuring the formulae into a linear sequence of bundles, each bundle consisting of just those formulae which define successive situations. Stephen Isard (1974) used a very simple version of such a representation. The successive situations were the successive states of the tic-tac-toe board. The description of any given situation consisted in effect of a set of facts defining the ownership of the squares by the two parties. And since each successive state of the game only differs from its predecessor and successor in respect of the ownership of a single square, all that really needed to be kept was an ordered sequence of moves of the game: from these, any given situation could be constructed. Such a representation has an ‘analogue’ character, directly representing and exploiting a property of the world which goes in the literature by the name of the ‘Frame Property’—that is, the fact that there are continuities between successive situations in the real world. This aspect of the representation clearly effects a saving in the number of facts that need to be stored. In such a miniscule world the saving may not be too important, but it will be crucial in representing the more complex episodes of the operating system world. (It was also essential to Isard’s program’s understanding of conditionals and modals, as called on by questions like the following:
(13) If I had taken square three when I took square four, what would you have done?

The same expedient was adopted by Winograd.

The current program exploits the advantages of this kind of representation in a similar way. As in Isard's program, an ordered list of events that have affected the state of the world is kept. And again, a representation of the state of the world at a given time is maintained, as a set of formulae. Also, the effect of a time adjunct such as a *whole* or *when* clause, is to cause this work model to be set to a certain situation in the past. The main clause is then interpreted with respect to that situation. However, apart from this basic similarity to Isard's program (and to some extent to Winograd's) it turns out that the problems associated with handling the kinds of event description that have been described in the introductory sections require a considerable elaboration of the basic scheme.

1.7 Representing period events

In setting up a representation of the kind described in the last section, the first problem is to decide how to represent periods, and how to represent their use as referents, as in

(14) While my program ran, how much CPU time did I use?

Since the representation of the history of the episode is to consist solely of *changes* in the state of the world, and changes of state are by definition instants, the solution to the first part of the problem is simple: we represent periods in the history by noting the instants with which they begin and end. For example, a very much simplified 'history' of a session is illustrated in Figure 3.

The figure represents an ordered sequence of 'bundles' of propositions each defining a number of simultaneous instantaneous changes to the state of the universe of discourse. Each proposition is represented as a data structure enclosed in square brackets, such as

(15a) [[INSTANT START PERIOD] ANN PRINT FILE1],
(15b) [[INSTANT] BETTY LOGIN].

Such data structures correspond to atomic formulae in more traditional logical inference systems. Each begins with a substructure identifying its type (that is whether it is a simple instant like someone logging into the system or the start or end of a period). The type is then followed by a string of symbols which define the particular nature of the event. It will be observed that the history in question is a somewhat artificial one: there are rather a lot of events that coincide exactly in time. It has been set up in this way deliberately, to
allow full scope for the examples that are to follow without making the history too complex.

Such a representation of the history is not unlike that used by Isard, apart from the fact that more than one thing can happen at a time. However, it is clear that in order to represent the temporal reference periods established by utterances like (14) it is no longer possible to identify the temporal referent with a single instantaneous situation or state of the world. Instead, the temporal referent must correspond to a whole segment of the time line, from the start to the end of the reference event, in this case my running my program. Thus the temporal referent itself must be distinguished from the model of the state of the world at any given instant. For the moment, it will suffice to think of the temporal referent established by (14) as a pair of numbers defining the extent of the reference ‘windows’ on the time line.

It should be noted in passing that although the history includes a repeated occurrence of Arthur talking to Alison, and in English these events can be referred to collectively as a repeated event of the kind discussed in the introduction, the fact that instant 1 is the start of such a repetition is not marked explicitly in the history. Such instants must be inferred in a way to be discussed below. Thus, although instants are the primitives of the system, not all
instants are primitive. Certain other kinds of event also are not directly represented in the history—for example, the instants at which the system prints messages to a user that have been left for him by the other users: there is a general rule of inference which says that people get their messages when they log in to the system, to be used in answering questions like

(16) Has Fred received the message that I sent him?

1.8 ‘Simple’ past tense

As long as questions about the operating system world do not involve progressive or perfect auxiliaries, the basic apparatus developed by Stephen Isard is quite adequate, despite the extension to events occupying a period of time. Consider for example

(17a) When Betty logged in, did Bert log in?
(17b) When Betty logged in, did she get my message?

As before, the referent-setting when clause is evaluated first, and it seems to set the context either to the instant of Betty’s logging in, or to the instant just after that. And again, the main clause is evaluated with respect to that reference time.

While clauses involving periods behave in a similar manner, at least when they do not involve the progressive auxiliary, as in

(18) While Ann edited her file, did she use the printer?

The above while clause sets a reference period as the context for the main clause, and behaves in every respect like a when clause. For example, the tense of the following supplementary question has the same ‘pronominal’ reference to the period of Ann’s editing.

(19) How much processor time did she use?

A slight complication is introduced when a when clause involves a period. At first glance the following question seems to ask much the same as (18)—that is, whether the two events were coextensive.

(20) When Ann edited her file, did she use the line printer?

However, this is not generally true of when clauses involving periods. Consider

(21a) When Ann edited her file, did John use the line printer?
(21b) When Ann ran her program, did John sign off?

In the first of these it is not necessarily the case that editing and printing were co-extensive, and in the second, the two events cannot be co-extensive, since one is a period, and the other an instant.
The behaviour of these sentences is due to an aspect of questions with *when* clauses that has not been made explicit up to now. A distinction was drawn using examples such as (2) between a 'simultaneous' and a 'sequential' relationship between events related by a *when* adjunct. However, the latter relationship would be better described as 'con-sequential'. Questions involving the so-called sequential relation invariably implicate or presuppose a consequential effect of the event in the subordinate clause upon that in the main clause, such as *enabling* or *causing* its occurrence. It is this meaning that is understood in all of the above three questions. They take on their particular meanings because one knows, for example, that if someone signs off because someone else runs a program then they may do so at some time during the run, but if someone uses a printer as a consequence of running their own program, then they tend to start at the same time and continue until they stop. The same ambiguity between questions about causation and simultaneity arose in Isard's (1974) tic-tac-toe world. The apparent difference in reference between

(22a) When I took five, did you take seven?

and

(22b) When I took five, did I win?

was handled by Isard simply on the basis of whether the subjects of the two clauses were the same or different. As he pointed out, this was unsatisfactory. In particular, it would give an inappropriate result for a question like

(23) When John logged in, did he get a message?

—where the two events are presumably consequent rather than simultaneous, despite having the same subject. The question of causal or consequential interpretations of time adjuncts is a complicated one, and will be discussed later in the context of the perfect auxiliary, whose meaning is intimately bound up with ideas of intention and cause. The question of exactly what it means to describe two events as standing in this 'consequential' relationship will also be deferred until then.4

*While* does not produce any ambiguity between a temporal meaning and a consequential one. Indeed, it seems expressly to *exclude* the idea of a logical connection between the two events: if you have reason to suppose that Ann's editing *caused* John's use of the printer, then you should ask a question like (21a), rather than the corresponding *while* question. The program represents a *while* or *when* question as a sequence of three 'goals' or steps of inference. The first of these goals is to establish a reference interval as the value of a variable *ref*, by searching the entire history of the episode for examples of the event or situation in the subordinate clause. The second stage is to search the history within that interval for any example(s) of the main clause event or
situation. The temporal extent thus defined becomes the value of another variable, *anaphor*. The third goal is to check that the two times defined by *re* and *anaphor* stand in the relation specified by the type of adjunct and main clause. For example, the question

(24) While Ann edited her program, did anyone use the line printer?

should only be answered affirmatively if the two times are co-extensive—that is, if the main clause event lasts throughout the reference interval defined by the subordinate clause.

The only constraint that has been placed on the search for the main clause events in the above example is that the search be conducted within the bounds of the reference time. Hence it may well happen that more than one instance will be found matching the main clause description. For example, in answering the last question, it may be the case that someone used the printer several times. These states of affairs can be represented graphically by the same kind of extension of Reichenbach's time-line diagram that was used in Figures 1 and 2.

```
(25) ref: [------] [------] [------] [------] [------] [------] [------] [------] [------] [------] [------] [------]

main: [------] [------] [------] [------]

person(s) printing
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In such a context, the simple procedure outlined above behaves in a manner which is strikingly similar to the way that hearers seem to behave with respect to the systematic ambiguity in English between single and repeated events. That is, the program will find *all* the instances within the reference period, whether there is one or there are many. These are collected into one compound event description. Once the period that has been found has been proved to be co-extensive with the reference time, as the *while* demands, the program can answer the question, either with a list of the people who have used the printer, or with a single name, whether or not this person's action was repeated. (Of course, in the case of a repeated action, a human question answerer might well judge it to be helpful to the questioner to mention this fact, by replying 'Jane did, *several times*'. However, the decision to give such a helpful amplification would depend upon inferences concerning the likely purposes of the questioner in obtaining the information. Such inferences are not the concern of this paper (but cf. Steedman & Johnson-Laird, 1978). The important goal for the program is merely to obtain the factual information from which such replies might be constructed. Presumably, a language which marks iterative aspect would only differ in that the last goal of the sequence, corresponding to the relationship established by the subordinate clause, would explicitly specify either a compound repeated event or a simple event.
Perhaps a more important respect in which the program appears to correspond to the human speaker’s treatment of this distinction is in the way it often does not consider the ambiguity. If the program is asked the same question in a context in which, although many people used the line printer, only one such occasion occurred within the scope of the reference period, then it will simply never consider the possibility that the iterative meaning of the question is intended, because its search for the main clause event never proceeds beyond those confines. This too seems to be a natural treatment of the distinction. Consider the case where two human conversants are discussing a party which one of them attended and the other asks

(26) While you talked to Mary, was the band playing?

If the band played several tunes in the relevant period, as part of a longer period of intermittent playing, the events can be represented by the familiar sort of diagram, thus:

ref: | / / / / / / / / / / / / |

(27) __________________________

main: | / / / / | / / / / | / / / / |

In such a context, the non-iterative meaning of the main clause does not seem to arise. By contrast, if the question is

(28) When Jane arrived, was the band playing?

then it is the iterative meaning that does not seem to arise. In particular, if the band wasn’t actually engaged in playing at the relevant time, as in the diagram below, it does not seem possible to answer ‘Yes’ to the question, at least without giving further explanation, even if its silence merely represents a temporary lull in a period of repeated playing.5

(29) ref: __________________________

main: | / / / / | / / / / | / / / / | / / / / |

Similar remarks can be made about the ‘inchoative’ aspectual interpretation of past tense, in which a clause, such as one of the interpretations of sentence (1) in the introduction to this paper, denotes the beginning of the period to which it ‘basically’ refers. However, further discussion of these questions will be deferred until the discussion of causation, with which they are considerably involved.

To summarize: a simple procedure for answering questions about an episode has been presented. It has been argued that the sense of such time connectives as while and when can be naturally expressed within such a framework, and that certain ambiguities of tensed sentences, notably so-
called iterative aspect, can be regarded as a natural consequence of the process of establishing reference, rather than as ambiguities of sense. In the next sections, this argument is extended to sentences including progressive and perfect auxiliaries.

2 THE PROGRESSIVE

2.1 During, throughout, and the progressive auxiliary

While clauses which include the progressive auxiliary verb be also function to set a temporal reference point for succeeding main clauses, like those with simple past tense. Thus the following sequence is directly analogous to the earlier examples:

(30a) While Anne was editing her program, did Betty log in? YES.
(30b) Did Alf log in?

As before, the supplementary main clause (b) is understood to refer to the reference time established in the previous question. However, the nature of this reference time is rather different from that of a definite reference instant or period. For, of course, it is not necessarily the case that Betty’s and Alf’s logging in to the system should have occurred at the same instant during Ann’s editing—merely that they both did it at some such instant.

The notoriously indefinite character of the progressive (Geis, 1970) is no easily captured in the time-line diagrams of Reichenbach’s account, and it is not surprising that those whose work stems most directly from Reichenbach’s (Smith, 1975, 1978; Hornstein, 1977) have not treated the topic in depth (but cf. Bull, 1963).

In order to capture the semantics of while clauses including the progressive auxiliary, two components of Reichenbach’s temporal reference point must be distinguished. One is a definite period or instant, corresponding to the reference event. The other is a reference relation, defining the temporal relationship of the main clause event to the reference event. In the case of a temporal referent established by a progressive time adjunct, as in (30) above the relation of the main clause event to the reference event is that of being included in its scope, and it is this relation which is understood to persist and be available for subsequent simple clauses such as (30b), rather than the time of the main clause event of (30a).

The separation of the step in the computation at which the reference even is found from that at which a particular relation between the two events tested was made in the earlier account of simple past tense, although it only becomes crucial to make this separation in dealing with the auxiliaries. The separation amounts to a distinction between two components in Reichen-
bach’s reference time $R$, as between the reference event and the reference relation. It is not the same as the similarly-named distinction drawn by Smith (1975), which is rather a translation of Reichenbach’s scheme into componential semantic terms. It is, however, related to distinctions drawn by Ritchie (1977, 1979). The two temporal relations that are concerned in the contrast between simple past tense and the progressive are those expressed in English using the prepositions throughout and during, respectively.

The existing apparatus might seem to be adequate to handle progressives as well as simple tensed clauses, simply with the addition of the procedure to test the relation of inclusion as well as that for testing coextension. However, once the effect of progressive main clauses is considered, it becomes clear that some extensions to the theory are necessary. In particular, the program’s model of the state of the world needs further elaboration.

Consider the question

(31) While I printed my files, was Ann editing her program?

—which can be represented by the usual sort of diagram, as follows:

(32) \[
\begin{align*}
\text{ref:} & \quad | / / / / / / / / / / / / |

\text{main:} & \quad | / / / / / / / / / / / / |
\end{align*}
\]

As matters stand so far, the only things that are present in the machine’s representation of a state of affairs in the world are the instants which compose the history of the episode, such as the one laid out in Figure 3. Since the basic procedure for answering questions about events is to conduct a search for the main clause event within the window defined by the reference event, and the instants with which the main clause event begins and ends do not fall within that window, the existing apparatus will not allow the program to answer such questions.

The solution lies in elaborating the program’s representation of the state of the world at a given instant. The program represents data about period events that are in progress in a body of facts, or a ‘data-base’, that describes the state of the world at any given instant, perhaps using atomic formulae of a form like the following

(33) [[IN-PROGRESS PERIOD] ANN EDIT PROGRAM3]

Of course it would be possible simply to include such facts among the ‘bundles’ of instants in the history of the episode. However, with the addition of a few simple ‘housekeeping’ procedures it is easy to make the program add these facts automatically to a representation of the state of the world at any given instant as it searches up and down the history. The apparatus for maintaining such models is well established, and in fact is provided ready-made in
POPLER, in the form of its version of PLANNER 'antecedent theorems'. The same device is used for certain other varieties of situation, such as an individual's being present on the system. The data base representing the state of affairs at time 6 in the history represented in Figure 3 is shown in Figure 4.

Using such a representation of states of affairs in the operating system world, questions like (30) can be answered quite simply; once the reference period in that question has been found, the representation of the state of affairs at every instant in it will express directly the fact that the main clause event is in progress.

The above representation of the progressive is quite compatible with the apparatus described earlier for establishing temporal referents. Since the standard procedure of searching through the episode for instances that match the pattern of the subordinate clause collects every such instance, the same process applied to a progressive such as the one in (34), below, will simply collect together all instants at which the corresponding progressive is in force in a manner precisely similar to the way in which an iterative or repeated event is found:

(34) While Ann was running her program, did Fred log in?

And the period that this process delivers will be of exactly the same extent as the corresponding question with a simple past tense subordinate clause. The difference lies in the reference relation, rather than the temporal extent of the reference event. It is perhaps worth noting in passing that a number of puzzling facts about the relationship between the progressive and simple tenses are explained by such a mechanism. The time adjuncts while she was playing and while she played only differ in the reference relationship that they establish and this relationship is only investigated as the last step in computing the meaning of sentences that include them. Hence it is only investigated after the events in question have been identified. It is therefore not surprising that while the second of the two following statements is strictly speaking anomalous (since John's leaving cannot have been co-extensive with the playing o
the sonata), nevertheless informants are very inconsistent in their judgements.

(35a) While she was playing the sonata, John left the room.
(35b) ?While she played the sonata, John left the room.

Secondly, just as the theory of reference explains why languages are free to vary as to whether they explicitly mark iterative aspect, so it explains why they are similarly free with regard to the marking of imperfective aspect. If the reference relation is distinguished in some other way, there is no practical difference between the progressive and simple tense. (French is an obvious example of a language which has in general no explicit mark of imperfective aspect.) The rule that determines the reference relationship used in the third step of the procedure for while is as follows:

(36) When the subordinate clause is of the ‘event’ variety, the relation is one of co-extension. When the subordinate clause is of the ‘situation’ type, the relation is one of inclusion.

It will be noted that this procedure allows the context to resolve the ambiguity between simple and iterated events in exactly the same manner as was described before for simple past tense.

To summarize this section: by addition of a data base, (of a kind quite standard in the literature of Computational Inference), which represents the state of the world at any given instant in its history, and by distinguishing two components of Reichenbach’s concept of reference time, it is possible to extend the model to cope with certain uses of the English progressive,\(^6\) whilst preserving the efficiency of the earlier representation, and also preserving its natural handling of the disambiguation of iterative and simple meanings of event descriptions. In the next section a further extension to deal with the perfect is considered.

3 THE PERFECT

3.1 Causation and consequence

Of all the categories under discussion here, the perfect is the most complex. Any attempt to characterize the perfect and past perfect in purely temporal terms, as ‘past in present’ and ‘past in past’ does not do it justice, whatever the virtues of Reichenbach’s original scheme and Smith’s (1975) translation of it into componential semantic terms. Unlike the uses of the progressive discussed above (but cf. note 6), the relations that it denotes are not purely temporal. It is not the case that *He had arrived at noon* means no more than *He arrived before noon*. The most basic meaning of the perfect appears to be to
do with the idea that the consequences of the event in question are in force at the (past or present) reference time. Thus, to felicitously say (37) below, it is not enough that John’s arrival be in the past with respect to the reference time (which is in this case the time of utterance). The consequences of John’s arrival, in particular his being present, must also hold at that time.

(37) John has arrived.

All of the many uses that have been distinguished for the English perfect (discussed by Comrie, 1976) appear to partake of this basic idea. Indeed, it seems likely that its temporal meaning may be merely secondary to the ‘consequent state of affairs’ meaning, and stems from the fact that it is in the nature of consequences to succeed their causes in time. (Such a proposal also has the merit of making auxiliary have seem closer to other causative uses of the verb, in sentences like She had it stuffed, I have a bone to pick, and He had to put a finger in the dyke.)

Much of the complex behaviour of the perfect can be explained in terms of this analysis. Sentences with auxiliary have, unlike progressive and simple past tense sentences, do not at first glance appear to behave in all the same manner in time adjuncts as in main clauses. So, whereas (37) refers to the state of affairs consequent upon John’s arrival, the perfect in (38a) seems a first glance to have much the same effect as the simple past tense of (38b)

(38a) When the guest of honour had arrived, the speeches began.
(38b) When the guest of honour arrived, the speeches began.

However, two meanings of when clauses have to be distinguished, one in which when can very roughly be paraphrased by just as, and another which has been rather vaguely related to the idea of causation and consequence, and in temporal terms seems to mean just after. It is only with respect to the second meaning of when that the above sentences are approximate paraphrases. In fact, when with the perfect can never mean the same as just as. Thus, the following sentences are not paraphrases, and the second is anomalous, because the situation of being speaking can hardly be caused by an arrival that occurs after it has begun. Such an arrival could only plausibly cause something like the beginning of speaking.

(39a) When the guest of honour arrived, the chairman was speaking.
(39b) When the guest of honour had arrived, the chairman was speaking.

On such an account, the reference time set up by both past tensed and perfect when clauses will be something like the ‘consequent state’ of the event in question. And the reference relation will similarly not be purely temporal, but will have to do with the main clause’s being a consequence of the event in the subordinate clause. Very often, of course, an event which is a consequence of
another event occurs just after that event. But such is by no means always the case, either for perfect or for simple when clauses, as the following examples will show:

(40) When Fred \{ had finished \} the course, did he \{ take the exam? get the degree? get a job? \}

It appears to make very little difference here whether the subordinate clause is in the perfect or not. (There is nevertheless one crucial difference, which will be discussed below.) And since all of the alternative main clauses are plausible consequences of the reference event, the fact that they would normally occur at very different intervals of time after it (and in the last case, after quite a long interval) does not seem to affect the reasonableness of the question.

If such an analysis is correct, once again a number of notorious problems become less puzzling. For one thing, the perplexing vagueness of the temporal intervals involved in the "just after" meaning of when is understandable (see, for example, Ritchie, 1979, for a sensitive exposition of this problem). The temporal interval denoted will depend entirely upon the nature of possible consequential relations between the two events in question. Another problem for which the analysis seems to suggest a solution is the notorious tendency for the perfect to take over the function of the simple past tense, as it has in the evolution of modern spoken French, and for the reverse to happen, as in some American dialects of English in which the past tense does double duty for both perfect and simple past. Even apart from their inclusion in time adjuncts, references to past events nearly always involve some kind of causal or consequential relation—purely accidental temporal coincidences simply aren't as interesting and important to human purposes. When we refer to an event, we are therefore nearly always concerned with its consequences as well. It is not surprising that the simple past may usurp the consequent state-defining function of the perfect, nor that the perfect may take over the more purely temporal function that is usually assumed to be primary to simple tense.

Unfortunately, the account given above does not exhaust the complexities of the perfect in when clauses. For of course there is a difference in meaning between a perfect when clause and the corresponding when clause with simple past tense. For example, the following is a perfectly unremarkable statement:

(41) When Jane spilled the coffee, Fred cleaned it up.

But the following is most unusual:

(42) ?When Jane had spilled the coffee, Fred cleaned it up.

What is odd about (42) is that it seems to carry the implication that the
spilling of the coffee was predicted by the speaker, perhaps because it was part of an intended or planned sequence. The implication is a curious one to make of such an event. It can be exposed even more clearly by contradicting it with an adverb like accidentally or suddenly: the addition makes the sentence even less acceptable:

(43) ??When Jane had accidentally spilled the coffee, Fred cleaned up the mess.

(Of course there is nothing wrong with such a proposition as a main clause:

(44) Jane had accidentally spilled the coffee.

The distinction brought out above was also latent between different versions of sentence (40).)

Since the distinction has once again to do with the role of the complements event in an overall plan or logical sequence, and since this idea has been associated both with the perfect itself and with the connective when, the question arises as to which of these two entities gives rise to it here. The answer is that it stems from the when, not from the perfect. To show this, it is necessary to step beyond the confines of reference to past events, and to consider for a moment the meaning of when clauses involving present (or rather, non-past) tense.

3.2 Reference to non-past time

A simple clause in the so-called present tense, with or without an auxiliary most basically refers to the time of utterance.

(45a) I win!
(45b) The fish is eating the bait.
(45c) I have crossed the bar.

(As before, other uses of the present tense, such as the ‘historic present’, are ignored here.) All of the earlier remarks concerning the meanings of the auxiliaries in main clauses and the anaphoric nature of tense apply unchanged, with the single provision that the temporal referent to which the present tense most basically refers to the instant of the time of utterance.

However, in a when time adjunct, a present tensed clause apparently refers to anything but the time of utterance:

(46a) When I win, I shall buy champagne for everyone.
(46b) When the fish is eating the bait, I shall shoot it.
(46c) I hope to see my pilot face to face, when I have crossed the bar.

(Again, the meaning of when corresponding to whenever, seen in When I take my sugar to tea I’m as happy as I can be, is not considered here.) What all of these when clauses seem to share, regardless of their auxiliary, is the idea c
the speaker's certain prediction of the proposition in question, whether or not he is correct in that prediction.

The idea of prediction invoked above is exactly the same as that which was needed to express the meaning of a past perfect when clause. The above sentences imply that the time at which the predicting is done is the present reference time (that is, the time of utterance). They also imply that the predicted situation is later than the reference time (that is, in the future). But certain past tensed clauses, including clauses in the past perfect, also denote situations. And the time at which the predicting is done is again the reference time, albeit the past reference time—if one has not been established then a past perfect when clause simply isn’t acceptable. And the predicted perfective situation itself—that is, the consequent state of the event in question—is again to be found later than the reference time.

In fact it seems that all when clauses which include a clause denoting a situation, as opposed to an event (as defined in Section 1.5 of this paper, and in Steedman, 1977), imply that the speaker predicts or predicted the situation in question. For example, stative verbs in past tensed when clauses seem to behave very much like the perfect, for example displaying the same incompatibility with situation-type main clauses that was noted in example (39b):

(47a) When I knew the answer, I immediately phoned the Grange.
(47b) ?When I knew the answer, Fred was telephoning the Grange.

Even past progressive when clauses (which are also defined as situations) seem to share this property, although the effect is a subtler one, and was glossed over in the earlier discussion.

The idea of prediction is not unrelated to the idea of logical consequence invoked earlier, so we must be careful to distinguish them. It will be recalled that, whereas a simple past tensed main clause, such as she won, demands a prior temporal referent for its past tense, a simple past tensed when clause does not. The when clause is rather used to set up a new reference point, and to over-write any prior one. However, the 'predictive' when clauses, including the perfect, do require a previously established reference point, and, like main clauses, cannot be used without one. One may begin a conversation with When Ann came to stay, . . . (provided the hearer can identify the occasion in question), but may not begin with When Ann had come to stay, . . . . The reason is that the latter demands a reference time at which it could be predicted that the person in question would come to stay (or at least attempt to do so). It is only if this condition is satisfied that the usual process associated with a when clause can take over, and the consequent state in question can be found.

Thus we distinguish two components to the idea of cause and consequence which has so bedevilled the above discussion of the temporal categories. The perfect denotes the state of affairs that is consequent upon the event which the
perfect dominates. On the other hand, the connective \textit{when} with a situation a
its complement seems to mean that the speaker can or could \textit{predict} the
situation. Since the most common basis for a prediction is that one knows the
chain of causes and consequences of which it is a part, it is perhaps no
surprising that these two aspects of temporal meaning, which are logically
quite distinct, interact in such a complex fashion.

It might seem that this idea of predictability at a reference time, invoked to
explain the behaviour of perfect \textit{when} clauses, considerably complicates the
idea of reference time itself. It is true that the notion that has been used so far
according to which the reference time of Reichenbach is represented as a
reference event or ‘window’ on the time-line (together with the reference
relation), will have to be elaborated once more. However, it will become
apparent that the elaboration in question is exactly what is needed in order to
explicate the further problem of the ‘consequential’ meaning of \textit{when} clause
with simple past tense, originally introduced in example (2b).

3.3 When and the perfect

The extension to the theory that is implied by the preceding observations is
simple in principle but complex in detail, and will be more fully developed
elsewhere. The basic apparatus, consisting of a history, a data base describing
the state of the world at any given instant, together with a set of housekeeping
routines for the management of the data base, plus a body of world knowledge
defined as inference procedures is still all that is required. However, the
nature of the information represented in the history needs to be elaborated.
In particular, it is no longer going to be adequate to represent the history of
events as the single time-line implied in the preceding discussion. It will rather
be necessary to represent it as comprising several time-lines, each associated
with a single causal or consequentially related sequence of events leading
towards the satisfaction of a particular goal, or intention. These sequence
may from time to time intersect or diverge, and may be nested one within the
other, the nested sequence representing the steps undertaken in achieving
sub-goal of the higher sequence. This representation has more of the character of a railway marshalling yard than the single main line of the earlier
account. It embodies the idea that it is only events that are consequent
related that necessarily have well defined temporal relations in memory.
Purely coincidental relations in time are less useful, and may be only vague
defined. The linguistic categories under discussion reflect implicitly such an
organization of episodic memory, which is closely related to the notion of
script or plan advanced by Schank & Abelson (1977).

Consider, for example, the history of this type that is represented in Figure
5, which corresponds directly to a data structure in the program. This histor
might be paraphrased as follows:

'John, in order to compute the 99th prime number, logs on to the system, edits the program which he needs, runs the program, and logs out again. Meanwhile, Betty, in order to edit her own program, logs on at the same time as John and begins her edit. At a point during the time that John is running his program, Betty stops editing, and logs out. Moreover, the history represents the fact that it is John's starting to run that for some reason causes Betty to stop her work and sign off. Finally, while all this is going on, Ann, in order to print a program, signs on, prints it, and signs off at the same time as Betty.'

Figure 5  A 'history' of the model world showing causal sequences
Such a history is of course extremely simplified, for purposes of exposition. For example there is no representation of why John’s actions cause Betty to stop what she is doing nor of the fact that John’s editing enables his running nor of the fact that Betty’s editing is an incomplete period, or in Vendler’s terms, an ‘activity’, unlike John’s. In a more complete simulation these facts would be represented either in the history or in more general knowledge about the world. However, the example will serve the present purpose.

The definition of the perfect is straightforward in terms of such a representation. The perfect of a core event is true at some time if some event or situation which is consequent upon that event (that is, subsequent to the core event and on the same causal sequence) is in force at that time. For example at the time 4 of the history we are considering the proposition that Betty has logged in is true, since the activity of her editing her program is in progress and it is an activity which is on the same causal sequence as was her logging in (E2 in the figure). On the other hand, at time 7 the same proposition is not true, since although the core event occurred before that time, the entire causal sequence of which it was a part is over.

In order to explicate the effect of when clauses, including the so-called causal variety, and those including auxiliary have, it will be necessary to revise our view of Reichenbach’s temporal reference point once more. The reference must not only include the ‘window’ defined by the core event itself. It must also include subsequent events in the same causal sequence. Consider for example questions about the history in Figure 5 which begin ‘When John ran his program, . . . ’. It is reasonable, given what we know, for these to continue as follows:

(48a) . . . , was Ann printing?
(48b) . . . , did he log out?
(48c) . . . , did Betty log out?

On the other hand, in spite of the fact that Ann logs out at exactly the same time as Betty, it is not reasonable to go on

(48d) . . . , did Ann log out?

Such a question implies or presupposes that John’s running caused Ann’s logging out, and that is not what this particular history describes.

What is the nature of the temporal referent to which these main clause refer? Clearly, as before, it must define a window, or pair of time point between which the state of the world can be examined using the data base to represent successive instants. That much is necessary in order to know where to look in order to answer (48a). But, equally clearly, it must allow for the search to go beyond the confines of the events itself, if (48b) and (48c) are to be answered. However, the question of where that search may be permitted to look is equally clearly not merely a question of defining a fixed interval
time, not even one whose extent is allowed to depend upon the character of
the reference event. Any purely temporal interval which allows the program
to see as far ahead as Betty's logging out is going to allow it to see Ann's as
well. It is therefore clear that the temporal referent must include some note of
the particular sub-history upon which the event itself is found. The search
later in the history for the main clause event must only take account of
events—like John's and Betty's logging out—which are causally related to
the reference event. It must be blind to all others.

We may therefore think for the moment of the temporal referent as a pair
of points on the time-line as before, plus a note of the parent sub-history or
sub-histories on which the reference event occurred. But how far along the
parent paths is the search to be allowed to proceed? Obviously, it may not
examine any earlier events on the parent paths than the reference event. It
might appear that all we need is to search as far as the next event on the
parent path(s). However, it will be recalled that certain events (such as the
repetitions discussed in Section 1) may be compound. There is therefore no
simple way to define such a scope. The current program therefore allows the
search for main clause events to 'see' all events later in the causal sequence on
which the core event is found.

With the new representation of the episode, the perfect in a when clause
has exactly the same meaning as it does in a main clause. For example, if the
when clause had been 'When John had run his program . . .', the referent that
would have been set up would simply be a period comprising all instants at
which the perfect itself was true—that is, all instants subsequent to the core
event at which some event or situation arising from the same causal chain
were in force. In order to express what has been referred to as the 'predictive'
quality of the perfect when clause, it is clear that the search for these instants
should be conducted with respect to an established temporal referent, rather
than with respect to the whole episode. The resulting new temporal referent is
therefore very similar to the one established by the related simple tensed
when clause, except that it does not include the core event, but only its
consequential state. Hence the puzzling fact that sentences (49a) and (49b)
below mean something very similar, while sentences (49c) and (49d) do not
is explained—cf. sentences (38) and (39) above:

(49a) When John ran his program, he logged out.
(49b) When John had run his program, he logged out.
(49c) When John ran his program, he was computing the 99th prime.
(49d) ?When John had run his program, he was computing the 99th
prime.

Two further aspects of the meaning of when clauses must be mentioned. First,
when the main clause is an event-description and the causal relation is pre-
supposed, it is also presupposed that the relation is direct—that is, that the
main event comes next on the path. This fact must be checked as part of the reference relationship. Secondly, none of the above searching beyond the bounds of the original reference event is allowed in the case where the main clause is of the state-like ‘situation’ variety, nor do these carry any connotations of causation. It therefore follows that in the case of stative main clauses: the search should be able to ‘see’ all the happenings in the history but should not proceed beyond the limits of the core event. That is to say that, for present purposes, when sentences with situation main clauses are very like the corresponding while sentences. It will be noted that such an account fails to explain the fact that most (but not all) sentences which have progressive or perfect main clauses with a perfect when clauses are anomalous (cf. Figure 1) that is to say that the program just described will produce the answer ‘Yes’ to the following questions about the history of Figure 5:

(50a) When John had run his program, was he computing the 99th prime?
(50b) When John had run his program, had he logged in?

However, not all such sentences are anomalous. In fact, they are acceptable just in case the imperfective or perfective situation described by the main clause is indeed a direct consequence of the core event of the when clause—for example:

(51a) When John had run his program, was he still computing the 99th prime?
(51b) When John had run his program, had he finished computing the 99th prime?

However, at present, the program will accept all such sentences. The distinction in acceptability between (50) and (51), which appears to be intimately involved with further questions concerning the aspectual adverbials and verb which appear in the latter sentences, will require further refinements to the definition of the consequential relation and its representation in the program.

To summarize this section: in order to account for the interaction of the perfect and causation in when clauses, a further elaboration of the concepts of episodic memory and reference time to include the idea of logical sequence of events has been necessary. Within this framework, the meaning of when clauses can be defined as follows. If the when clause is of the ‘situation variety, then the search for the new temporal referent is to be conducted within an establishing referent. If the when clause is of the ‘event’ variety then the whole episode is searched. If the main clause is a situation, then the search for that situation is confined to the scope of the core event, and the whole effect is rather similar to that of a while sentence. If the main clause is an event, then the search for that event includes the consequences of the core event in the when clause.
4 CONCLUSION

In the preceding sections of the paper a model has been outlined of the way people answer questions about episodes. The discussion has concentrated on the function of *while* and *when* clauses. By successive refinements of Reichenbach’s (1947) original notion of the temporal reference point that is established by such clauses, it has been possible to account for certain apparent ambiguities of tense, and of the progressive and the perfect, as being ambiguities of reference, arising from a single sense. The relation of causal or consequential meanings to more purely temporal ones has been discussed. In particular, the intimate relation of both the perfect and the connective *when* with causation and prediction has been examined. The tendency of simple past tense and the perfect not only to appear ambiguous, but also to take on each other’s roles, has also been explicated in terms of the model.

The model hinges upon the idea that memory for episodes is linearly ordered, by analogy with the temporal sequences that it represents. The functions of tense, the auxiliaries, and the time adverbials are to direct the hearer’s attention to certain points in such a structure, and to move the shared point of attention up and down the time-line that such a memory emulates.

The story has been a complex one. The reason has been that at every turn the idea of causation has intruded into the simple localist paradise of purely temporal descriptions suggested by the theories of Reichenbach and Isard with which the account began. Indeed, it seems that episodic memory should not be thought of as a single linear ordering of events, but rather as being further structured into sub-histories of events which are related as successive elements in causal chains constituting the plans and intentions of participants in the episode. Several such sub-histories will typically be in progress at any one time. Certain of the time adverbials, like *while* adjuncts, express purely temporal relations between events, and apply across different causal chains. Others, like *when* adjuncts, will have more to do with relations of sequence *within* such chains.

It is perhaps worth concluding by attempting to identify the significance of the computer in the development of this model, and for the study of deixis and reference in general. Any phenomenon in natural language which depends upon the changing context of a conversation presents the theorist with the problem of formalizing processes of change in the situation referred to. Deictic and anaphoric reference, including such reference to events, depends upon such processes of change in the context of discourse. A computer program expresses very directly the processes that result when it is run on the computer. For such a process, the idea of a context corresponds closely to that of the changing state of the variables which the program accesses during the computation, as Isard (1975) has pointed out. Programs therefore offer a helpful notation for precisely those pragmatic aspects of reference that are
most intractable in non-procedural terms, and with which the meanings of time descriptions considered here are intimately bound up.

NOTES

1. This work has continually been influenced by many discussions with Stephen Isart He, Gill Brown, Jeb Ellman, Orvokki Heinamaki, Wolfgang Klein, Chris Mellish Carlota Smith, and Cathy Urwin kindly read earlier drafts and made many helpful suggestions. Earlier versions were presented to the Max-Planck-Gessellschaft conference on Spatial Deixis, Nijmegen, March 1978, the Psycholinguistics Summer School Mulsjo, August 1979, and the Semantics Workshop on Events, Situations and Actions, Austin, October 1980. The research was supported by a grant for computation from the SSRC and a Visiting Fellowship from the Sloan Foundation held at the Center for Cognitive Science of the University of Texas at Austin.

2. The word meaning will be used throughout the paper in an intentionally vague common-language sense to refer indiscriminately to all aspects of meaning. When it necessary to be more precise, such terms as sense, reference, and denotation will be used.

3. It should be remarked in passing that although a when clause is always evaluate before the main clause, and establishes the referent for its tense, it is not always the case that this referent endures for the tense of later ‘naked’ main clauses to refer to. The setting up of an enduring permanent temporal referent seems always to be marked by an intonation break, whether the relative clause precedes or succeeds the main clause or is parenthetically embedded within the main clause as in

(i) John, when he saw the expression on my face, made an excuse and left.

A when clause which is not set off from its matrix by intonation, does not set up temporal reference point which outlasts the matrix sentence. An example is sentence (ii b) of the following exchange.

(ii a) When John arrived, did Mary leave?
NO.
(ii b) Did Mary leave when Fred arrived?
NO.
(ii c) *Did Ann arrive?

Sentence (ii a) sets up the temporal referent of John’s arrival, as usual. Had sentence (ii c) followed immediately, it would have been understood as referring to the same reference time. However, although the when clause of (ii b) sets the temporal referer for its main clause, it does not establish Fred’s arrival as a permanent reference point and so sentence (ii c) fails to refer to that time. (To make sentence (ii c) successful refer to Fred’s arrival, it would be necessary to include the word then, which explicitly refers to the most recently mentioned time, rather than to an established reference time. Then has rather the effect that the phrase at that time has, and itself may set up new and enduring temporal referent.) What is more, sentence (ii b) seems to render the reference point set up by (ii a) inaccessible to the temporally anaphoric tense c (ii c).

The above variety of functions that may be performed by when clauses are closest related to those involved in Halliday’s (1967) constructs of theme and information. Elsewhere, Steedman & Johnson-Laird (1978) have related semantics of theme an information in general to the same fundamental characteristic of the huma
REFERENCE TO PAST TIME

language-understanding mechanism that is exploited here, namely that it is a left to right process (albeit one that is under a hierarchical control), in which as much interpretation as possible is done as soon as possible. However, the present discussion is limited, like that of Isard (1974), to temporal relative clauses which establish an enduring temporal referent, that is to say to those separated from their main clause by one or more intonation breaks.

4. It will be obvious that the notion of cause or consequence is a complex one. For example, two events are held to stand in this relationship if the former merely enabled the occurrence of the latter, as well as when it actually caused it. Schank (1975) provides one possible taxonomy of the varieties of logical sequence of events in episodes.

5. This analysis is not meant to imply that no events involving repetition are represented as a whole in people's histories of episodes. Events like bands playing and programs running are perhaps prototypically single, non-repeated events. But activities like talking to Mary are likely to be repeated en bloc, not as a lot of individual utterances, and would not behave like examples (27) and (29).

6. The current paper will not deal with progressives of 'achievements', such as

   (i) John was winning the race

which designate a prospective situation of activity leading up to the core event. While space prohibits any discussion of them here (but cf. Vlach, 1977; Dowty, 1979) it seems likely that the notion of causal or consequential sequences of events which is involved in the treatment of the perfect will be crucial to the analysis of these and the associated 'imperfective paradox' as well.

7. It is not quite clear whether this fact is in the domain of semantics or pragmatics. This detail is not currently implemented.

REFERENCES


