


lattice. For all eventualities \( e_1, e_2 \in EV \), the following relations are defined:

- part of: \( e_1 \Pi_E e_2 \iff e_1 \oplus_E e_2 = e_2 \)
- overlap: \( e_1 \odot e_2 \iff \exists e_3 (e_3 \Pi_E e_1 \land e_3 \Pi_E e_2) \)

- The time domain \( T \) is an atomic complete join semi-lattice \( \langle T, \oplus_T, <, \text{at}(\cdot) \rangle \), where \( T \) is a set of periods, \( \text{at}(t) \) holds for an atomic period \( t \), called an instant. Instants are linearly ordered by the relation \( < \) (temporal precedence), and \( \oplus_T \) is the join relation of the semi-lattice. Let \( t_1, t_2 \) be elements of \( T \), then:

- \( \Pi_T \) is the corresponding ‘part of’ relation.
- The temporal precedence relation is extended from instants to arbitrary periods by:
  \[
  t_1 < t_2 \iff \forall t'_1, t'_2 \in T \left[ \text{at}(t'_1) \land \text{at}(t'_2) \land t'_1 \Pi_T t_1 \land t'_2 \Pi_T t_2 \rightarrow t'_1 < t'_2 \right]
  \]
- \( t_1 \subseteq t_2 \iff \forall t' \in T [\text{at}(t') \land t' \Pi_T t_1 \rightarrow t' \Pi_T t_2] \)

- \( ET \) is a function from \( EV \) to \( T \), s.t.

  - \( t \odot e' \rightarrow \exists t' \in T [\text{at}(t') \land t \Pi_T ET(e) \land t \Pi_T ET(e')] \)

- Using \( ET \), we define the following relations:

  - temporal precedence - for all \( e_1, e_2 \in EV \): \( e_1 < e_2 \iff ET(e_1) < ET(e_2) \)
  - temporal overlap - for any eventuality \( e \) and time \( t \):
    \[
    e \odot t \iff \exists e' \in T [\text{at}(t') \land t' \Pi_T t \land t' \Pi_T ET(e)]
    \]
  - temporal inclusion - for any eventuality \( e \) and time \( t \):
    \[
    e \subseteq t \iff ET(e) \subseteq t.
    \]

It is a simple matter to check that the event domain with the definitions of temporal precedence and temporal overlap satisfies a set of seven axioms which appear in (Kamp and Reyle, 1993) (page 667) and go back to (Russell, 1956). The embedding conditions of DRSs is the same as in (Kamp and Reyle, 1993) with the following additions, for model \( M \) and embedding function \( f \), DRS \( K \), and events \( e, e' \in EV \):

- \( M \models_f E = e \oplus_E e' \iff f(E) = f(e) \oplus_E f(e') \) in \( M \)
- \( M \models_f e \Pi_E e' \iff f(e) \Pi_E f(e') \) in \( M \)
- \( M \models_f E = \Sigma_E K \text{ iff } f(E) = \oplus_E \{e' : e' \in EV \land M \models_{f(t,e')} K \} \)

### References


8 Conclusion

In this paper we have presented an analysis of sentences and short discourses which contain temporal anaphora and quantification over events. Accepting both the BSA and Hinrichs' POA as basic plausible assumptions, we have shown how they can be integrated into a single account which is a direct extrapolation of the analysis of temporal anaphora in non-quantified sentences. We adopt Kamp and Reyle's split in the roles of the reference time. The apparent 'overloading' of too many roles on the single reference time mechanism seems to have complicated things rather than making them simpler. Based on this split, we propose a DRT solution for PQP. This solution achieves the existential quantification, which has to be explicitly stipulated in de Swart's solution of PQP, 'for free'.

This split further allows an enhancement of the analogy of NP-anaphora and temporal anaphora. Plural temporal anaphora is presented as an analog of plural NP-anaphora. We show how the similarity between Link's analysis of NP plurals using i-sums, and Krifka's lattice-theoretical analysis of events, allows a new analysis of plural temporal anaphora. This view of plural temporal anaphora better explains how one eventuality can be anaphorically linked to more than one eventuality or time. Such an analysis is difficult within previous accounts.

A final issue discussed in this paper is narrative discourse in quantified contexts. In discourses where the first sentence is quantified, following sentences that continue the narrative cannot be construed to be within the scope of the quantifier. By a direct analogy with Evans' E-type analysis of NP anaphora, we are able to analyze such cases.

9 Acknowledgments

We wish to thank two anonymous referees for their comments on an earlier version of this paper. The work of the second author was partially supported by a grant from the Israeli ministry of science "Programming languages induced computational linguistics", and by the fund for the promotion of research in the Technion.

A Model theory

The model theoretic interpretation of these constructions is based on the model theory in (Kamp and Reyle, 1993) (part 2, pages 676 – 678), with a few modifications, which reflect the semi-lattice based structure of the event and temporal domains, taken from (Krifka, 1989). Note, that unlike Krifka, we include states as well as events in the structure. A Model $M$ should include the following:

- The event domain $\mathcal{E}V =< EV, \oplus_E >$ is a complete join semi-lattice without bottom element$^{21}$, where $EV$ is a set of eventualities and $\oplus_E$ is the join operation of the semi-

$^{21}$The presence of a bottom element would undesirably cause any two eventualities to overlap.
of the second sentence as the main event of the first sentence\(^{20}\). As in the general procedures for anaphora resolution, the choice of proper antecedent in case there are many possible candidates is non-deterministic. Here too, in case of a long narrative discourse, we allow a non-deterministic choice of temporal antecedent over which abstraction is applied. In such cases, when we interpret some sentence in the narrative, instead of picking out its immediate predecessor as the antecedent of the temporal anaphora, we may choose a previously described event in the discourse.

The determination of how the choice is made depends on general discourse mechanisms. For example, the mechanisms of (Spejewski, 1994; Carlson and Spejewski, 1997) for the representation of event subordination relations can be taken into account here in order to correctly choose the suitable events over which to apply abstraction. Thus, in essence we are adopting a refined version of Hypothesis 2, similarly to the choice made by (Carlson and Spejewski, 1997).

Another point raised by Carlson and Spejewski (1997) has to do with the truth conditions of discourses such as the Grandma discourse above. They claim that for such discourses, even in situations in which one of the sentences does not hold, we still have pretty clear intuitions about the occurrence of the rest. For example, consider the following variant of the “Grandma passage”, which is the same as (41), omitting the quantifier “sometimes” from (e):

(43)  
\begin{enumerate}
  \item My grandmother used to bake the most wonderful pies on Saturdays.
  \item She would go to the orchard on Shady Lane early in the morning.
  \item She used to pick a basket each of apples and peaches.
  \item Then she would go into the kitchen and shoo everyone else away.
  \item Then she would shoo the dog out too.
  \item About 4 o’clock an irresistible aroma wafted through the entire house.
\end{enumerate}

Consider a situation in which (e) doesn’t hold, i.e. Grandma did not shoo the dog out. In such a situation, we still expect (f) to happen. This is explained by Carlson and Spejewski (1997) by their use of temporal subordination information. Since (f) is not subordinate to (e), there is no quantificational dependency between them.

In our framework, we do not have access to this subordination information. Again, we can solve this problem using the non-deterministic choice of temporal anaphoric antecedent. Here, we could choose the event described by (d) as the antecedent for (f). We do not provide a procedure for choosing between antecedent candidates. Such a procedure could well take into account such subordination information.

In conclusion of this section, we have presented a temporal analog of E-type anaphora. This analysis further strengthens the ties between nominal and temporal anaphora.

\(^{20}\) We focus here on the E-type reading.
7.8 Long sequences of quantified narrative discourse

As we have already mentioned, Carlson and Spejewski (1997) do not adopt Hypothesis 2 per se. In fact, they introduce a refinement based on the conclusion that this hypothesis is too strong. We will now examine this refinement and its implication for our analysis.

Carlson and Spejewski (1997) believe that Hypothesis 2, which requires each different sentence to introduce its own generic quantifier and to include in its restrictor all the preceding events, is too strong. The reasoning is as follows: Consider situations in which an event described by one of the sentences does not occur. In such cases, we still have relatively strong intuitions regarding the occurrence of the other events. For example, they consider the following variant of the “Grandma passage” (25) above:

(41) a. My grandmother used to bake the most wonderful pies on Saturdays.
    b. She would go to the orchard on Shady Lane early in the morning.
    c. She used to pick a basket each of apples and peaches.
    d. Then she would go into the kitchen and shoo everyone else away.
    e. Then she would sometimes shoo the dog out too.
    f. About 4 o’clock an irresistible aroma wafted through the entire house.

(Carlson and Spejewski, 1997)

Now, consider a situation in which (e) does not hold, i.e. the grandmother bakes a cake going through the steps (b-d), but does allow the dog to stay. In such a situation, sentence (f) is still required to hold, i.e. even if the dog stays, it is still the case that an irresistible aroma wafted through the house. Note that whether or not (f) is required to hold depends on the relation between the two events described by (e) and (f). If (f) were a subordinate event to (e), then (f) would be required to hold just when (e) does occur. This can be seen by considering the following continuation (f') instead of (f):

(42) f'. She would wield the broom in a menacing fashion and yell "Get out!".

This consideration leads Carlson and Spejewski (1997) to refine the analysis. The revised analysis does not require a quantificational dependency between each pair of subsequent events in the narrative. Instead, they claim that such a dependency is required only between subordinate and superordinate events and is left optional between pairs of adjacent events. The framework of (Spejewski, 1994; Carlson and Spejewski, 1997) allows the representation of such subordination relations between events. Based on this information, it is possible to deduce quantificational dependencies. The determination of subordination relations between events is based on human reasoning and is not formulated as part of the computational DRS-construction algorithm.

In the account presented in this paper, we do not have access to this information. How can we account then, for the quantificational dependencies in the previous discourse? In the consideration of short quantified narrative discourse above, we chose the temporal anaphoric antecedent
7.7.3 Ambiguity in discourses containing quantification over events

Discourse (27), which contained an upwards monotonic quantifier was ambiguous between an E-type and a non E-type reading. We have already seen examples of discourses with downwards monotonic quantification that exhibit the E-type reading. The following discourse has the complementary quantificalional pattern:

\[(40) \quad \text{When John was an alcoholic, he rarely accepted a drink. He drank it in one shot and felt guilty all evening.}\]

7.7.4 Our solution

As shown above, it is possible to find examples exhibiting both quantificalional patterns, both in the NP domain and in the temporal domain, regardless of the direction of monotonicity of the quantifier. We have already seen how the E-type reading can be accounted for using abstraction. How should we account for the non E-type readings?

One way to solve this would be to stipulate a rule that would allow the abstraction operation defined above to operate not only on the union of both boxes of the duplex condition, but optionally just on the left one. This rule would allow readings in which the antecedent, constructed by the abstraction operation, would be just the set that satisfies the restrictor of the quantification. Optional application of this rule would give the non E-type readings.

Allowing such a rule would also explain the case of ‘no’ (for NPs) or ‘never’ (for events). In discourses containing these quantifiers, this optional rule must be applied since the alternative E-type interpretation leads to vacuity. The regular abstraction rule calls for constructing the union of both sides of the duplex condition. However, when the quantifier in the duplex condition is ‘no’ there can be no individual (or event), which satisfies both boxes. Therefore, it would be vacuous to claim something about such individuals (events). We assume that such vacuous readings are ruled out 19.

While we saw some examples exhibiting both kinds of quantificalional patterns, it is not the case that the different readings are equally salient in all cases. For example, it seems that there is a clear preference for non E-type readings in the temporal domain when the quantifier is downwards monotonic. The question of when this optional rule should be applied is a matter for further research. However, we believe that there is a strong connection between the understanding of the principles behind such a rule in the NP domain to those in the temporal domain. A better understanding of one is bound to shed light on the other.

19Kibble (1996) independently discusses the similarity between pronominal E-type anaphora, temporal adverbials and modal subordination. He also notices the quantificalional pattern arising most commonly with downwards monotonic quantifiers, but attributes it to the controversial operation of anaphoric reference to the complement set. In our solution, we do not allow anaphoric reference to the complement set, but allow reference to the set over which quantification is applied.
Also, note that the events of the second clause cannot be understood as falling within the scope of the quantifier in the first sentence. The same quantificational pattern appears if we replace "rarely" with "never".

Proceeding according to the construction rules introduced for upwards monotonic quantifiers, would thus seem to give wrong truth conditions for downwards monotonic quantifiers. We would introduce a duplex condition with the quantifier "few", and then abstract over those events that satisfy both the left and the right boxes of the duplex condition. This would give reading (37).

There is a genuine difference between the quantificational pattern exhibited by (36), and that exhibited by (30a). In both cases, a downwards monotonic quantifier is present. However, the quantificational pattern is different. In (30a), the pronoun ‘they’ referred to those few congressmen who admire Kennedy. In (36), we cannot accept those few situations in which he came home and switched on the TV as the antecedent of the temporal anaphora.

On first sight, this difference appears to be a difference between the nominal and temporal domain with respect to downwards monotonic quantifiers. However, we wish to show that both quantificational patterns may be found both in the nominal and the temporal domain. Also, while the problem becomes most apparent with downwards monotonic quantifiers, both kinds of quantificational patterns occur with all kinds of quantifiers. We show such examples for both domains.

### 7.7.2 Ambiguity in discourses containing quantification over NPs

In the classical examples of E-/type anaphora the plural pronoun ‘they’ refers to the set of elements that satisfy the DRS composed of both parts of the duplex DRS-condition. However, there are also discourses with similar structure, which have the non E-/type reading. In these discourses, it seems the pronoun ‘they’ refers to those elements that satisfy just the antecedent box. Here are two such discourses:

(39)  

| a. Few Computer Science students are on the volleyball team. They just don't have time to practice. |
| b. Few piano players practice Karate. Their hands are too delicate. |
| c. Most people who live in the suburbs have a barbecue on Sunday. They commute to work on Monday. |

In (39a) the pronoun ‘they’ is most naturally understood as referring not to the set of few CS students who are on the volleyball team, but to the set of all such students. Similarly, in (39b), ‘their hands’ more naturally refers not to the hands of those few piano players that do practice Karate, but rather to those of the entire set of piano players. In (39c), ‘they’ most naturally refers to the set of people who live in the suburbs, not necessarily those who have barbecues. The E-/type reading is also acceptable in these discourses. Replacing the quantifier with ‘no’ blocks the E-/type reading altogether.

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7.7.1 An apparent problem with downwards monotonic quantifiers

As it turns out, downwards monotonic quantifiers over events sometimes yield a different quantificational pattern. If we place a downwards monotonic quantifier in the first sentence of such discourses, the narrative sequence is not understood as following the main clause event in the first sentence, but rather as occurring instead of it. This is illustrated by considering (36).

(36) When he came home he rarely switched on the TV. He took a beer and sat down in his armchair to forget the day.

Thus, this discourse cannot have the paraphrase in (37). It should rather be understood as in (38). We call these readings the E-type and non E-type readings respectively.

(37) Few situations in which he came home are such that he switched on the TV. Furthermore, all situations in which he switched on the TV after coming home, are such that he took a beer and sat down in his armchair to forget the day.

(38) Few of the situations in which he came home are such that he switched on the TV. Instead, most situations in which he came home, are such that he took a beer and sat down in his armchair to forget the day.
applied, there must be a suitable accessible antecedent, represented by a discourse marker in the DRS. The event markers in the duplex condition are not accessible from outside the duplex condition. The intermediate step of applying abstraction makes them accessible.

There are cases similar to the collective constructions of the previous section, where the compound event plays a bigger role. One such example is the following discourse in which we need to collectively refer to the compound event:

(34) (John had a dental appointment Yesterday.) Whenever the dentist operated the drill, John started yelling. He became hoarse.

In this discourse, the event of John’s becoming hoarse follows the compound event composed of all the component events in which John yelled.

Note also that by the Event Abstraction construction rule we are allowed to abstract over any event discourse referent in the union of the two parts of the duplex condition.

7.6 Applying the analysis to “usually”

The E-type analysis presented above gives the correct truth conditions for discourses, in which the quantifier “always” is replaced with the quantifier “usually”. We illustrate this by constructing a DRS for the following simplification of Example (27).

(35) When he came home, he usually switched on the TV. He took a beer.

The DRS for this discourse would be similar to that of Figure 14 except that the first conditional DRS - condition of the type $K_1 \Rightarrow K_2$ would be replaced by a duplex condition as shown in Figure 15. In this DRS, the event in the second sentence of taking a beer falls outside the scope of the quantifier ‘usually’. Thus, the wrong prediction of Hypothesis 1 is avoided.

7.7 Extending the analysis for additional quantifiers

As we have seen above, the proposed E-type analysis gives the required truth conditions for both “always” and “usually”. A natural question is whether the same pattern is shared by other quantifiers as well.

Recall that the rule allowed the choice of any $e'$ from $U_{K_e}$. This non-determinism is copied from the parallel NP abstraction rule, where the NP abstracted over may be in the object position, e.g. Few swimmers wear a wristwatch. They are ruined by water. In this discourse, ‘they’ refers to the wristwatches, not the swimmers. In the temporal case, since the discourse is a narrative progression, we usually choose the latter event as the antecedent. This freedom becomes useful in cases where there is anaphoric reference to the subordinate clause event.

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18Recall that the rule allowed the choice of any $e'$ from $U_{K_e}$. This non-determinism is copied from the parallel NP abstraction rule, where the NP abstracted over may be in the object position, e.g. Few swimmers wear a wristwatch. They are ruined by water. In this discourse, ‘they’ refers to the wristwatches, not the swimmers. In the temporal case, since the discourse is a narrative progression, we usually choose the latter event as the antecedent. This freedom becomes useful in cases where there is anaphoric reference to the subordinate clause event.
When he came home he always switched on the TV. He took a beer.

Figure 14: When he came home he always switched on the TV. He took a beer.

This DRS in is constructed as follows:

1. By the BSA, a duplex condition is constructed for the first sentence.

2. Abstraction is applied over the events $e_2$, using the operator $\Sigma_E$. This operator maps the set of events $e_2$ that satisfy the DRS to its right onto their sum, $E_1$.

3. The sum $E_1$ is now chosen as the antecedent of the temporal anaphora.

4. Applying the optional rule of distributive expansion as given in 6.6.1, another duplex condition is added. This condition asserts that each event $e_2$ that is a part of $E_1$ is followed by an event $e_3$ of taking a beer.

5. The temporal relation between the events $e_2$ and $e_3$ is restricted using the $Rpt$, as is done in cases of regular narrative progression.

In this example, we have applied abstraction, giving the compound event $E_1$ only to later distribute over each of $E_1$’s component events. Thus, abstraction plays only an intermediate role in the construction. However, this role is still important since we assume that the temporal relation between the two sentences involves temporal anaphora. In order for anaphora to be
This DRT analysis captures the spirit of E-type pronouns. In the discourses discussed, the \( i \)-sum of the individual elements that satisfy the antecedent clause is constructed. This \( i \)-sum can be referred to either collectively, as in (12) or distributively as in (13).

### 7.5 E-type temporal anaphora

After seeing how E-type anaphora in the NP domain can be handled in DRT, we present an analogous construction for the temporal domain. It is our view that the phenomenon encountered in the short discourse (27), is similar to that encountered with E-type pronouns as in (30). In both cases, an analysis that sees the anaphoric element (whether pronominal or temporal) as a bound variable inside the scope of a quantifier, fails to give the required readings. In analogy to the nominal domain, we view the temporal anaphoric element not as a bound variable, but rather as a definite description. The basis of this analysis is the introduction of an abstraction operator on events, \( \Sigma_E \). The truth conditions for this operator are given in the appendix.

In sequences such as (2), we first introduce a duplex condition for the first sentence, according to the BSA. We then apply abstraction on this duplex condition. Abstraction introduces a new discourse marker for the sum of the events that satisfy the duplex condition. Once this new discourse marker is introduced, it can be referred to either collectively or distributively, using the construction rules presented in Section 6.6.1. The construction rule for abstraction is the following. It is based on the similar rule for NP abstraction above.

**Event Abstraction**

<table>
<thead>
<tr>
<th>Triggering configurations:</th>
<th>( \gamma \subseteq \gamma \in Con_K )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operations:</td>
<td>Form the union ( K_0 = K_1 \cup K_2 ) of the two component DRSs of the condition. Choose an event discourse referent ( e' ) from ( U_{K_0} ). Introduce into ( U_K ) a new discourse referent ( E ) and add to ( Con_K ) the condition ( E = \Sigma_{Ee'} : K_0 )</td>
</tr>
</tbody>
</table>

For the sake of simplicity, we illustrate this analysis by constructing a DRS not for (2) but for the shorter discourse (33), in Figure 14.
Triggering configurations:

\[ \gamma \subseteq \gamma \in Con_K \]

Operations:

Form the union \( K_0 = K_1 \cup K_2 \) of the two component DRSs of the condition. Choose a discourse referent \( w \) from \( U_K \).

Introduce into \( U_K \) a new discourse referent \( Y \) and add to \( Con_K \) the condition

\[ Y = \Sigma w : K_0 \]

Using this operation, it is possible to represent discourses such as (31). In this discourse, the plural pronoun ‘they’ refers to the books that Susan found. What this discourse asserts is not that Susan found most books that are both needed by Bill and are on his desk. Rather, she found most of the books that Bill needs, and all of these are on his desk.

(31) Susan has found most books which Bill needs. They are on his desk.

In the DRS for this discourse, abstraction has been applied to the duplex condition. This is represented by using the \( \Sigma \) operator. The discourse marker \( Y \) is the \( i \)-sum of individuals \( y \) that satisfy the sub-DRS to the right of \( y \). The previously discussed rule of distributive expansion may also be applied to \( i \)-sums which have been introduced through an operation of abstraction. For example, if we continue Discourse (31) with (32), we add another duplex condition to the DRS as shown in Figure 13, asserting that each \( u \) s.t. \( u \mathcal{I} U \) was read by Bill.

(32) He has read them.
This reading is not predicted by Hypothesis 1. Thus, it cannot be the case that the quantifi-
cational force in the discourse arises solely from the quantifier in the first sentence. The reading
in (29) would be predicted by Hypothesis 2. In the next subsection we give some motivation for
this hypothesis.

7.3 A temporal analog of E-type anaphora - motivation

As we have seen, the simplest hypothesis fails to predict the required reading of discourses such
as (27). How can we account for these readings? Once again, we turn to NP anaphora in search
of an analogous phenomena. Such an analog is found in the form of E-type anaphora\(^{17}\) (Evans,
1980; Chierchia, 1995). We shall introduce a temporal analog of E-type anaphora, after giving
a brief review of E-type anaphora in the classical NP domain.

7.3.1 E-type anaphora

An E-type analysis of pronouns was suggested in (Evans, 1980) to account for sentences such as
the following:

\[(30) \quad \begin{array}{l}
a. \text{Few congressmen admire Kennedy and are very junior.} \\
b. \text{Few congressmen admire Kennedy and they are very junior.}
\end{array}\]

The two sentences above are not equivalent. Sentence (30a), says that the number of congressmen
who both admire Kennedy and are very junior is small. Sentence (30b), on the other hand, is
different. It says that the number of congressmen who admire Kennedy is small, and that every
congressmen who admires Kennedy is very junior. Evans (1980) analyzed this difference as
being based on the interpretation of the pronoun ‘they’. Classical accounts, which hold that
(non-deictic) pronouns should be interpreted as bound variables fail to capture this difference.
For instance, such an account for (30b) would introduce a variable for the pronoun ‘they’, within
the scope of the quantifier ‘few’. This would give a reading equivalent to that of (30a), which is
not the intended reading.

As an alternative to the bound variable account, Evans (1980) suggested that there is another
type of pronouns, which he termed E-type pronouns. Instead of introducing a variable, these
pronouns should be interpreted as definite descriptions, which select the individuals that satisfy
the antecedent clause.

7.4 A DRT implementation of E-type anaphora

Within the DRT framework, Kamp and Reyle (1993) deal with E-type anaphora using an ab-
straction operator. This operator maps a set of individuals satisfying some DRS onto their
\(\iota\)-sum:

\(^{17}\)The resemblance to E-type anaphora was brought to our attention by Shalom Lappin.
Hypothesis 2 The first sentence of the discourse introduces a universal/generic quantifier. Further events in the narrative sequence each introduce their own generic quantifier. In addition, previous events in the narrative sequence are added to the restrictor of the quantification through a process of accommodation.

In this paper, we independently present a different argument against Hypothesis 1. The consideration of different factors, lead us to develop a temporal analog of E-type anaphora (Evans, 1980; Chierchia, 1995) in the NP domain. This E-type approach will lead to a solution of the problem, closely related to Hypothesis 2. While this analysis turns out to be very similar to that of Carlson and Spejewski (1997), it may still be of independent interest for several reasons. Mainly, the introduction of temporal E-type anaphora serves to strengthen the ties between nominal and temporal anaphora even further. As we have tried to show throughout this paper, these ties provide an important link and an insightful and fruitful line of research. In addition, our E-type analysis naturally leads to the discussion of additional contexts, not previously considered by Carlson and Spejewski (1997), such as downwards monotonic quantifiers over events.

7.2 An argument against quantifiers scoping over narrative discourse

Hypothesis 1 cannot be maintained, if we consider the truth conditions of (27). This discourse is created from (2) by replacing the quantifier “always” by “usually”.

(27) When he came home, he usually switched on the TV. He took a beer and sat down in his armchair to forget the day.

Hypothesis 1 gives this discourse a reading according to which, most events of coming home are continued by the sequence of events described in the remainder of the discourse:

(28) Most situations in which he came home, are such that he did the following things:
    - he switched on the TV.
    - he took a beer.
    - he sat down in his armchair to forget the day.

While this reading is possible, this discourse has another, more salient reading, which may be paraphrased as in (29). According to this reading, the scope of the quantifier “usually” is restricted to the first sentence.

(29) Most situations in which he came home are such that he switched on the TV. Furthermore, all the situations in which he switched on the TV after coming home, are such that he took a beer and sat down in his armchair to forget the day.
(1991) points out that in such cases there is some influence of the quantifier of the first sentence on the events described by the second sentence. In fact, the first sentence describes a habitual sequence of events. The second sentence seems to continue the sequence. de Swart (1991) does not suggest how to account for this pattern.

This sort of discourse is closely related to the “generic passages” discussed in (Carlson and Spejewski, 1997). The main focus of that paper is on discourses which consist of a “summary sentence”, which describes a generically recurring event, and subsequent sentences which describe a sequence of events detailing how the recurring event occurred. An example of this kind is the following discourse (25). While the main focus of (Carlson and Spejewski, 1997) is this sort of discourse, they note that their analysis also carries over to discourses closer to (2), in which there is no summary sentence describing the overall recurring event.

(25)  a. My grandmother used to bake the most wonderful pies on Saturdays.
    b. She would go to the orchard on Shady Lane early in the morning.
    c. She used to pick a basket each of apples and peaches.
    d. Then she would go into the kitchen and shoo everyone else away.
    e. About 4 o’clock an irresistible aroma wafted through the entire house.
    (Carlson and Spejewski, 1997)

Carlson and Spejewski (1997) show that in such discourses, the sequence of sentences, excluding the first, form a narrative sequence. One of the main differences between this kind of sequence and regular narrative discourses is that the events described in the narrative are understood to be recurring.

How should the quantificational pattern that appears in discourses such as (2) and (25) be accounted for? The simplest hypothesis is the following:

**Hypothesis 1** *The first sentence of the discourse introduces a universal/generic quantifier. The narrative sequence of subsequent sentences falls within the scope of this quantifier.*

Applying this hypothesis to the analysis of (2), would let the quantifier “always” in the first sentence of the discourse take scope over the narrative sequence of the second sentence. This hypothesis would analyze (2) as asserting the following:

(26) For each event of coming home, there is a sequence of events of switching on the TV, taking a beer and sitting in the armchair.

A similar analysis can be given for (25). While Hypothesis 1 gives intuitively correct truth conditions for these discourses, it also suffers from several shortcomings. Some problems with this hypothesis are shown in Carlson and Spejewski (1997). These factors lead them to present an alternative hypothesis for such discourses. Basically, their analysis is a refinement of the following hypothesis. We will first consider the hypothesis per se, and defer the treatment of the refinement to Subsection 7.8.
The optional distribution construction rule may be applied. This will give a duplex condition, quantifying over a new event referent $e$, restricted to be a part of $E$. $e$ may now be chosen as the Rpt for the second sentence. This gives a reading according to which each such event $e$ is followed by an event of the type described by the second sentence.

7 Quantified narrative discourse

In the previous sections, we have looked at several temporal anaphora phenomena. We have given an analysis of temporal anaphora, based on the analogy to pronominal anaphora, and seen how this analogy can give insight into the temporal anaphora phenomena. In this section, we look at another such phenomenon.

7.1 The quantification pattern of quantified narrative discourse

We have already discussed at some length the interaction of temporal anaphora and quantification over eventualities. We now wish to examine how narrative progression behaves in such quantified contexts. As an example, consider Example (2) repeated here.

(2) When he came home, he always switched on the TV. He took a beer and sat down in his armchair to forget the day. (de Swart, 1991)

This discourse contains a narrative progression of events. As in regular narrative discourse (of the typed studied extensively by (Hinrichs, 1981; Partee, 1984; Hinrichs, 1986) and others), events seem to move time forward. What makes this discourse different than the regular narrative progression examples, is the presence of the quantifier “always” in the first sentence. de Swart...
Optional Distribution for Eventualities

<table>
<thead>
<tr>
<th>Triggering configurations:</th>
<th>$S(e')$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\gamma \in Con_K$</td>
<td></td>
</tr>
</tbody>
</table>

Operations:  

$$
\begin{array}{c}
\epsilon \\
\epsilon \Pi_{E} E \\
\text{every} \\
\epsilon \\
Rpt := \epsilon \\
S(e')
\end{array}
$$

where $\epsilon$ is a new eventuality discourse referent and $E$ is a discourse marker for a compound eventuality accessible from $\gamma$.

Based on this construction rule, the collective/distributive ambiguity in (6) (repeated here) is captured as follows. The pair of DRSs is given in Figure 11.

(6) John gave a lecture on Sunday and on Monday. He became very tired.

- The first sentence introduces two event discourse markers for the two events of John’s giving a lecture.
- Using the summation construction rule, their join, $E$, is constructed.
- Now, there are two options:
  - $E$ may be chosen as the Rpt, and the second sentence analyzed according to this Rpt. Since the second sentence is eventive, the event follows the Rpt, in this case the compound event, and therefore both its component events.  

16Strictly speaking, not only $E$ is available as a candidate Rpt, but so are $e_1$ and $e_2$. Recall that according to (Kamp and Reyle, 1993), the Rpt is chosen non-deterministically as some event or time discourse marker already present in the DRS. Thus, strictly speaking, both $e_1$ and $e_2$ remain viable options for the Rpt, and indeed there may be contexts in which such readings are available. The reason for preferring $E$ as an Rpt is that we are focusing on narrative sequences. Just as in ordinary narrative sequences the immediate predecessor event is chosen as the Rpt, here too we may choose only $E$. In discourses in which the narrative progression is violated, we may indeed use other events as the Rpt.
The superscript \( pl \) on the discourse referent \( x \) denotes the fact that the referent was introduced by a plural NP. Only such referents may serve as antecedents for a plural pronoun.

The symbol \( \Pi \) is used for the ‘part of’ relation\(^\text{15}\).

<table>
<thead>
<tr>
<th>NP Optional Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Kamp and Reyle, 1993)</td>
</tr>
</tbody>
</table>

**Triggering configurations:**

\[ \gamma \subseteq \gamma \in Con_K \]

\[ S \quad \text{(i)} \quad V P \quad \text{(ii)} \quad V \quad X \]

**Operations:**

\( \gamma \) may be replaced by the duplex condition

\[ x^{pl} \quad \text{every} \quad x \quad \gamma' \]

where \( x \) is a new individual discourse referent and \( \gamma' \) is obtained from \( \gamma \) by replacing \( X \) by \( x \)

Using this construction rule, the collective/distributive ambiguity in (24) (repeated here) is captured as follows. The pair of DRSs is given in (10).

(24) John is a lawyer and Mary is a lawyer. They hired a new secretary.

- The first sentence is analyzed using the individual summation construction rule, introducing a new plural discourse referent \( Y \).
- The pronoun ‘they’ introduces a new discourse referent \( X \), which is identified with \( Y \).
- Now, there are two options:
  - The collective reading is obtained by applying the predicate to \( X \). This reading means that John and Mary hired a new secretary together.
  - The distributive reading is obtained by applying the “optional distribution” construction rule. This causes the introduction of a duplex condition, quantifying over a new discourse referent \( x \), restricting it to be a part of \( X \), and applying the predicate to \( x \) in the consequent box. This reading means that John and Mary each separately hired a new secretary.

Based on the plural NP optional distribution construction rule, we introduce the following optional distribution construction rule for eventualities:

\(^\text{15}\)We prefer to use the symbol \( \Pi \) instead of Kamp and Reyle’s use of the symbol \( \in \) for the ‘part of’ relation.
The temporal relation between the combined event $E$ and the event $e_3$ of Mary’s sighing is recorded as a relation between the combined event time, $T$, and $t_3$, the location time of $e_3$. This relation is recorded in the DRS as a result of employing the general construction rule for temporal subordinate clauses. As in the case of single eventualities, the temporal relation is recorded as a relation between the event time of the subordinate clause, here, the event time $T$ of the combined event $E$, and the location time of the main clause eventuality, $t_3$.

Because of the way the temporal precedence relation, $<$, was defined, any time that follows the compound event time automatically also follows the event times of the atomic events that compose the compound event. Since $t_3$ is later than $t$, it is also later than both $t_4$ and $t_5$.

Note that this DRS does not contain any information about the relative ordering of the component events, $e_1$ and $e_2$. The fact that Mary’s sighing follows both these events is independent of their temporal order.

A similar DRS can be constructed for (5), where the temporal relation is again between the compound event time of the subordinate clause and the location time of the main clause. The only difference being the fact that in a DRS for this sentence, the temporal relation is reversed, i.e. the location time of the main clause event precedes the combined event time of the subordinate clause, and thus both the event times of the component events.

By thus extending the semantic construction rules, we arrive at DRSs that give the right truth conditions for the examples, without having to stipulate different construction rules for each temporal connective. Rather, the only differences between the construction rules for different temporal connectives are a direct application of the regular (i.e. singular event) construction rules for the temporal connectives combined with the summation construction rules.

### 6.6.1 Distributive vs. collective readings

We now turn to the question of distributive and collective readings of sentences involving plural eventualities. We have already seen such ambiguity in discourses such as Discourse (6) and related it to the distributive/collective ambiguity seen in discourses such as (24). Both discourses are repeated below:

(6) John gave a lecture on Sunday and on Monday. He became very tired.

(24) John is a lawyer and Mary is a lawyer. They hired a new secretary.

Once again, we wish to model the construction rules for dealing with the collective/distributive ambiguity in the temporal anaphoric case according to the rules for the plural pronominal anaphoric case. (Kamp and Reyle, 1993) give an optional distribution construction rule. This rule operates on NPs in the subject or object position. If the discourse marker assigned to the NP is $X$, the S subtree is replaced by a duplex condition. This condition quantifies over a fresh marker $x$, restricts $x$ to be part of $X$, and adds a new DRS-condition, applying the predicate of the VP to $x$. This gives a quantificational structure, according to which for every part $x$ of $U$, the predicate applies. In this construction rule the following ‘new’ symbols are used:
Verb Phrase conjunction

Triggering configurations:

\[ \gamma \in Con_K \]

\[ \begin{array}{c}
V P \\
V P_1[\varepsilon_1] \quad \text{and} \quad V P_2[\varepsilon_2]
\end{array} \]

Operations:

1. Introduce a new plural eventuality marker, \( E \), into \( U_K \)
2. Replace \( \gamma \) by \( V P(E) \)
3. Introduce into \( Con_K \) the condition:
   \[ E = \varepsilon_1 \oplus E \varepsilon_2 \]

Eventuality summation

Triggering configurations:

\[ K' \leq K \] and \( \varepsilon_1, \varepsilon_2, \ldots, \varepsilon_k (k \geq 2) \) are eventuality markers occurring in \( K \) and accessible from \( K' \)

Operations:

1. Introduce a new plural eventuality \( E \) into \( U_{K'} \)
2. Introduce into \( Con_{K'} \) the condition:
   \[ E = \varepsilon_1 \oplus E \varepsilon_2 \oplus \ldots \oplus E \varepsilon_k \]

Employing these construction rules, (4) is represented by the DRS in Figure 9.

\[
\begin{array}{ccccccccc}
  x & y & z & e_1 & e_2 & e_3 & E & t_1 & t_2 & t_3 & t_4 & t_5 & T & n \\
  \text{John(}x\text{)} & \text{Bill(}y\text{)} & \text{Mary(}z\text{)} \\
  \text{t}_1 < n & \text{t}_2 < n & \text{t}_3 < n & \varepsilon_1 \subseteq \text{t}_1 & \varepsilon_2 \subseteq \text{t}_2 \\
  e_1 : \text{spill coffee(}x\text{)} & e_2 : \text{trip on rug(}y\text{)} \\
  \text{t}_4 = \text{ET(}e_1\text{)} & \text{t}_5 = \text{ET(}e_2\text{)} \\
  \text{E} = \varepsilon_1 \oplus \text{E} \varepsilon_2 & \text{T} = \text{ET(}E\text{)} \\
  \varepsilon_3 \subseteq \text{t}_3 & \text{t}_3 < \text{t}_3 \\
  \text{e}_3 : \text{sigh(}z\text{)}
\end{array}
\]

Figure 9: When John spilled his coffee and Bill tripped on the rug, Mary sighed.

This DRS contains the following elements:

- events:
  - \( e_1 \)- John’s spilling his coffee
  - \( e_2 \)- Bill’s tripping on the rug
  - \( E \)- the join of the events \( e_1 \) and \( e_2 \), formed as a result of the eventuality summation construction rule.
  - \( e_3 \)- Mary’s sighing

- times:
  - \( t_4 \)- the event time of \( e_1 \)
  - \( t_5 \)- the event time of \( e_2 \)
  - \( T \)- the event time of the combined event \( E \).
  - \( t_3 \)- the location time of \( e_3 \)
• $\oplus_E$ - the symbol for the summation operator on eventuality discourse markers, mapping the markers to their join.

• Compound eventualities have temporal traces, just as atomic events do. These are regular temporal intervals (minimal covers of the traces of the component events). We will usually denote them by capital letters, e.g. $T$.

Now that we have introduced a new operation of summation on eventualities, we need to see when this operation is applied. Again, we turn to the construction rules for plural individuals for hints. Summation over individual markers is done in (Kamp and Reyle, 1993) in the following cases:

• The occurrence of $k$ accessible individual discourse markers causes the introduction of a new plural discourse marker $Z$ and a DRS-condition asserting that $Z$ is the sum of the $k$ individuals.

• NP conjunction causes the introduction of a plural marker, which is the sum of the two individuals of each of the conjuncts.

By analogy, we introduce the following construction rules. In these rules, we employ the following notation taken from (Kamp and Reyle, 1993):

• A DRS $K$ is an ordered pair $<U_K, Con_K>$, where $U_K$ is the universe of the DRS and $Con_K$ are its DRS-conditions.

• We write $K' \leq K$ if $K'$ is a sub-DRS of $K$ ($K'$ can also be $K$ itself).

• We write $S(\epsilon)(VP(\epsilon))$ in case $\epsilon$ is the eventuality described by the sentence $S$ (verb phrase $VP$).

<table>
<thead>
<tr>
<th>Sentence conjunction</th>
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</thead>
<tbody>
<tr>
<td>Triggering configurations:</td>
</tr>
<tr>
<td>$\gamma \in Con_K$</td>
</tr>
<tr>
<td>$\text{Operations:}$</td>
</tr>
<tr>
<td>(1) Introduce a new plural eventuality marker, $E$, into $U_K$</td>
</tr>
<tr>
<td>(2) Replace $\gamma$ by $S(E)$</td>
</tr>
<tr>
<td>(3) Introduce into $Con_K$ the condition:</td>
</tr>
<tr>
<td>$E = \epsilon_1 \oplus_E \epsilon_2$</td>
</tr>
</tbody>
</table>
antecedent is already present. At this stage, all that is left to do is to refer to this compound antecedent. We will introduce a temporal analog of the optional distribution rule. This rule can optionally be applied, giving the distributive reading, or not applied, giving the collective reading. The only difference is that instead of having two different kind of pronouns: singular ones, which can refer to single entities and plural ones, which can refer to compound entities, we have a single kind of tense morpheme. This morpheme behaves as a temporal anaphoric element which can refer either to a singular eventuality antecedent or a compound one.

6.6 Incorporating combined events into DRT

In order to incorporate the analysis of combined events into DRT, we review the analysis of plural pronominal anaphora in DRT. In (Kamp and Reyle, 1993), a summation operator symbol, $\oplus$, is introduced into the DRT language. The corresponding function maps a pair of individual entities in the model onto their sum, a non-atomic entity. This operator is utilized in the DRS construction for sentences such as (23) as shown in Figure 8.

\[
\begin{array}{c}
u \ v \ y \\ John(u) \\
Mary(v) \\
Acapulco(y) \\
take(u, v, y) \in U \\
Z = u \oplus v \\
U = Z \\
had\text{Lousy\_time}(U)
\end{array}
\]

Figure 8: John took Mary to Acapulco. They had a lousy time.

This DRS contains the following ‘new’ elements:

- Discourse markers for combined individuals:
  - Such discourse markers are given capital letters, e.g. $Z, U$.
  - They may serve as arguments to (collective) predicates, e.g. $\text{had\_Lousy\_time}(U)$.

- The summation operator $\oplus$, which maps a pair of individual markers to their join. For instance in this DRS the individual markers for John and Mary, $u$ and $v$, are summed using $\oplus$, to give $Z$.

By analogy with these constructions for the individual domain, we introduce the following extensions to the temporal DRT language. We postpone the model-theoretic interpretation of these elements to the appendix. In essence, this interpretation follows Krifka (1989), as summarized in Section 6.4.

- Discourse markers for compound eventualities, using capital letters, e.g. $E, S$. 

21
of the pronoun. However, while pronouns come in both singular and plural varieties, the tense morpheme doesn't have such a distinction. In particular, there is no temporal analog for a plural pronoun. To see how this affects the plural-like construction rules for temporal anaphora involving multiple eventuality antecedents, we look more closely at the stages of anaphora handling.

The handling of both nominal and temporal anaphora within DRT, can be divided into the following two stages:\(^{13}\):

1. Processing the antecedent: This causes the introduction of a discourse marker for the antecedent.
2. Processing the anaphoric element: This includes introducing a discourse marker for the anaphoric element and choosing an appropriate antecedent discourse marker, with which the newly introduced marker is equated.

These two steps are clearly distinguished in both the classical DRT treatment of nominal anaphora, and in the handling of temporal anaphora in (Kamp and Reyle, 1993)\(^{14}\).

How are these two stages realized in plural pronominal anaphora? Plural pronominal anaphora involves two ‘new’ operations: summation over individuals and optional distributive expansion. When the antecedent is comprised of several individuals, anaphora handling operates according to the two following stages (details are given in the next section):

1. Processing the antecedent: This causes the introduction of separate discourse markers for the antecedent individuals, and an additional plural discourse marker for their sum.
2. Processing the anaphoric element: This includes introducing a discourse marker for the plural anaphoric element and choosing an appropriate antecedent discourse marker. Now, either the newly introduced marker is equated with the antecedent’s marker (giving the collective reading) or an optional rule of distributive expansion is applied (giving the distributive reading).

The importance of this distinction between the stages in which each operation is performed is the following. While the occurrence of a plural pronoun provides strong evidence for a plural construction, on deeper examination, we see that it is not the trigger for the plural construction. Thus the lack of a temporal analog for a plural pronoun is not such a limiting factor. The main operation of the plural construction, i.e. joining together the individual elements does not depend on the occurrence of the plural pronoun. During the second stage of the construction, when the plural pronoun or the tense morpheme are encountered, an appropriate compound

---

\(^{13}\)The order of these operations is reversed in kataphoric constructions.

\(^{14}\)Note however, that the analysis of Hinrichs and Partee differs slightly from this template. Hinrichs’ POA (see Section (1.1)) separates the processing of the antecedent clause (containing the antecedent) from the processing of the main clause (containing the anaphoric element). However, according to their analysis, an event clause advances the reference time. This is done during the processing of the antecedent (stage 1). In (Kamp and Reyle, 1993), the Rpt is chosen when processing the anaphoric element (stage 2), as a time or event marker already present in the DRS. Thus, the analysis of (Kamp and Reyle, 1993) is more consistent with the general scheme of anaphora handling.
proposed for plural pronominal anaphora Link (1983) and compound events (Krifka, 1989; Lasersohn, 1992). It therefore makes sense to model an analysis of multiple event temporal anaphora based on the analysis of plural pronominal anaphora. This is precisely what is done in the sequel.

### 6.4 Plural individuals and combined events

Kamp and Reyle (1993) present a DRT analysis of plurals, which models the domain of individuals using a *complete free atomic upper semi-lattice with bottom element*. This account is based on Link’s (1983) \(i\)-sums.

The lattice-theoretic accounts of (Krifka, 1989) and (Lasersohn, 1992) are a framework in which combined events may be constructed from atomic events. Krifka (1989) defines the event and time domain as follows:

- An event structure is a *complete join semi-lattice without bottom element*.
- The time domain is an *atomic complete join semi-lattice without bottom element*. It has the following features:
  - The atoms are time points.
  - The set of time points is linearly ordered by a transitive relation of temporal precedence \(<\).
  - \(<\) is extended to a relation between times in general, by defining \(t < t'\) iff for every part \(s\) of \(t\) and \(s'\) of \(t'\), \(s < s'\).
- A temporal trace function, \(TR\), mapping an event to its temporal trace (which is what we have been calling the event time). \(TR\) is a homomorphism relative to the joins of the two semi-lattices.

Thus, model-theoretically, there is indeed a great similarity between the way in which plural NPs are analyzed in DRT and the analysis of combined events of (Krifka, 1989).

### 6.5 Triggering plural temporal anaphora

In this paper, we wish to consistently see both temporal relations induced by temporal connectives and narrative discourse as forms of temporal anaphora. This view leads us to model the analysis of temporal anaphora on the more familiar analysis of pronominal anaphora. We have already seen an important difference between the two kinds of anaphora, i.e. the reference time. The reference time (or more accurately, the different manifestations of it) is an added element of temporal anaphora, which has no analog in pronominal anaphora.

Another important difference between the two kinds of anaphora, is the use of pronouns in nominal anaphora. Partee (1984) sees the tense morpheme of a clause as the temporal analog
This idea of combining individual events into compound events is not new. It has been proposed in (Krifka, 1989; Lasersohn, 1992) within the framework of lattice-theoretical event-based semantics. Indeed, we shall make use of some of the mechanisms proposed by Krifka (1989), incorporating them within DRT. What is new in this paper, to our knowledge, is our outlook on these phenomena as temporal analogs of plural pronominal anaphora. In the following section, we point out the analogy between the problems we encountered in analyzing temporal anaphora involving multiple eventualities and plural pronominal anaphora.

6.3 The similarity to plural pronominal anaphora

As it turns out, there is great similarity between the problem of temporal anaphoric reference involving multiple eventuality antecedents and plural pronominal anaphora, as arises in the following sentences (adapted from (Kamp and Reyle, 1993)):

\[(23)\] John took Mary to Acapulco. They had a lousy time.

\[(24)\] John is a lawyer and Mary is a lawyer. They hired a new secretary.

The second sentence in both these example discourses contains the plural pronoun “They”, which anaphorically refers to John and Mary, together. The short discourse (24) exhibits an ambiguity between a collective and a distributive reading. According to the collective reading, John and Mary hired a new secretary together, while the distributive reading asserts that each of them hired a new secretary separately. An account of plural pronominal anaphora is provided in (Link, 1983). A version of this account is incorporated in DRT in (Kamp and Reyle, 1993). The basis of the analysis is the construction of ‘individual sums’ (i-sums) from the individuals. Such i-sums can be anaphorically referred to by a plural pronoun either collectively or distributively. Model-theoretically, i-sums are based on a lattice-theoretical construction. The details of this analysis will be reviewed in the sequel.

We can now see the similarity we have been alluding to between temporal anaphoric links to multiple eventuality antecedents and plural pronominal anaphora. In both cases, we have anaphoric links to entities comprised of combined individual entities (persons or events):

- In Examples (23) and (4), the antecedent is the combined individual/event.
- In (24) and (6) there is an anaphoric reference to the combined entity exhibiting a collective/distributive ambiguity.

Of course, a major difference between the pronominal and temporal anaphora examples, is the occurrence of a plural pronoun (“they”) in the sentence. The occurrence of a plural pronoun provides strong evidence for a plural construction. Nevertheless, there is evidence for the need for a plural-like construction in the temporal case as well. In Section 6.5, we will see how the lack of pronoun (or pronoun analog) comes into effect in the construction rules.

Besides the similarity between the two linguistic phenomena of plural pronominal anaphora and plural temporal anaphora, there is also a great similarity in the model-theoretic approaches.
Such examples are not discussed in the previous DRT work on temporal anaphora. Furthermore, attempting to accommodate such examples within these frameworks immediately encounters difficulties. This is because temporal anaphoric links in these frameworks always link pairs of eventualities. In these frameworks, the temporal relation contained in (4) and (5) would have to be captured as a temporal anaphoric link between the main clause eventuality and one of the subordinate clause eventualities. Thus, accounting for these examples would require rules to determine which of the two eventualities in the subordinate clause is the temporal anaphoric antecedent in each of the two sentences.

Such an approach suffers from two problems. First, we do not know the temporal ordering of the subordinate clause eventualities. This ordering does not necessarily reflect the syntactic ordering of the conjuncts in the subordinate clause, as can be seen in (4). In this discourse, we cannot really tell which event happened first. Second, even if we would allow a semantic operation of choosing the first or last event of a set of events, this approach remains highly artificial. This is because it would seem to determine the event antecedent according to the temporal connective. This requires a stipulation of a different rule for choosing the event antecedent for each temporal connective. Thus, for example, for a ‘when’ clause, the event antecedent should be the latest event. This would give the required reading, according to which, the main clause eventuality follows the latest event and therefore all the events in the subordinate clause. For ‘before’ clauses, a converse rule would be required. It would choose the earliest event as the temporal antecedent. This would give the required reading, according to which, the main clause event precedes the earliest event and therefore all the subordinate clause events.

A related problem occurs in cases such as (6). Trying to analyze this example according to the “narrative sequence” constructions discussed above would place the event of John’s becoming tired after either one of the events of his giving a lecture. None of these options is compatible with the distributive reading, according to which John became tired after each lecture. Such a reading is available for the discourse.

Thus, trying to analyze these examples using a temporal anaphoric relation between a pair of eventualities raises many problems. Intuitively, the temporal relation in these examples is between the main clause eventuality and a combined event antecedent in the subordinate clause.

6.2 Combined eventualities

Enhancing the construction rules with a method for combining individual events would offer an elegant solution for the problems raised. For example, in sentences (4) and (5), the temporal anaphoric link would be between the main clause event and the combined event of John’s spilling his coffee and Bill’s tripping on the rug. The temporal relation in such sentences should be between the location time of the event in the main clause and the event time of the combined event in the subordinate clause. Similarly, constructing a combined event for the pair of events in the first sentence of Example (6), would give the collective/distributive distinction by referring to the combined event either collectively or by distributively.

12The justification of the asymmetry of using the location time for the main clause event vs. the event time of the subordinate clause event has been discussed in Section 3.
Figure 7: When John is at the beach, he always squints when the sun is shining.

6 Plural temporal anaphora

In the account presented in Section 3 of temporal anaphora, based on (Kamp and Reyle, 1993), eventualities and their temporal indices served as the basic components of the analysis of temporal expressions in discourse. In this section, an account of temporal anaphora involving simultaneous reference to multiple eventualities is proposed. This account reveals more extensive connections between NP-anaphora and temporal anaphora than the connections arising in previous work.

6.1 The problem posed by multiple eventualities

Consider examples (4)—(6) (repeated here). The common denominator to these examples is the existence of a temporal anaphoric link between an eventuality in the main clause and multiple eventualities in the subordinate clause.

(4) When John spilled his coffee and Bill tripped on the rug, Mary sighed.

(5) Before John spilled his coffee and Bill tripped on the rug, Mary sighed.

(6) John gave a lecture on Sunday and on Monday. He became very tired.

In (4), the main clause eventuality follows both events in the subordinate clause. In (5), it precedes them. In the short discourse (6), there is an ambiguity between a “collective” and a “distributive” reading. This ambiguity stems from the question of whether John became very tired after giving the two lectures or after each lecture.
5.2 Iterated quantifiers

De Swart (1991) analyzes (3) (repeated here) as containing an iteration of quantifiers: an implicit generic quantifier and the explicit adverbial always. Adopting Chierchia’s previously mentioned suggestion of introducing complex states, de Swart (1991) proposes a representation as in (21):

(3) When John is at the beach, he always squints when the sun is shining.

(21) \( \text{Gen}(S_z, \{e_1 | \exists(S_m, TC_{e_1})\}) \)

In (21), the following symbols are used:

- \( \text{Gen} \) is the \( Q \)-adverb corresponding to the implicit generic quantifier
- \( S_z \) is the set of events denoted by the subordinate clause John is at the beach
- \( TC_{e_1} \) is the image set of the temporal connective when
- \( S_m \) is the set of complex states in which the following holds:

(22) \( \text{ALWAYS}(S_{\text{shine}}, \{e_3 | \exists(S_{\text{squint}}, TC_{1e_3})\}) \)

where:

- \( S_{\text{shine}} \) is the set of events denoted by the embedded subordinate clause the sun is shining
- \( S_{\text{squint}} \) - the set of events denoted by the embedded main clause he squints
- \( TC_{1e_3} \) - the image set of the nested temporal connective when.

Note that in this analysis there are two instances of existential quantification, which have to be stipulated. The DRT analysis, which is a straightforward extension of our solution to Partee’s quantification problem achieves the existential quantification (in both cases) for free, because of the embedding conditions of the DRS.

Using a conditional structure of box-splitting embedded within another conditional structure, we get the DRS\(^1\) in Figure 7. In this DRS, the situation described by John’s always squinting when the sun is shining is analyzed as a complex state \( s_3 \). This state holds whenever John is at the beach, recorded by the condition that the location time, \( t_2 \), of \( s_3 \) overlaps the event time \( t_1 \) of John’s being at the beach, \( s_2 \).

\(^1\)Because of typographical considerations, we have split the DRS into two. The sub-DRS labeled \( s_3 \) should replace ‘ZOOM’.
De Swart gives this example to illustrate the necessity of using reference times in the interpretation of temporal connectives. This is done to refute any approach that would try to overcome Partee’s quantification problem by getting rid of reference times altogether. The past perfect tense in the subordinate clause has the Reichenbachian schema $E - R - S$ (meaning that the reference time ($R$) is in the past of the speech time ($S$), and the event time ($E$) precedes $R$). The state in the main clause has to be temporally linked not to $E$, the event time of the subordinate clause, but to $R$, its reference time. Thus, goes the argument, the reference time is essential to the analysis of such sentences.

This point would seem to be troublesome for our approach, which uses event times and location times and not the “monolithic” reference time. But this is only seemingly difficult, since our analysis of perfect tenses is not Reichenbachian. Following (Kamp and Reyle, 1993), the perfect is analyzed by using the perfect operator. According to this analysis, the eventuality referred to by the subordinate clause is the resultant state of a previous event. In this case, it is the result state of the event of Anne’s sleeping late. The temporal relation in the sentence is between this result state and the state in the main clause.

This analysis is illustrated by the DRS in Figure 6 for (20). Since the sentence contains the quantifier ‘often’, we construct a DRS with a duplex condition. The subordinate clause introduces the event, $e_1$, of Anne’s sleeping late and its resultant state, $s_2$. The main clause introduces the state $s_3$ of Anne’s having a headache. The temporal relation is between the event time $t_2$ of $s_2$, and the location time $t_3$ of $s_3$. The whole duplex condition is considered a complex state, $s_1$, the location time of which is $t_1$.

![Figure 6: Often, when Anne had slept late, she had a headache.](image-url)
There exists a time $t$ (a time of John’s phoning) there exists a $t' < t$ (a time of John’s smoking). This quantificational structure does not need to be stipulated as part of the Q-adverb’s meaning (as in (de Swart, 1991)), but arises directly from an extension of the principles used in the analysis of non-quantified sentences.

This solution to PQP is not prone to de Swart’s criticism against the naive solution of moving the reference time to the right DRS. The (preposed) temporal clause may be processed before the main clause, adhering to Hinrichs’ POA. This is so because $t'$, the location time of $e'$, which ‘replaces’ $r_1$, the reference time of Partee’s analysis, as the temporal index of the eventuality in the main clause, arises from processing the main clause, and not from updating the reference time of the subordinate clause.

As for the model-theoretic interpretation of complex states, like $s$ in Figure 5a, (de Swart and Molendijk, 1994) point out that (Kamp and Reyle, 1993) propose a construal of simple states as triples $\langle t, x, P \rangle$, where $t$ is a period of time, $x$ an individual and $P$ a property, such that $t$ is an interval of time, during which $x$ has property $P$. Generalizing this, they propose to construe states as pairs $\langle t, \gamma \rangle$, where $t$ is a period of time and $\gamma$ is a possibly complex condition holding during time $t$.

Thus, we reach a solution of PQP. This solution is based solely on applying Kamp and Reyle’s split of the reference time to sentences containing quantification over eventualities. Note that the crucial property of the analysis that solves PQP is the fact that an event introduces its own location time. This contrasts with the way in which Hinrichs’ and Partee’s reference time is updated during discourse, where the introduction of an event updates the reference time for the next event. Note that we did not have to stipulate this property of the location time particularly for the solution of PQP. Rather, it was an independent property of the general construction rules of (Kamp and Reyle, 1993) for temporal adverbials.

### 5 Other applications

In this section we apply the analysis described above to related constructions, the past perfect and iterated quantifiers. We show how these phenomena, previously analyzed by using the original notion of reference time, can be given a more satisfactory analysis by adopting the split in the roles of the reference time.

#### 5.1 Past perfect

First, let us consider the past perfect tense, as in (20).
We adopt a suggestion by Chierchia, cited in (Partee, 1984), that the whole implication be rendered a complex state. This state introduces a location time of its own and a condition linking the state to the location time. The rules for this condition are just the same as for simple states.

This analysis is illustrated by constructing a DRS for (1) (repeated here). To allow easy comparison with Partee’s analysis, we give this DRS in Figure 5b together with the DRS according to Partee’s analysis for the same sentence shown in Figure 5a.

(1) Before John makes a phone call, he always lights up a cigarette.

The adverb ‘always’ in this sentence triggers box-splitting. The subordinate clause ‘John makes a phone call’ is interpreted in the left box. It causes the introduction of an event marker, \( e \), with its corresponding event time marker \( t = ET(e) \). The main clause ‘he lights up a cigarette’ triggers the introduction of an event marker \( e' \), and its location time marker \( t' \), with the DRS-condition \( e' \subseteq t' \). Since the temporal connective in this sentence is ‘before’, the relation between these two markers is one of precedence, represented via the condition \( t' < t \). In this DRS, \( n \) denotes the utterance time. The whole implication is considered a state \( s \). This state is no longer an atomic eventuality. Rather, it is a complex state denoting John’s habit. This encompassing state holds during the present, and so its location time is \( n \), according to the regular construction rules regarding the location times of states.

In this analysis, the event time of the eventuality in the subordinate clause serves as the antecedent for the location time of the eventuality in the main clause. Since the subordinate clause and the main clause are each interpreted in their own sub-DRS, each of the relevant temporal markers resides in its appropriate box, yielding the correct quantificational structure: For every

\[ e \subseteq t \quad t = ET(e) \]

\[ e' \subseteq t' \]

\[ t' < t \]

\[ x = y \]

For simplicity, we disregard here the usual aspect of NP anaphora representation, which in full detail introduces another marker, \( y \) and the condition \( x = y \).
a single reference time, which was supposed to account for both kinds of phenomena in previous analyses.

(18) Bill left. Mary wrote the letter.

4. The Perfect

The perfect is dealt with in (Kamp and Reyle, 1993) as an aspectual operator and analyzed by using the notion of a *nucleus* (Moen and Steedman, 1988) to account for the inner structure of an eventuality. A nucleus is defined as a structure containing the following elements:

- preparatory process
- culmination
- consequent state

The categorization of verb phrases into different aspectual classes can be given in terms of the part of the nucleus they refer to. The eventualities described by the perfect of a verb refer to the consequent state of its nucleus. For example, (19) denotes the state $s$ holding at the present, that Mary has met the president. This state is a result of the event $e$, in which Mary met the president. Temporally, the state $s$ starts just when $e$ ends, or as it is put in (Kamp and Reyle, 1993): $e$ and $s$ abut, (represented as $e \supset s$).

(19) Mary has met the president.

5. The TPpt

The temporal perspective point (TPpt) will not be discussed in this paper for the sake of simplicity.

4 An alternative solution of PQP

As we saw, Partee’s (1984) analysis of sentences that contain quantification over eventualities led to what we have informally termed Partee’s quantification problem (PQP). This analysis was based on the interpretation rules of non-quantified sentences. By adopting the split between the different roles of the reference time, as developed in (Kamp and Reyle, 1993), an alternative DRT solution to PQP is proposed. The processing of sentences that contain a (preposed) temporal subordinate clause and quantification over events proceeds as follows:

- By the BSA, such sentences trigger box-splitting, with the temporal subordinate clause interpreted in the antecedent box, and the main clause in the consequent box.
- The temporal subordinate clause introduces an eventuality $e_{sub}$ with an event time $t_{sub}$.
- The main clause introduces an eventuality $e_{main}$ with a location time $t_{main}$, and in addition, a condition asserting a temporal relation between $t_{sub}$ and $t_{main}$. The exact temporal relation depends on the temporal connective. The asymmetry in using the event time for $e_{sub}$ and the location time for $e_{main}$ arises from the interpretation rules of temporal connectives based on (Kamp and Reyle, 1993) (as summarized in Section 3).
location time takes on one of the roles of Reichenbach’s original reference time, in the interpretation of temporal adverbials. A temporal adverbial restricts the location time of the eventuality, not its event time. A temporal adverb adds a condition on the location time of the eventuality. For example, in constructing a DRS for (17), we would introduce a state marker $s$ for the state of John’s being happy, and a time marker $t$ for the location time of $s$. As a result of the DRS construction rules, a condition would be added to the effect that $\epsilon$ and $t$ overlap. The added temporal adverbial on Sunday would restrict the location time $t$. By following this strategy, we are not restricting the whole of the state of John’s being happy to fall on Sunday. Rather, we are restricting its location time, i.e., some temporal interval overlapping this state to do so.

(17) John was happy on Sunday.

In much the same way, a temporal adverbial clause also restricts the location time of the main clause eventuality. This is achieved by relating this location time with the time span of the subordinate clause eventuality, i.e., its event time. One side effect of this is an asymmetry between the temporal indices used in main and subordinate clauses, using the location time for the main clause but the event time for the subordinate clause. This can be seen in the analysis cited above for (17). We will encounter this asymmetry several times during the paper.

3. The Rpt

Narrative progression in discourse is dealt with in this analysis by using the $Rpt$ as follows:\(^6\):

- The Rpt can be either an event or a time discourse marker, already present in the DRS (recorded as an assignment $Rpt := \epsilon$).
- Eventualities are interpreted with respect to the Rpt:
  - **events**: follow the current Rpt, states: include the Rpt.
- The Rpt is updated during the processing of the discourse.
- In a ‘terminal’ DRS (ready for an embedding test), all the auxiliary Rpts ‘disappear’ (do not participate in the embedding).

For example, Discourse (18) would introduce an event marker, $\epsilon_{leave}$, for the event of the first sentence, and restrict it to follow the $Rpt$, which is chosen to be some event already present in the DRS (if there is one). Then, when processing the second sentence, $\epsilon_{leave}$ may be chosen as the $Rpt$, recorded as $Rpt := \epsilon_{leave}$, and the event of the second sentence, $\epsilon_{write}$, would follow $\epsilon_{leave}$.

We should point out at this point, that the mechanism for handling Discourse (18) is quite different than that used to handle (16). Thus, while in processing this discourse, $\epsilon_{leave}$ acts as the $Rpt$ for the interpretation of the second sentence, it does not do so in (16). In the processing of that sentence, we use the event time of $\epsilon_{leave}$ to restrict the location time of $\epsilon_{write}$. Thus, although the end result is similar in terms of truth conditions, the construction rules are quite different. These two different mechanisms are used instead of

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\(^6\)One of the consequences of splitting the different roles of the reference time is that the Rpt is used in narrative progression, but not in other constructions, e.g., not in the relation between main and subordinate clause eventualities.
2. the Location time

The location time is used according to these principles:

- The location time is an interval $t$, used to temporally locate eventualities, in accordance with their aspectual classification:
  - **events**: are included in $t$ (recorded in the DRS as a condition $e \subseteq t$ on the respective markers),
  - **states**: temporally overlap $t$ (recorded as $s \cap t$).

- The verb tense determines the relation between the location time $t$ and the utterance time $n$. For example:
  - **simple past**: $t$ lies anteriorly to $n$.
  - **simple present**: $t$ coincides with $n$.

- Temporal adverbials restrict the location time $t$:
  - temporal adverbs introduce a DRS-condition on $t$
  - temporal subordinate clauses introduce a relation between two different indices:
    - (a) the location time $t_{main}$ of the eventuality of the main clause.
    - (b) the event time $t_{sub}$ of the eventuality $e_{sub}$ of the subordinate clause.
  - The exact temporal relation denoted by a temporal connective depends on the aspectual classes of the eventualities related by it. In this paper, we shall focus only on the temporal connectives: “before”, “after” and “when”. Following (Kamp and Reyle, 1993), we assign the following relations for “when” cf. (Hinrichs, 1986):
    - (a) If both the when-clause and the main clause denote states, then their respective time indices overlap.
    - (b) If both are events, then the times are temporally close, with the exact relation undetermined. For concreteness, we will assume here that the time index of the event in the main clause is “just after” the time index of the event in the subordinate clause, bearing in mind that this is not always the correct interpretation.
    - (c) When one is a state and the other an event, then the time index of the state includes that of the event.

For example, in (15), the event triggers the introduction of an event marker $e$, and location time marker $t$ into the DRS, with the DRS-condition $e \subseteq t$. The past tense of the verb adds the condition $t < n$. In (16), the location time of the event in the main clause is restricted to fall (just) after the event time of the event of the subordinate clause.

(15) Mary wrote the letter.

(16) Mary wrote the letter when Bill left.

At this point, it is fruitful to compare the event time with the location time. The event time is a much more obvious temporal index than the location time, since it denotes the exact temporal span of the eventuality. The location time, on the other hand, imposes a much less stringent constraint on the temporal whereabouts of the eventuality. The

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5Since the utterance time, $n$, is a point in (Kamp and Reyle, 1993), the overlap relation between a state that holds in the present and $n$ degenerates to inclusion.
De Swart's solution does overcome PQP, although not within DRT. As such, the existential quantification in (13) and in (14) has to be stipulated, whereas the analysis presented here acquires this existential quantification 'for free'.

3 Splitting the roles of the reference time

The DRT-based analysis of PQP in this paper uses a different notion of reference time than that used by the accounts in the exposition above. This notion of reference time is based on the analysis of temporal expressions in (Kamp and Reyle, 1993). This analysis distributes the different roles, which were attributed to the reference time in previous accounts, between several different temporal indices. This split allows a more fine-grained and precise analysis of temporal phenomena than the use of a single monolithic reference time. In one place (p. 594) Kamp and Reyle write:

"We will follow Reichenbach in what we consider to be the spirit of his proposal, though not in its details. For some of the specific proposals he made do not seem to stand up to scrutiny. In fact, we believe that Reichenbach went astray when he wanted his notion of reference point to do too many things at once. In particular, he writes as if the reference time which is required for the interpretation of past perfects like the one in [...] is of a kind with the reference times we discussed in Section [...] where they were needed in the interpretation of sequences of sentences in the past progressive and simple past tense."

In this section we briefly summarize the analysis of Kamp and Reyle (1993). The interpretation of temporal expressions makes use of the following mechanisms:

1. Event time
2. Location time
3. Reference Point (Rpt)
4. Perfect
5. Temporal Perspective Point (TPpt)

Each of these indices (besides the event time) takes on one role of the original monolithic reference time. We briefly summarize the use of each of these temporal indices.

1. The event time

The event time of an eventuality is defined as the the smallest interval that includes it. For an eventuality \( \epsilon \), the event time \( t \) is recorded in the DRS as \( t = ET(\epsilon) \).

\(^4\)Kamp and Reyle (1993) use the relation name 'loc' where we use 'ET'. We prefer to use this relation name to avoid confusion between the event time and the location time.
the right box is updated, i.e. the processing of the main clause. In our proposed solution, the ‘reference time’ is indeed moved to the right box, but it is a different notion of reference time, and is exempt (as will be shown) from this criticism.

2 The proportion problem

De Swart (1991) sees PQP as a temporal manifestation of the notorious proportion problem, which arises in donkey sentences such as:

(11) Most women who own a cat are happy. (Kadmon, 1990)

The sentence is false in the case where out of ten women, one owns 50 cats and is happy, while the other nine women own only one cat each, and are miserable. This is not predicted by the unselective binding of quantifiers in DRT, which quantify over all the free variables in their scope, in this case women-cat pairs. According to de Swart (1991), PQP is similar. The universal quantifier in sentences such as (1) binds pairs of events and updated reference times, whereas the desired quantificational scheme is universal quantification over the event and existential over the reference time.

De Swart (1991) offers a solution from a Generalized Quantifier approach, based on the analysis of quantified NPs in transitive sentences. In this analysis, the reference time is an implicit variable, which is needed in the interpretation of the temporal relation, but is not part of the quantificational structure.

The denotation of a temporal connective is a relation, \( TC \subseteq E \times E \), between two sets of events. For example, the denotation of ‘before’ is given in (12).

(12) \( \{ (e_1, e_2) \mid e_1 < e_2 \} \)

The quantificational structure of such sentences can be analyzed either by an iteration of monadic quantifiers, or as a single dyadic quantifier of type \( \langle 1, 1, 2 \rangle \). In the first approach, adverbs of quantification (Q-adverbs) are assigned the structure:

(13) \( Q(S_s, \{ e_1 \mid \exists (S_m, TC_{e_1}) \}) \)

In (13), \( S_s \) and \( S_m \) denote, respectively, the sets of events described by the subordinate and the main clause, \( TC_{e_1} \) denotes the image set of \( e_1 \) under the temporal connective \( TC \), i.e. the set of events \( e_2 \) which are related to \( e_1 \) via the relation \( TC \). The Q-adverb establishes a relation between the set \( S_s \) and the set \( \{ e_1 \mid \exists (S_m, TC_{e_1}) \} \).

According to the second approach, the structure is the one given in (14). The dyadic quantifier \( [Q, \exists] \) establishes a relation between two sets of events: \( S_s, S_m \), and a binary relation between events: \( TC \).
marker, which lies ‘just after’ $e_1$. The stative clause ‘Sam was asleep’ causes the introduction of a state $s_1$, which includes the reference time $r_1$.

The embedding conditions for the whole construction are just like those for a regular ‘if’ or ‘every’ clause, i.e. the sentence is true, if every proper embedding of the antecedent box can be extended to a proper embedding of the combination of the antecedent and the consequent boxes. This means, as desired, that for each choice of an event $e_1$ of Mary’s telephoning, and reference time $r_1$ ‘just after’ it, there is a state of Sam’s being asleep, that surrounds $r_1$.

A sentence such as (9a), which has the same meaning as (9), except the ‘whenever’ is replaced by ‘when’, and ‘always’ is added in the main clause, would get the same DRS$^3$.

(9a) When Mary telephoned, Sam was always asleep.

1.3 Extending the analysis

As noted by (Partee, 1984), this analysis does not extend in a straightforward manner to cases in which the operator when is replaced by (an unrestricted) before or after, in such quantified contexts. Constructing a similar DRS for such sentences yields wrong truth conditions. For instance, Figure 1 shows a DRS for (1), adhering to the principles above. The reference time marker $r_1$, used for the interpretation of the main clause, is placed in the universe of the antecedent box. Because the temporal connective is ‘before’, $r_1$ is restricted to lie before $e_1$. The embedding conditions determine that this reference time be universally quantified over, causing an erroneous reading in which for each event $e_1$, of John’s calling, for each earlier time $r_1$, he lights up a cigarette. Paraphrasing this, we could say that John lights up cigarettes at all times preceding each phone call, not just once preceding each phone call. This problem is not present in the DRS in Figure 4, since although the reference time $r_1$ is universally quantified over in that DRS as well, it is also restricted to immediately follow $e_1$. It is similarly restricted if ‘before’ is replaced with ‘just before’ or ‘ten minutes before’. But, (unrestricted) ‘before’ is analyzed as ‘some time before’, and thus the problem arises. We henceforth informally refer to this problem as “Partee’s Quantification Problem” (PQP).

Partee (1984) suggests that in these cases we somehow have to ensure that the reference time marker, $r_1$, appears in the universe of the consequent DRS, causing it to be existentially quantified over, giving the desired interpretation. As noted by de Swart (1991), the trivial solution of moving the reference time marker to the right box does not agree with Hinrichs’ POA. According to the POA, the subordinate clause is processed before the main clause. Simply moving the reference time marker to the right box would seem to defer part of the processing of the subordinate clause, namely, the updating of the reference time, to the processing stage in which

$^3$Note, however, that such sentences are sometimes ambiguous as is the following:

(10) Before John left town, he always wore a tie.

This sentence can refer to one event of John’s leaving town, asserting that before it John always wore a tie. Alternatively, it can quantify over all events in which John left town, asserting that each one is preceded by an event of his wearing a tie. The ambiguity stems from the different possible relative scopes of the temporal connective (before) and the quantifying adverbial (always). In this paper we will concentrate only on the latter reading. We believe the former reading is well handled by an analysis along the lines of (Kamp and Reyle, 1993).
1.2 Quantification over events

Partee (1984) extends Hinrichs’ treatment of temporal anaphora to the analysis of sentences that contain a temporal adverbial and quantification over eventualities. A major assumption included in her analysis is the Box-Splitting assumption (BSA):

**Assumption 2 (BSA)** Temporal adverbials and quantification over eventualities trigger box-splitting as do if or every clauses in DRT.

Consider the following example from (Partee, 1984) with its DRS in Figure 4:

(9) Whenever Mary telephoned, Sam was asleep.

The subordinate clause ‘Mary telephoned’ cannot be interpreted relative to a reference time denoting a single time period, since Mary’s telephoning is not specified to occur at some specific time. Still, the sentence has to be interpreted relative to some reference time. This reference time can be taken to be a large interval, and should contain each of the relevant occurrences of Mary’s telephoning, during which Sam was asleep. This reference time is represented in Figure 4 as $r_0$ in the top sub-DRS.

By the BSA, the quantifier ‘whenever’ triggers box-splitting. The event marker $e_1$ is added to the antecedent box, with the condition that it is temporally included in the current reference time, $r_0$ and is prior to $n$. ‘Whenever’ also causes the introduction of $r_1$, a new reference time.
Adverbial modifications, whether phrasal (e.g. ‘On Sunday’) or clausal (e.g. ‘When Bill left’), introduce a new reference time, which overrides the current reference time. An important assumption referred to here as Hinrichs’ processing-order assumption (POA) is the following:

**Assumption 1 (POA)** Proposed temporal subordinate clauses are processed before the main clause.

Temporal subordinate clauses are interpreted according to the POA as follows:

- The subordinate clause eventuality, $e_{sub}$:
  1. is not constrained to occur within the current reference time $r_{curr}$, but rather follows it, and
  2. introduces a new reference time $r_{new}$, which in cases of simple linear progression follows $r_{curr}$, regardless of the temporal connective.
  3. The temporal connective determines the relation between $e_{sub}$ and $r_{new}$. For example, in ‘when’ clauses, $e_{sub} \leq r_{new}$.

- The main clause eventuality $e_{main}$ is interpreted with respect to $r_{new}$, as discussed earlier, regarding narrative progression:
  1. A state includes $r_{new}$
  2. An event is included in it and updates it further.

For example, consider the following discourse (Partee, 1984). Following Partee, instead of giving the full DRS for it, we illustrate the analysis using the diagram in Figure 3, with circles denoting inclusion.

(8) Mary turned the corner. When John saw her, she crossed the street. She hurried into a store.
different tense forms uses the temporal relations between three temporal indices: the *utterance time*, *event time* and *reference time*. These temporal indices are points of time, the relation between which determines the interpretation of the tense form. The reference time according to Reichenbach is determined either by context, or by temporal adverbials.

1.1 A unified analysis of temporal anaphora

Hinrichs’ and Partee’s use of the reference time provides for a unified treatment of temporal anaphoric relations in discourse, including narrative progression (especially in sequences of simple past tense sentences), temporal adverbs and temporal adverbial clauses, introduced by a temporal connective. This reference time is no longer an instant of time, but rather an interval. This approach can be summarized as follows: in processing a discourse \( (S_1, S_2, \ldots, S_n) \), \( S_1 \) requires a contextually-determined initial reference time \( r_0 \). Subsequent clauses \( S_i \), for \( i \geq 0 \) are interpreted relative to \( r_{i-1} \) and update it to \( r_i \), as follows:

- **An event clause:**
  - Introduces a new event \( e \), s.t. \( e \subseteq r_{i-1} \)
  - Updates \( r_i \) to be ‘just after’ \( r_{i-1} \) (Partee, 1984). This is denoted by \( r_{i-1} \leq r_i \).

- **A state clause:**
  - Introduces a new state \( s \), s.t. \( r_{i-1} \subseteq s \)
  - The reference time is not updated (i.e. \( r_i = r_{i-1} \)).

As an example of such an analysis, consider the following narrative discourse (Partee, 1984):

(7) **John got up, went to the window, and raised the blind. It was light out. He pulled the blind down and went back to bed. He wasn’t ready to face the day. He was too depressed.**

Figure 2 shows a DRS for the first two sentences of this discourse, according to Hinrichs’ and Partee’s analysis. It contains the following components:

- The ‘n’ in the top DRS is a mnemonic for ‘now’ - the utterance time.
- \( e_1 \) stands for the first event in the discourse – John’s getting up. This event is interpreted relative to a contextually-provided reference time, \( r_0 \), whereby \( e_1 \subseteq r_0 \).
- \( r_1 \) - A new reference time marker is then introduced with \( r_0 \leq r_1 \).
- \( r_1 \) serves as the current reference time for the following event \( e_2 \).
- Updating the reference time continues in this fashion, until the second sentence is processed. This sentence introduces a state, \( s_1 \), with \( r_2 \subseteq s_1 \), and so on...
To examine temporal anaphora involving anaphoric reference to multiple eventualities we discuss the following examples:

(4) When John spilled his coffee and Bill tripped on the rug, Mary sighed.

(5) Before John spilled his coffee and Bill tripped on the rug, Mary sighed.

(6) John gave a lecture on Sunday and on Monday. He became very tired.

What is common to these examples, is a temporal anaphoric link between an eventuality and multiple eventuality antecedents. In (4) and (5), Mary’s sighing follows or precedes both events of John’s spilling the coffee and Bill’s tripping on the rug. In (6), John’s becoming tired is linked to either one of the events of his giving a lecture or to both. We show that dealing with such cases requires an operation which combines individual eventualities into compound ones. We introduce such an analysis based on the analysis of plural pronominal anaphora. This enhances the relation between nominal and temporal anaphora.

1 Background

An analysis of the mechanism of temporal anaphoric reference hinges upon an understanding of the ontological and logical foundations of temporal reference. Different concepts have been used in the literature as primitives. These include temporal instants as in Tense logic (Prior, 1967), intervals of time (Bennet and Partee, 1972) as in the analysis of temporal connectives in (Heinämäki, 1978), event structures (Kamp, 1979) as in Hinrichs’ (1981; 1986) analysis of temporal anaphora, and event lattices as in (Krifka, 1989).

An important factor in the interpretation of temporal expressions is the classification of situations into different aspectual classes (or Aktionsarten), which is based on distributional and semantic properties. In this paper, we only consider events and states, termed together eventualities in (Bach, 1981). In narrative sequences, event clauses seem to advance the narrative time, while states block its progression. The mechanism used to account for this phenomena in (Hinrichs, 1981) and (Partee, 1984) is based on the notion of reference time, originally proposed by Reichenbach (1947). Reichenbach’s well-known account of the interpretation of the

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2We thank an anonymous referee for suggesting example (4).
Introduction

In (Partee, 1973), Partee introduced the notion of *temporal anaphora* to account for ways, in which temporal expressions depend on surrounding elements in the discourse for their semantic contribution to the discourse. This analogy between NP anaphora and temporal anaphora has been an important factor in the analysis of temporal expressions in natural language semantics and a driving force in the early stages of the development of Discourse Representation Theory (DRT)\(^1\) (Kamp, 1981; Heim, 1982; Kamp and Reyle, 1993) in particular.

A factor vital to the analysis of temporal anaphora, which is absent from the analysis of NP anaphora is the well-known notion of *reference time* (Reichenbach, 1947). Thus the analysis of temporal anaphora has an added level of complexity relative to analyses of nominal anaphora. This may be seen in the unified treatment of temporal expressions in discourse given by (Hinrichs, 1981; Partee, 1984; Hinrichs, 1986). In these works, a heavily-burdened reference time plays an important role.

In this paper, we examine temporal anaphora under two kinds of special circumstances: the interaction of temporal anaphora with quantification over eventualities and anaphoric links to multiple eventualities. Such circumstances, while interesting in their own right, are also good test-beds for theories of the semantic interpretation of temporal expressions.

In order to investigate temporal anaphora under quantification over eventualities we examine the following examples:

1. *Before* John makes a phone call, *he always* lights up a cigarette. (Partee, 1984)
2. *When* he came home, *he always* switched on the tv. He took a beer and sat down in his armchair to forget the day. (de Swart, 1991)
3. *When* John is at the beach, *he always* squints *when* the sun is shining. (de Swart, 1991)

The analysis of sentences such as (1) in (Partee, 1984) yields wrong truth-conditions for the temporal connectives *before* or *after*. In Partee’s DRT-based analysis, such sentences trigger box-splitting with the eventuality of the subordinate clause and an updated reference time located in the antecedent box, and the eventuality of the main clause located in the consequent box. Figure 1 shows a DRS obtained by Partee’s analysis for sentence (1). As can be seen in this DRS, the placement of the updated reference time, \(r_1\) in the antecedent box, causes undesirable universal quantification over it.

We show how this problem can be solved by adopting a refinement of the notion of reference time adopted from (Kamp and Reyle, 1993). This refinement involves splitting the roles of the reference time between several different temporal indices. We show how this split provides a straightforward solution to this problem and also gives a satisfactory account of examples such as (2) and (3).

\(^1\)Some familiarity with DRT is assumed.
Splitting the Reference Time: The Analogy Between Nominal and Temporal Anaphora Revisited *

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May 25, 1998

Abstract

The analysis in (Partee, 1984) of quantified sentences, introduced by a temporal connective, gives the wrong truth conditions when the connective is before or after. In this paper, we show how splitting the different roles of Reichenbach’s reference time, may be used in order to solve this problem. We further enhance the analogy between pronominal and temporal anaphora, by proposing an analog of plural NP-anaphora in the form of temporal anaphora involving multiple event antecedents and an analog of an E-type analysis of pronouns in the analysis of quantified narrative discourse.