I. Introduction

A number of parallels between temporal and nominal anaphora were noted in Partee (1973); there I tried to account for them by invoking explicit variables over times and treating the tense morphemes *Present* and *Past* as directly analogous to pronouns. I now believe that a much better explanation of the parallels is available as the result of recent work on the formal semantics and pragmatics of temporal discourse and of pronoun anaphora. One key ingredient is the incorporation of a version of Reichenbach’s notion of ‘reference time’ into a formal semantic framework, as developed by Bäuerle (1977) and further extended by Hinrichs (1981). In these accounts reference time is at the heart of temporal anaphora, as has been argued in less formal accounts (e.g. Smith (1978)), and the similarity between tense morphemes and pronouns can be seen as a derivative phenomenon. A second crucial ingredient is the unified treatment of pronouns provided by the theory of discourse representations of Kamp (1981a) or the ‘file-card’ semantics of Heim (1982). The task of unifying these advances is carried out to a large extent in Hinrichs (1981); in this study I draw heavily on the work of Hinrichs and show how it can be extended to cases of temporal quantification and temporal analogs of ‘donkey-pronouns’.

Among the data to be accounted for, described more fully in Section II, are temporal analogs of deictic pronouns, anaphoric pronouns with definite and indefinite antecedents, ‘bound-variable’ pronouns, and ‘donkey-sentence’ pronouns. The unified treatment of all these uses of pronouns provided by the frameworks of Kamp and Heim is reviewed in Section III. In Section IV I describe and slightly modify Hinrichs’ treatment of tenses, adverbs, and temporal anaphora in simple linear discourse and in sentences with *when*, *before*, and *after*-clauses. In Hinrichs’ treatment, events, processes, and states are taken as primitives rather than instants or intervals of time, following Kamp (1979), (1980) (cf. also Bach (1980), (1981)); ‘reference events’ are added to take over the function of earlier authors’ ‘reference times’. Hinrichs’ overall framework fits into Kamp’s theory of discourse representation structures, allowing ‘discourse events’ to be treated similarly to ‘discourse entities’. Section V summarizes the explanation provided by these accounts for the parallels between temporal and nominal anaphora in the deictic case and
Pronouns can be used without an antecedent when their reference is

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(3)(a) Pedro owns a donkey. He beats it.

We will say more about such cases in Section III, but for now note that the antecedent of a past tense may be similarly indefinite in the sense of not specifying a particular time, as in (3b).

(3)(b) Mary woke up sometime during the night. She turned on the light.

The first sentence of (3a) is presumably true if Pedro owns at least one donkey, and the first sentence of (3b) similarly true if Mary woke up at least once during the night. The problem is then to say how the ‘it’ of (3a) or the past tense of the second sentence of (3b) gets its reference when the antecedent is apparently not referential but existentially quantified. (Case (2b) of the previous section might be argued to belong here insofar as the antecedent does not specify when on Friday the party was.)

D. Bound variables

Typical uses of pronouns as bound variables are illustrated in (4a–b); apparently comparable cases of temporal bound variable cases are given in (5a–d).

(4)(a) Every woman believes that she is happy.

(b) No woman fully appreciates her mother.

(5)(a) Whenever Mary telephoned, Sam was asleep.

(b) When Mary telephoned, Sam was always asleep.

(c) Whenever Mary wrote a letter, Sam answered it two days later.

(d) Whenever John got a letter, he answered it immediately.

E. ‘Donkey-sentences’

The famous “donkey-sentences” introduced by Geach (1962) are given in the versions of Kamp (1981a) in (6a–b), along with possible temporal analogs in (6c–d); discussion of the problem raised and possible solutions to them is deferred to subsequent sections.

(6)(a) If Pedro owns a donkey, he beats it.

(b) Every farmer who owns a donkey beats it.

(c) If Mary telephoned on a Friday, it was (always) Peter that answered.

(d) Whenever Mary telephoned on a Friday, Sam was asleep.

There is also an apparent parallel in negative data that we will account for:

(7)(a) *If every man owns a donkey, he beats it.

(b) *If Sheila always walks into the room, Peter wakes up.

(cf. (b)’ If Sheila walks into the room, Peter always wakes up.)

All of the data above are at this point only suggestive; we have not yet offered any arguments for giving similar analyses of nominal and temporal anaphora, and there are clearly many differences between them. In the remaining sections of the paper, we show how Kamp’s ‘discourse representation’ approach, which offers a unified treatment of nominal anaphora, if taken together with an approach to tense, aspect, and time adverbials which takes ‘eventualities’ rather than (or possibly in addition to) times as basic and incorporates the notion of reference time, provides a framework in which the parallels observed above receive a natural explanation.

III. Discourse representations

In this section we sketch the key features of Kamp’s theory of discourse representations (Kamp, 1981a) as it applies to nominal anaphora. (A theory of anaphora which shares many properties with Kamp’s approach is developed in Heim (1982 and 1983); we are presenting Kamp’s version in part because it is more widely accessible and in part because Kamp and Hinrichs have made substantial progress in extending that framework to deal with temporal anaphora, but we believe that the same kind of account is in principle equally compatible with Heim’s framework.) The reader familiar with Kamp (1981a) can skip this section.

Kamp’s approach makes crucial use of an intermediate level of representation, ‘discourse representation structures’, mediating between syntax and model-theoretic interpretation. In rough terms, a discourse representation can be thought of in the simplest cases as a description of a partial model. A simple discourse representation counts as true with respect to a complete model if it is embeddable into the model; embeddability is a technical notion in Kamp’s system which plays a role somewhat analogous to satisfaction conditions in standard semantics for predicate logic. (I will not give the definition – see Kamp (1981a) – but I will illustrate it with examples shortly.) In more complex cases, the discourse representation structure consists of a structured set of discourse representations, and the embeddability conditions for the entire structure are recursively defined in terms of the embeddability of the substructures.

The fragment of English treated in Kamp (1981a), which is sufficient for our purposes in this section, includes simple sentences with transitive and intransitive verbs, proper nouns, third-person singular pronouns, and noun
sentences (6a) reported here are (6) repeated here as (6a). We illustrate this with the conditional expression of donkey-scramble, where the discursive interaction between the two clauses is processed in the matrix clause. The conditional expression of donkey-scramble, where the discursive interaction between the two clauses is processed in the matrix clause.
If Pedro owns a donkey, he beats it.

The first step in constructing a discourse representation structure (DRS) for (9) is, as usual, to build a DR containing just the whole sentence:

\[
\text{DR}_0(9) \quad \text{If Pedro owns a donkey, he beats it}
\]

Since the if-then rule was the last rule applied in the construction of the sentence, the corresponding DRS construction rule is the first to be applied. That rule creates two additional DR’s, \(\text{DR}_1(9)\) and \(\text{DR}_2(9)\), with \(\text{DR}_1(9)\) containing the antecedent clause and \(\text{DR}_2(9)\) the consequent, and with the stipulation\(^{10}\) that \(\text{DR}_1\) is subordinate to \(\text{DR}_0\) and \(\text{DR}_2\) is subordinate to \(\text{DR}_1\). (The subordination relation that holds among DR’s does not correspond directly to the syntactic notion of subordination; it does play a crucial role in determining the accessibility of discourse entities for pronoun assignment.) Each of the two DR’s is then processed in the usual way, antecedent first, with the following proviso: when a discourse entity is introduced for a proper noun, it and its identity condition are placed in the top DR of the whole current DRS (making it available for assignment to any subsequently processed pronoun), but when an indefinite noun phrase is processed, the newly introduced entity is placed in the DR being processed (and therefore accessible to pronouns only in the same or subordinate DR’s). The complete DRS for (9) is then as follows (from Kamp (1981a, p. 315); I have added arrows marking the subordination relation); numbers in parentheses indicate steps in the processing sequence.

\[
\text{DR}_0(9):
\]

\[
\begin{align*}
\text{DR}_1(9) & \quad \text{(2) } u \\
\text{DR}_2(9) & \quad \text{(0) If Pedro owns a donkey, he beats it} \\
& \quad \text{(2) } u = \text{Pedro}
\end{align*}
\]

In steps (4) and (5) we are able to assign the entities \(u\) and \(v\) to the pronouns because \(\text{DR}_2\) is subordinate to both \(\text{DR}_1\) and \(\text{DR}_0\).

The embeddability condition for DRS’s resulting from the if-then construction rule is roughly as follows (see Kamp (1981a) for full details of this and other rules): DRS(9) is embeddable in M if there is a mapping which satisfies the atomic conditions in \(\text{DR}_0\) (i.e. which assigns \(u\) to Pedro) such that every extension of it which satisfies \(\text{DR}_1\) also satisfies (or can be extended to satisfy) \(\text{DR}_2\).

Before discussing the example further, let us introduce the final new rule of discourse representation construction, the rule for noun phrases introduced by every. When such a noun phrase is processed, two new DR’s are introduced, with subordination structure exactly like that of conditional structures.\(^{11}\) To the ‘antecedent’ are added a new discourse entity and conditions on it corresponding to the content of the common noun (and relative clause, if any). To the ‘consequent’ part is added a condition corresponding to the remainder of the sentence, with the new discourse entity in place of the original noun phrase. This is illustrated in the DRS for (6b), repeated here as (10), with parenthesized numbers again showing the order of construction.

\[
\text{(10) Every farmer who owns a donkey beats it.}
\]

\[
\text{DRS(10)}:
\]

\[
\begin{align*}
\text{DR}_0(10) & \quad \text{(0) every farmer who owns a donkey beats it} \\
\text{DR}_1(10) & \quad \text{(1) } x \quad (2) \quad v \\
& \quad \text{(1) farmer (x)} \\
& \quad \text{(1) } x \quad \text{owns a donkey} \\
& \quad \text{(2) donkey (v)} \\
& \quad \text{(2) } x \quad \text{owns } v
\end{align*}
\]

The embeddability condition for every-constructions is the same as that for if-then sentences: every embedding that satisfies \(\text{DR}_1\) must be extendable to an embedding that satisfies \(\text{DR}_2\). I will refer to such DRS configurations henceforth as universal/conditional structures.

Note that while the construction of DRS’s is determined (up to the
I. THE TEMPORAL SYSTEM

The temporal system plays a crucial role in the processing of language. It is involved in the interpretation of time-related expressions and the construction of temporal relations between events.

II. NOMINAL AND TEMPORAL ANAPHORA

Anaphora is a linguistic phenomenon where words or phrases refer to previous words or phrases in the text. Nominal and temporal anaphora refer to the use of nouns and time expressions, respectively, to refer back to previous mentions in the text.

For example, in the sentence "I saw Mary yesterday," the pronoun "Mary" is an anaphoric reference to a noun mentioned earlier in the text.

The study of anaphora helps us understand how language is used to convey meaning and how we interpret the temporal relationships between events.

Further reading on the topic of anaphora and temporal anaphora can be found in various linguistic and cognitive psychology texts.
an event of John’s getting up.\textsuperscript{16}

\textbf{DR(14)}
\begin{align*}
\begin{array}{llllllllll}
e_1 & e_2 & e_3 & e_4 & e_5 & s_1 & s_2 & s_3 & r_2 \\
& & & & & . & . & . & . & . & . \\
e_1 < e_2 < e_3 < e_4 < e_5 < r_2 \\
John & get & up & (e_1) \\
\vdots & & & & & & & & & & \\
John & go & back & to & bed & (e_5) \\
s_1 & 0 & e_3 \\
s_2 & 0 & e_5 \\
s_3 & 0 & e_5 \\
It & be & light & out & (s_1) \\
\vdots & & & & & & & & & & \\
John & be & too & depressed & (s_3) \\
\end{array}
\end{align*}

The main oversimplification we have made in this example is in ignoring Hinrichs’ use of ‘reference time’ (Reichenbach (1947)). For one thing, the first sentence of the discourse is not interpretable without some understood past reference time (Partee (1973), Bäuerle (1979), Hinrichs (1981)), so we need to assume that there is a past reference time \( r_0 \), specified at the start of the discourse, and that the introduction of new event sentences moves the reference time forward.\textsuperscript{17} Furthermore, Hinrichs has noted that the states and processes introduced need not always be understood as overlapping the last-mentioned event, as illustrated in (15) below (Hinrichs’ example (108), p. 66).

\textbf{(15)} Jameson entered the room, shut the door carefully, \( e_1 \) and switched off the light. It was pitch dark around him, \( e_2 \) because the Venetian blinds were closed. \( s_1 \) \( s_2 \)

Hinrichs proposes that each new past-tense event sentence is specified to occur within the then-current reference time, and it subsequently causes the reference time to be shifted to a new reference time which follows the just-introduced event. States and processes are required to include the current reference time but need not overlap the event that led to the introduction of that reference time. Intuitively, the reference time introduced by an event-sentence is located ‘just after’ that event; we will discuss this requirement further and make it more explicit in connection with later examples. Below we give an approximate representation of

\textbf{DR(15)} as a first illustration of the introduction of reference times; in subsequent examples we will be more explicit about the order of construction steps, particularly about the dynamics of the shifting ‘current reference time’. The notation in DR(15) combines elements from Kamp and Hinrichs; ‘\( \leq \)’ stands for the relation of temporal inclusion, which is definable in terms of \(<\) and O(verlap), and the specification of the events and states by means of DR-boxes follows Kamp (1981b) and can be read as \( e_1 \) is an event-token of the event-type given in the box following.\textsuperscript{7} (In subsequent examples we will carry out the internal processing of such boxes.) We assume that we start with a given past reference time \( r_0 \) and present reference time \( r_1 \); the other reference times \( r_1, r_2, \) and \( r_3 \) are introduced during the construction.

\textbf{DR(15)}
\begin{align*}
\begin{array}{llllllllll}
r_0 & e_1 & r_1 & e_2 & r_2 & e_3 & r_3 & s_1 & s_2 & r_5 \\
& & & & & . & . & . & . & . & . \\
e_1 & \leq & r_0 \\
e_1 & < & r_1 & < & r_5 \\
e_2 & \leq & r_1 \\
e_2 & < & r_2 & < & r_5 \\
e_3 & \leq & r_2 \\
e_3 & < & r_3 & < & r_5 \\
r_5 & \leq & s_1 \\
r_1 & \leq & s_2 \\
e_1: & Jameson & enter & the & room \\
\vdots & & & & & & & & & & \\
e_2: & & & & & & & & & & \\
\vdots & & & & & & & & & & \\
\end{array}
\end{align*}

From the fact that there are conditions requiring reference times to include events (\( e_2 \leq r_3 \), etc.) and to be included within states, i.e., within some period for which a given state holds (\( r_5 \leq s_1 \), etc.) it follows that reference times must be construed as protracted events or bounded intervals. Hinrichs construes them as events with no descriptive content stipulated, but as far as I can see we could just as well think of them as intervals for present purposes, given Kamp’s way of reconstructing instant and interval structures from event structures. In any case, the embedding conditions for DR(15) will simply require that there be some events (or intervals) \( r_1, r_2, r_3 \) which satisfy the specified ordering relations. The net effect of the ordering specifications in DR(15) is that \( e_1 < e_2 < e_3 < r_5 \), and \( s_1 \) and \( s_2 \) must both overlap some time ‘just after’ \( e_3 \); they may but need not
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important for a more comprehensive treatment of the
focusing on the structure of speech acts, a number of issues that would be
relevant to this kind of anaphora. In particular, we are interested in
the role of anaphora in discourse and the way it
conditioned by the structure of speech acts. This
spans a wide range of phenomena, from

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the reference time to a time ‘just after’ the main clause event. Thus the reference time in effect after the complete sentence is processed depends on which clause was the main clause; this corresponds with the informal observation that it is main clauses that carry the main story line along in a narrative. We will show this asymmetry with examples involving before and after further below, and first consider Hinrichs’ basic treatment of when-clauses.

Suppose we are interpreting a simple past tense narrative, our most recently established past reference time is \( r_1 \), and the next sentence begins with a when-clause. The when-clause triggers the updating of the reference time to a new value, let’s say \( r_2 \), and the content of the when-clause puts conditions on \( r_2 \). (It is also required that \( r_2 \) follows \( r_1 \), a stipulation that we will try to justify and generalize later.) The main clause is then interpreted with respect to \( r_2 \) just as it would have been if it were a simple sentence with the reference time \( r_2 \) provided by previous context. For illustration consider the little narrative (16), which includes example (2c) from Section II as a subpart.

(16) Mary turned the corner. When John saw her, she crossed the street.

The following discourse representation, DRS(16), incorporates Hinrichs’ treatment into a Kamp-style diagram, with parenthesized numbers showing the order of construction steps. Because Hinrichs’ rules refer to ‘the current reference time \( r_p \),’ which changes in the course of the construction, I have used square brackets to enclose the conditions which update the reference time (‘\( r_p = r_0 \),’ ‘\( r_p = r_1 \),’ etc.); only the most recent of them is in effect at any given point in the construction of the representation. The DRS construction rules which depend on reference time make reference only to ‘\( r_p \),’ i.e. to whatever is the current reference time. In showing the effects of applying the construction rules I have filled in the values, \( r_0, r_1, \) etc., according to what the current reference time was at the corresponding point in the construction. The (past) reference time at the beginning of the processing is \( r_0 \); the reference times \( r_1, r_2, \) and \( r_3 \) are introduced in the course of processing. The resulting DRS is in a sense then a dynamic representation rather than a static one; in the long run we clearly need a more systematic representation of how the relevant context-parameters, of which reference time is just one, change in the process of interpretation.

In this and subsequent DRS’s, I have used ‘now’ rather than ‘\( r_1 \)’ for the present reference time, simply for mnemonic convenience.
nominal and temporal anaphora
time. Compare the anomalous discourse (19) with the normal (20).

(19) People began to leave. The room was empty. The janitors came in.

(20) People began to leave. When the room was empty, the janitors came in.

Discourse (19) is anomalous, presumably because we don’t expect the state of the room being empty to hold ‘just after’ people begin to leave, but state-expressing sentences cannot by themselves move the action forward. The when-clause of (20), on the other hand, signals the introduction of a new, later, reference time; we interpret ‘the janitors came in’ with respect to a time which is after people began to leave and just after the room became empty. The asymmetry between main and subordinate clause is even clearer in the case of before and after. Sentences with before- or after-clauses also make it particularly clear that the account of temporal anaphora cannot be directly in terms of the tense morphemes in the main and subordinate clauses, as proposed in Partee (1973). Truth-conditionally, ‘after A, B’ and ‘before B, A’ are equivalent (except possibly for the non-factivity of before-clauses, which we will return to below), but in simple linear narratives they can be seen to have different effects on the establishment of reference time and hence on the temporal interpretation of the discourse as a whole. To appreciate the difference, we need a three-sentence discourse. We begin by extending (16) to (21) as a basis for comparison with (22) and (23).

(21) Mary turned the corner. When John saw her, she crossed the street. She hurried into a store.

(22) Mary turned the corner. Before John saw her, she crossed the street. She hurried into a store.

(23) Mary turned the corner. After she crossed the street, John saw her. She hurried into a store.

We will not construct complete DRS’s for these examples, but consider just the sketches of the resulting temporal conditions in the manner of (17*). Here again I am departing from Hinrichs in not putting the subordinate-clause event within any reference time of its own; to dispense with the additional reference time that he uses for before- and after-clauses, I have to claim that what is within the before- or after-clause cannot be a state or process. I believe that is correct, and that apparent state or process descriptions in such clauses have to be interpreted as events – again usually inchoatively, sometimes, especially with after, ‘terminatively’. See also Bach (1981). In all other respects I believe the sketches below, (21*)–(23*), conform to Hinrichs’ analysis. The events have been given mnemonic names instead of numbers. In the actual processing rules the subordinate clause is always processed before the main clause and introduces the reference time with respect to which the main clause is interpreted. In each case, presumably as a result of the simple linear progression mode, the reference time \( r_3 \) introduced by the subordinate clause comes after the previous reference time \( r_1 \), regardless of which subordinating conjunction introduces the clause. If we break the subordinating clause into its conjunction (before, after, or when, which I’ll abbreviate collectively as BAW) and its clause, we can say that the clause characterizes an event type and BAW tells where the new reference time \( r_3 \) is located relative to some event of that type.

\[
\begin{align*}
(21^*) & \quad \epsilon_{\text{turn}} \leq r_1 < \epsilon_{\text{see}} \leq \epsilon_{\text{cross}} \leq \epsilon_{\text{hurry}} \leq r_4 \\
(22^*) & \quad \epsilon_{\text{turn}} \leq r_1 < \epsilon_{\text{cross}} \leq \epsilon_{\text{hurry}} \leq r_4 \\
(23^*) & \quad \epsilon_{\text{turn}} \leq r_1 < \epsilon_{\text{cross}} < \epsilon_{\text{see}} \leq \epsilon_{\text{hurry}} \leq r_4
\end{align*}
\]

The striking difference between the before-clause case and the others is that the event in the before-clause does not end up in the linear order at all; it helps to describe the temporal location of \( r_2 \) and hence of the crossing event, but is not otherwise connected, even in the context of a simple linear narrative. This seems to be a natural reflection of two factors, iconicity of order in simple linear narratives and the dynamics of successive introduction of reference times in the interpretation process. Why does the before-clause event not end up linearly ordered with the other events of the discourse, while the events of the when-clause and the after-clause do? If we process just the first two sentences of each discourse and leave out the reference time \( r_3 \) introduced in the final steps of that part, we have the following structures, all linear.

\[
\begin{align*}
(21^*) & \quad \epsilon_{\text{turn}} \leq r_1 < \epsilon_{\text{see}} \leq \epsilon_{\text{cross}} \\
(22^*) & \quad \epsilon_{\text{turn}} \leq r_1 < \epsilon_{\text{cross}} \leq \epsilon_{\text{sec}} \\
(23^*) & \quad \epsilon_{\text{turn}} \leq r_1 < \epsilon_{\text{cross}} \leq \epsilon_{\text{see}}
\end{align*}
\]

The difference arises because the next reference time, \( r_3 \), is introduced in
the processing of the main clause of the second sentence in each case is...
duced spontaneously or via a process of accommodation in Lewis's sense) without having to arise as translations of actual constituents of the sentences of the discourse. Treating pronouns as variables has some plausibility and a considerable tradition; but 'reference time', which appears to lie at the heart of temporal anaphora, does not correspond uniformly to any single constituent of the sentence, so there does not seem to be any reasonable way to introduce it systematically in a direct model-theoretic interpretation of the syntax.

B. Definite anaphors with definite antecedents

The pronominal case was illustrated with proper name antecedents in Section III. In the temporal cases discussed in Section IV, the 'definite antecedent' was the reference time introduced in the processing of the previous sentence or clause. This is more like the case of a definite description antecedent (see Heim (1982)) than a proper noun antecedent; a closer analog to the latter would be a sentence like (25).

(25) At 3 p.m. June 21st, 1960, Mary had a brilliant idea.

Hinrichs treats the adverb in such cases as serving to fix the reference time (replacing any previously current reference time) with respect to which the rest of the sentence is interpreted; the adverb thus functions much like a proper noun antecedent for a pronoun, although in the temporal case we do not have a common syntactic category of expressions denoting the antecedent and the anaphor as we do in the nominal case.

C. Indefinite antecedents

The treatment of pronouns with indefinite antecedents was one of the main innovations in Kamp's and Heim's proposals. In the temporal case the contrast between definite and indefinite is not always clearly marked; a newly introduced reference time might be thought of as definite in those cases where its introduction is accompanied by a condition that it be 'just after' some uniquely specified event, and indefinite in those cases where it is introduced with conditions that merely constrain it to be before, after, or within some given event or interval, or 'just after' an event whose description is not uniquely specifying. But the distinction is not marked by any obligatory grammatical signals (at least in English); our temporal system is in that respect more like the nominal system of languages that lack the definite and indefinite article, and Kamp's and Heim's unified treatment of these cases (see especially Heim's work on this point) therefore makes it much easier to account for the parallels between nominal and temporal anaphora in English as well as for the existence of article-less languages.

The examples with before and after in Section IV were in effect cases of indefinite antecedents, since the conditions on the reference times introduced by such clauses amounted to 'at some time (after the previous reference time and) before/after such-and-such.' An indefinite antecedent can also be introduced via an indefinite adverb, as in (3b), repeated here as (26).

(26) Mary woke up sometime during the night. She turned on the light.

We show below a DRS for (26) which conforms to Hinrichs' construction. Hinrichs does not treat the specific locution 'sometime during the night' but does give explicit rules for other 'frame adverbs' like 'on Friday', 'in 1976', and the permissible complex adverbs that can be built up by combining appropriately nestable simple ones. We assume that 'sometime during the night' would work similarly, yielding the condition $r_1 \leq i_1$ in DRS(26), and we also leave definite NP's like the 'night' and the 'light' unanalyzed. We have parenthesized the initial past reference time $r_0$ and the conditions that pertain to it; following the observations of Smith (1978), Hinrichs provides both for frame adverbs like two days later which can only be interpreted in a context which includes a current $r_0$ and ones like in June 1970 which do not require such a context. The present example requires contextual support for the expression the night, but that could in principle come either from having the night available as an entity already introduced or from a reference time which specified a given period only containing one night. A similar example with 'the night of June 21st 1960' would not require any $r_0$ present in the context, so there would be otherwise parallel DRS's with and without the parts parenthesized in DRS(26). I introduce an interval-variable $i_1$ for the night', but perhaps it could just as well be viewed as a protracted event (cf. 'during the fight'). In DRS(26) it is the reference time $r_1$ that plays the role of 'indefinite antecedent'. The parallels to Kamp's treatment of pronouns with indefinite antecedents should be clear: the role of $r_1$ in the subsequent processing of the two clauses is exactly the same as it would have been if it had been specified 'definitely', e.g. 'at 3 a.m. on the night of ...', just as the role of a discourse entity is the same for the interpretation of subsequent pronouns regardless of whether that entity is characterized by a definite condition like $u = Pedro$ or an indefinite one like 'farmer (u)'.

To complete the account of the parallels between temporal and nominal
The basic idea of the construction is to end up with a DRS topology of the

whenever Magic happened, Sam was asleep.

considered an example, Example (28) from Section II is repeated below as

To see how we can put the ideas of Sections III and IV together, let's

assertion in the statement of the coextensional condition for the whole DRS.

assumptions in the statement of the coextensional condition for the whole DRS.

assertion is the statement of the coextensional condition for the whole DRS.

assumptions is the statement of the coextensional condition for the whole DRS.

assertion is the statement of the coextensional condition for the whole DRS.

assertion is the statement of the coextensional condition for the whole DRS.
form (27'), analogous to DRS(9) for the conditional example in Section III.

\[
(27')
\]

\[
\text{DR}_1(27')
\]

\[
\text{DR}_2(27')
\]

(Here \( s_i \) is a discourse state.) One new factor we have to deal with is that although we are still considering an example with simple past tenses in both clauses, we are not dealing with a simple linear narrative anymore. The antecedent clause cannot be anchored to a single specific reference time as it was in the simple when-clause cases, yet the whole sentence does presumably have to be interpreted relative to some (sufficiently large) reference period. (The whole sentence should be characterized as describing a state, and the DRS should perhaps have a big box around it labelling the whole thing as a state (Gennaro Chierchia, personal communication), but I will ignore that factor here.) We can handle that by assuming that there is a reference time \( r_0 \) already current in the top box and that the discourse event \( e_i \) in the antecedent box is introduced with a condition that it fall within the current reference time. (That has to be part of what happens in the initial box-splitting step triggered by whenever, since the clause that follows whenever is internally just like any other subordinate clause, and should therefore be processed within its box by the normal rules.)

The embedding conditions for the whole configuration will be just like those for the if-clause and the every construction: the whole sentence is true just in case every proper embedding of the antecedent part can be extended to a proper embedding of the combination of the antecedent part and the consequent part. The main thing missing from the rough sketch in (27') is the indication of temporal connectedness between the antecedent and the consequent. When I discussed such sentences in Partee (1973), I didn't see any way to capture such 'bound variable' temporal cases without an explicit variable over times in the representation. But the abstract

notion of reference time (or reference event or situation) together with the general embeddability conditions just described can do the job just as well, as we will now show.33

Here is a more complete picture of the DRS for (27), with parenthesized numbers showing the order of construction. Asterisks signal the application of the one new rule needed for this construction; the new rule is a straightforward adaptation of Kamp's rule for universal/conditional sentences. The remaining steps follow the rules of Kamp and/or Hinrichs (continuing with the modification of Hinrichs' treatment introduced with (17') in Section IV).34

\[
\text{DR}_1(27)
\]

\[
\text{DR}_2(27)
\]

\[
*(1) e_1 \ (2) r_1
\]

\[*(1) \text{Mary telephoned}
\]

\[*(1) e_1 \leq r_0
\]

\[*(2) e_1 < \text{now}
\]

\[*(2) r_1 < \text{now}
\]

\[*(3) e_i = r_i
\]

\[*(3) \text{Mary telephone}
\]

\[*(4) u \text{ telephone}
\]

\[*(5) r_i = r_i
\]

\[
\text{DR}_3(27)
\]

\[
\text{DR}_4(27)
\]

\[ (0) \text{now} \ (0) r_0 \ (4) u \ (5) v
\]

\[ (0) r_i = r_i
\]

\[ (0) \text{Whenever Mary telephoned, Sam was asleep} \]

\[ (4) u = \text{Mary} \]

\[ (8) v = \text{Sam} \]

It is important to recall at this point that the representation of the consequent box \( \text{DR}_3(27) \) is an abbreviation for a fuller representation which incorporates all of the contents of the antecedent box, \( \text{DR}_1(27) \) and
consonant close to the times on Fridays when Mary called.

Whenever Mary called on Fridays, Sam was always happy.

(32) When Mary makes a phone call, she always looks happy and excited.

Before John makes a phone call, he always looks happy and excited.

(11) If we accept this hypothesis, there is no problem with the consonant close to the times on Fridays when Mary called.

(12) If we accept this hypothesis, there is no problem with the consonant close to the times on Fridays when Mary called.

(33) Whenever Mary calls on a Friday, she always answers it immediately.

(34) Whenever John goes for a walk, he answers it immediately two days later.

Regardless of the sequence of the events, the effect on the consonant close to the time in the information about the calls is the same whether or not the consonant close to the calls is the same.

The sentence in (35) expresses the same idea as in (32): Whenever Mary calls on a Friday, she always answers it immediately.

(35) Whenever Mary calls on a Friday, she always answers it immediately.

(36) Whenever John goes for a walk, he answers it immediately two days later.

The sentence in (37) expresses the same idea as in (34): Whenever John goes for a walk, he answers it immediately two days later.

(37) Whenever John goes for a walk, he answers it immediately two days later.

(38) Whenever Mary calls on a Friday, she always answers it immediately.

(39) Whenever John goes for a walk, he answers it immediately two days later.

(40) Whenever Mary calls on a Friday, she always answers it immediately.

(41) Whenever John goes for a walk, he answers it immediately two days later.

The sentence in (42) expresses the same idea as in (35): Whenever Mary calls on a Friday, she always answers it immediately.

(42) Whenever Mary calls on a Friday, she always answers it immediately.

(43) Whenever John goes for a walk, he answers it immediately two days later.

The sentence in (44) expresses the same idea as in (34): Whenever John goes for a walk, he answers it immediately two days later.

(44) Whenever John goes for a walk, he answers it immediately two days later.

The sentence in (45) expresses the same idea as in (36): Whenever John goes for a walk, he answers it immediately two days later.

(45) Whenever John goes for a walk, he answers it immediately two days later.

(46) Whenever Mary calls on a Friday, she always answers it immediately.

(47) Whenever John goes for a walk, he answers it immediately two days later.

The sentence in (48) expresses the same idea as in (37): Whenever John goes for a walk, he answers it immediately two days later.

(48) Whenever John goes for a walk, he answers it immediately two days later.

(49) Whenever Mary calls on a Friday, she always answers it immediately.

(50) Whenever John goes for a walk, he answers it immediately two days later.

The sentence in (51) expresses the same idea as in (38): Whenever John goes for a walk, he answers it immediately two days later.

(51) Whenever John goes for a walk, he answers it immediately two days later.

(52) Whenever Mary calls on a Friday, she always answers it immediately.

(53) Whenever John goes for a walk, he answers it immediately two days later.

The sentence in (54) expresses the same idea as in (40): Whenever John goes for a walk, he answers it immediately two days later.

(54) Whenever John goes for a walk, he answers it immediately two days later.
On Kamp's account of (7a) the occurrence of *every* in the antecedent will trigger (as always) the introduction of a pair of DRS's, subordinate in this case to the DR for the *if*-clause. Because of the subordination structure, the discourse entity corresponding to 'every man' will not be an accessible value for the *he* in the main clause. (See also the discussion of examples (11) and (12) in Section III.) A similar account for (7b) can be given, since the *always* in the antecedent will trigger a similar DR-split, with the new DR's subordinate to the *if*-clause DR, and the *always* absorbed into their embeddability conditions, so to speak. Only a reference time introduced at the level of the *if*-clause as a whole will be accessible for the main clause interpretation; the 'variable' reference time corresponding to *always* will not be.

We thus see that the proposals of Kamp (and Heim) and Hinrichs generalize straightforwardly to an account of quantified temporal anaphora. It should be reemphasized that the distinction between 'bound variable' cases and 'donkey sentence' cases, like that between cases of definite and indefinite antecedents, has no theoretical status in this approach but merely reflects the earlier descriptive classification of Partee (1973). This unification is particularly welcome in the temporal case, where the distinctions in question are quite artificial.

VII. Conclusions and open problems

This completes our account of the parallels between temporal and nominal anaphora. I consider this a much more satisfying account than the one offered in Partee (1973), which in retrospect can be seen to have suffered from two inadequacies: (i) the lack of a unified treatment of pronominal anaphora, which did not become available until the work of Kamp and Heim; and (ii) the claim that tenses themselves acted like pronouns and the consequent belief that they therefore had to correspond to explicit time variables in a logical representation. Intuitively, noun phrases 'refer' and tenses don't; nominal anaphora can be viewed as involving a generalization and explication of the notion inaccurately but intuitively labelled 'coreference'. Temporal anaphora is more subtle because of the categorial variety of the expressions involved – tenses, adverbs, adverbal clauses, and main clauses (including the aspectual classification of the clauses themselves into event-like and state-like). It is still fair to say that tenses, like pronouns, are anaphoric, and like pronouns can be construed with either linguistic or non-linguistic antecedents; but it doesn't follow that they 'refer' to times to the degree that pronouns 'refer' to individuals.

Two general points deserve mention here.\(^{37}\) Kamp motivated the level
An example of a much broader problem of determining what follows in the order of ideas recognized by an expert is the 4-word chain, one that is most common in discussions involving a particular group of ideas. The 4-word chain is often used as an indicator of the four-part sequence of ideas, but it is not always the case that the ideas follow in the order of the chain, even when the expert is discussing them.

In the 4-word chain, the first word is often the subject of the discussion. The second word is the verb, which gives a sense of the direction of the discussion. The third word is usually a noun, which provides a context for the discussion. The fourth word is often a verb again, which reinforces the direction of the discussion. In some cases, the fourth word may be a pronoun, but this is less common.

The 4-word chain is a useful tool for determining the order of ideas, but it should not be used as the sole indicator of the sequence of ideas. Other factors, such as the context in which the discussion is taking place, should also be considered.

In summary, the 4-word chain is a useful tool for determining the order of ideas, but it should be used in conjunction with other factors to ensure an accurate understanding of the discussion.
‘antecedent box’ in a conditional/universal DRS. Closely connected with this is a problem of interpreting the embedding condition for conditional DRS’s, namely how to individuate proper embeddings of the antecedent part. This problem is perhaps best illustrated by the problem that arises in trying to extend Kamp’s treatment to *most* or *almost every*, noted by Heim (1982). Whereas (34) and (35) have the same truth-conditions (at least in the respects relevant here), (36) and (37) seem not to: (37), but not (36), seems to be falsified by a situation in which just one donkey-owner fails to beat any of his donkeys but he owns most of the donkeys.

(34) Every man who owns a donkey beats it.
(35) 
  \{ Always \} if a man owns a donkey, he beats it.

(36) Almost every man who owns a donkey beats it.
(37) 
  \{ Almost always \} if a man owns a donkey, he beats it.

Intuitions seem to be sharper with event-clauses (perhaps since it’s not so clear what a ‘case’ of a state holding is). The difference in truth-conditions between (38) and (39) seems more certain than that between (36) and (37) (although still conceivably disputable).

(38) Almost every man who swam the channel took more than 12 hours.
(39) In almost every case, if a man swam the channel, he took more than 12 hours.

The difference evidently arises because in the case where the quantifier is combined with *man* we have to count men, and in the other case we have to count cases of channel swimmings and the same man may be involved in many swimmings. As Schä (1983) argues, when we have to deal with quantification with a complicated and possibly uncertain underlying ontology, we need to specify a ‘sort’ (for the quantifier to ‘live on’ in the sense of Barwise and Cooper (1981)) separately from whatever further restrictions we want to add (perhaps in terms of ‘cases’) about which instances of the sort we are quantifying over. In terms of Kamp’s framework this means that we have to worry not only about what belongs in the antecedent box but also how to distinguish a substructure within it that plays the role of sortal (the head noun in the NP case).

This is turn relates to the syntagmatically of *every* in Kamp’s treatment and the corresponding treatment of *always* in this paper. How, for instance, can *almost* modify *always* or *every* if they are not part of the semantic representation? I suspect that many of the ingredients for a better articulation of how the meanings of the various parts combine in these cases could be gotten out of a combination of the proposals in Stump (1981) for the treatment of free adjuncts in combination with frequency adverbs, Kratzer (1978) for the treatment of *if*-clauses and modals, Heim (1982) for a more Kratzer-like treatment of the quantifier cases, and the ideas of Kamp and Hinrichs presented here. But it is important to recognize that the source of these problems for the Kamp and Heim frameworks is their abandonment of Montague’s unified treatment of noun phrases as generalized quantifiers, in which determiners can be assigned a uniform semantic type and modifiers of determiners could be added straightforwardly.

I don’t see how to incorporate Montague’s elegant treatment of compositionality into the framework followed in this paper, nor do I see how to reproduce within Montague’s theory the unified and explanatory account of nominal and temporal anaphora provided by these extensions of Kamp’s, Heim’s, and Hinrichs’ work. So the next task is to try to construct a theoretical framework which incorporates the insights of both approaches.40

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Notes

1 All references to Hinrichs’ work in this paper are based on Hinrichs (1981); Hinrichs has now written a paper in English on this topic, Hinrichs (1982), which I have not seen.
2 Among other approaches which have emphasized a dynamic view of semantic interpretation are Hinrichs’ game-theoretical semantics and procedural semantics (Isard 1975); attention to dynamic aspects of context has been standard in studies of the semantics of programming languages.
not been addressed explicitly in any work that I know of; the question is potentially important for theories of language comprehension. Discussion of related issues in other domains, e.g. discourse about spatial relations, can be found in Johnson-Laird (1983). Johnson-Laird has conducted experiments to study differences in comprehension strategy for discourse like (i), which can be mapped into a determinate partial model and those like (ii) which cannot.

(i) A is to the right of B. C is to the right of A.
(ii) A is to the right of B. C is to the right of B.

In particular, Dowty's arguments described in Note 14 challenge the inclusion at this level of any conditions that depend on aspatial distinctions (here simplified to the event/state dichotomy). I believe that a potential resolution may lie in a clearer articulation of the dynamic aspects of DRS-construction and the corresponding dynamic aspects of context change as it both affects and is affected by interpretation. To make this more concrete, note that there are just two points in Hinrichs' DRS-construction rules where the event/state dichotomy makes a difference: (i) in the choice between the conditions 

\[ e_s \subseteq r_s \]  

and 

\[ e_s \subseteq r_s \]  

relating a given event/state to the current reference time, and (ii) in whether a new reference time is introduced or not at the end of processing a simple clause. For the first, we could let the syntax-driven DRS construction rules introduce a context-dependent variable over temporal relations, whose value will be determined as \( e_s \subseteq r_s \) or \( e_s \subseteq r_s \) from the context after the clause has been interpreted; for the second, the syntax-driven rules could in effect just say ‘reset \( r_s \)’ at the end of each simple clause, deferring until further interpretation of the clause in context the decision as to whether the reference time has moved forward or not. I am not at all sure of the best way to articulate the implement such suggestions, however.

20 See the chapters on 'egocentric logic' in Prior and Fine (1977) for a discussion of a totally different logically possible (but linguistically implausible) way of assimilating pronouns to tenses, treating both as operators.

21 Another principal shortcoming of the proposal of Partee (1973), not to mention its inexplicability about the mapping from syntax to semantics, was its failure to extend from when-clauses to before- and after-clauses, a direct consequence of the attempt, in effect, to make direct anaphoric connection to 'event times' without the intermediary of 'reference times'. It also failed to account for a number of uses of past perfect; Hinrichs includes extensive treatment of past perfect, which I am ignoring here for simplicity.

22 See Cooper (1979b) for discussion of both this problem and a similar problem concerning subject-agreement markers in languages where the subject is only optionally present, so that the agreement marker may be redundant or not. Cooper notes that such phenomena may be particularly pervasive in polysynthetic languages; his suggested solution for such cases invokes the notion of 'rule clusters' and requires in the temporal case that the past tense operator and the time adverb be added by a single syntactic rule when both are present, and thus differs from the approach of Bach and Parsons discussed below and that of Hinrichs.

23 Hinrichs treats postponed and preposed temporal adverbs alike; I would rather restrict this account to preposed adverbs and leave internal and final adverbs out of consideration in this paper. See Note 32.

24 I am following a suggestion of Ewan Klein in making the form of the 'update' statements purposely resemble variable assignment statements used in programming languages.

25 A referee suggested that a clearer example of main-clause events preceding the when-clause event might be (i):

(i) When Smith spoke, Jones introduced him.

Actually, it seems to me that in both (iib) and (i), there is a strong tendency to interpret the when-clause event description broadly so that the main-clause event occurs within it: throwing a party can include planning and sending invitations, and the introduction of the speaker can be counted as part of a speaking event. The fact that we automatically construe

spoke in (i) as 'making a speech' supports this idea.

26 I recognize that this is a controversial assumption, one that will probably have to be replaced by a theory of the interaction among context, content, inference, and implicatures. Perhaps all that the grammar determines in the initial stages of DRS construction is a free relation variable connecting the event-reference with the newly introduced reference time, and the setting of specific values like 'just after' is the result of subsequent processes involved in integrating the information in the DRS with background knowledge and contextual information. In any case, I believe we have to imagine as 'just after' condition that will turn out to be parallel in the when-clause constructions and strings of simple sentences.

27 To make this change, we must claim that sentence-initial when-clauses within discourses in the linear progression mode must be event-clauses and not state-clauses, since we could not otherwise characterize the introduced reference time as 'just after' the when-clause event. We will argue for this claim below in connection with examples (19) and (20).

28 Ewan Klein has suggested the following formal characterization of my notion of 'just after', which I accept: \( e' \) is just after \( e \) iff \( e' \) is after \( e \) and there is no contextually relevant \( e' \) between \( e' \) and \( e \). See also Note 35.

29 The only changes in DRS (16) to yield the ordering shown in (17) are the replacement of the three conditions numbered (8) by the condition(s) \( e_t < e_s < t < \text{now} \) and the deletion of the condition \( e_t < t_1 \) in step (10).

30 Both Hinrichs' original treatment and my modification of it account for the difference between (19) and (20). Closer inspection of (20) shows one of my reasons for the modification: on Hinrichs' account, since 'the room was empty' describes a state, that state should surround the event of the janitors coming in, which it cannot. I believe we have to reinterpret states as inchoatives to fit them into when-clauses (at least preposed ones in linear narrative); then on my account the reference time is characterized as a time just after the room emptied, which seems correct.

31 The ontological status of states remains unclear, but I can try to elucidate what I have in mind. States can be temporally unbounded, but with those which are bounded on at least one end one could associate a corresponding event of beginning-to-hold (inchoative) or ending (terminative). With those which are bounded on both ends one can in principle associate a corresponding event temporally coinciding with the state (holistic). After Mary was in the hospital, for instance, is ambiguous: it can mean after she began to be in the hospital (inchoative), or after her whole hospital stay (which could be analyzed as either terminative or holistic). When-clauses in general can contain state and process descriptions, but not (I am claiming) in linear narrative. There, as in (20), it seems that an inchoative reading is always imposed. I leave as open problems the best way to characterize these effects and the existence of 'terminative' and/or 'holistic' readings; the existence of inchoative readings is already widely accepted.

32 As noted earlier, Hinrichs always processes the subordinate clause first, even when it follows the main clause. I have limited my examples to cases where the subordinate clause comes first, because I don't believe the order of the clauses is irrelevant. There is more relevant literature than I care to try to cite – but one would have to consider issues of real-time processing, within-sentence temporal iconicity, topic-focus structure, backwards anaphora, S- versus VP-attachment of temporal adverbial clauses, and restrictive versus non-restrictive adverbial clauses. I believe that sentence-internal adverbs can help characterize event types; see Bach (1980). Some preposed temporal adverbs are probably topological VP-adverbs; I leave them out of consideration here.

33 And in fact if we didn't have independent reasons to invoke the notion of reference time we could also achieve an appropriate linking with a condition \( e_t < t \) in the consequent box, since \( e_t \) and \( t_1 \), like discourse entities, can also end up having either particular or 'variable' referents depending on the embedding condition of the DRS's in which they occur.

34 The requirement that \( e_t \) precede 'now' is in this case redundant, given the condition \( e_t < r_s \) and the specification of \( r_s \) as a past reference time, but is included since it is
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