Temporal semantics of prepositions in context

David S. Brée and Ian E. Pratt

Computer Science Department, University of Manchester, M13 9PL, U.K.

Abstract

We examine how the temporal semantics of prepositions and verbs interact to determine the interval in which the main proposition in a sentence holds. The central question is whether these two sources of temporal semantics are simply additive or rather interactive. Only preposition phrases specifying a temporal interval, such as *1992*, are considered, not those specifying a duration, such as *two years*. Also, the present tense, modals and generics are not considered. It is shown that the interaction is usually additive except that:

- quantification is generally determined by the aspect, when present, and by the type of verb otherwise, except that THROUGHOUT and UNTIL require universal and AFTER and BEFORE require existential quantification;
- temporal SINCE must have the perfective aspect, as was known.
- BY can only take the perfective aspect with event verbs;
- for most prepositions the progressive aspect requires the time of reference to be first updated to within the interval determined by the preposition.

We have developed a temporal logic suitable for capturing the semantics of temporal prepositional phrases (Pratt & Brée, 1995). In this logic it is also possible to record the temporal semantics provided by the tense and aspect of the verb in the sentence. The purpose of this paper is to ascertain whether these two sources of temporal semantics can simply be summed, or whether there is an interaction between them.

There is clearly some interaction: SINCE is only given a temporal interpretation if the sentence in which it occurs has a perfect aspect, otherwise it is inferential (Brée, 1985). However, it is quite possible that there is no other interaction; the semantics of tense and aspect on the one hand and that of temporal prepositions on the other may be simply additive. From the point of view of cognitive simplicity, this would be what one would expect. Hence the issue addressed in this paper.

1 Preliminaries

We will consider only declarative sentences having two parts: a matrix and an optional temporal prepositional phrase. The **matrix** has a tensed verb and an optional aspect, given by an auxiliary verb. (Modals are not considered.) The **temporal prepositional phrase** has a preposition and a temporal noun phrase. When processed, the sentence yields a timeless proposition and a temporal interval over which this quantified timeless proposition holds. The context and the matrix verb (and auxiliary, if present) contribute to the fixing of this interval globally. The temporal prepositional phrase, if present, refines this interval.

We assume each sentence is spoken (or written) at a particular time, the **time of utterance**, or `tou`. It describes a situation that holds at some time, often called the **time of event** or `toe` (even though the situation described might not be an event at all but some state). The `toe` is usually different from the `tou`; they are only the same when a speaker is describing ongoing situations, such as in sports reporting on the radio.

Each sentence is interpreted within a temporal context which is set in two ways:

- by the **time of reference** (`tor`), in the Reichenbachian sense. Any narrative or description assumes that the writer and reader have agreed on a `tor` that may be different from both the `tou` and the `toe`. The `tor` may be earlier, at the same time as or later than the `tou`, as reflected by the tense of the matrix verb (Section 2.2).

  The `toe` is set relative to the `tor` rather than to the `tou` (but recall that the `tor` may be the same as the `tou`). In English the aspect of the matrix verb partially determines this relationship (Section 2.3).[1]
- by the **situation**, for example:

  (1) Gunner had staked out the joint.

  must clearly mean that the *staking out* occurred within a reasonable period before the `tor`, not several years earlier, let alone a millennium earlier. We indicate this context by stating that the proposition holds within an interval which we will simple call `Context`.

A temporal prepositional phrase may introduce either a time **duration**, i.e. a length of time not tied to the time line, e.g. *two months*, or a temporal **interval**, i.e. a length of time located on the time line, e.g. *1992*. We will only consider temporal intervals.

Some matrix clauses are generic, e.g. they may indicate a habit. Generics can generally be distinguished from non-generics as they accept frequency adverbials, such as *frequently* or *always*, whereas non-generics do not, cf.

(2) Gunner killed $\left\{\begin{array}{c}\text{*Ridley}\\ \text{rats}\end{array}\right\}$ at dawn, frequently.

Generics are not covered in this paper.

We now introduce a simple framework for representing the temporal information conveyed by verbal tense and aspect before turning to the main topic of this paper: the semantics of temporal prepositions (Section 3) and how this interacts with tense and aspect, for both past and future of the matrix verb (Section 4). The present tense has several uses, in particular for generics, and is not covered in this paper.

2 The matrix

The tense and aspect of the verb in a sentence together set temporal constraints on the possible interval in which the main event in the sentence occurs. We will now summarise the ways they do this, as presented in Quirk et al. (1985). Our purpose is to provide a background against which the semantics of temporal prepositions can be investigated, not to add to the knowledge of the semantics of tense and aspect. But first we need to consider the type of verb, because this too plays a role in determining the temporal semantics

2.1 Verb types

The acceptability of some temporal prepositions depends on the type of verb used in the matrix, cf.

(3) Gunner killed Ridley $\left\{\begin{array}{c}\text{in}\\ \text{?for}\end{array}\right\}$ five minutes.

(4) Gunner liked Ridley $\left\{\begin{array}{c}\text{*in}\\ \text{for}\end{array}\right\}$ five years.

Therefore we need to distinguish different types of verb. The most common classification is that due to Vendler (1957) in which a distinction is made between states, achievements, accomplishments and activities. Note that many verbs can be classified into more than one of these semantic types, depending on the context in which they are used, for example transitively or intransitively, cf.

(5) Gunner climbed $\left\{ \begin{array}{ll} \text{the tower.} & [transitive - achievement] \\ \text{for pleasure.} & [intranstivie - state] \end{array} \right\}$

We will not consider these differences due to context here, but rather we assume that the classification into semantic type is made by some other device which has access not only to the verb but also to all the matrix (other than the verb's tense and aspect) and its context. When we refer to the type of a verb, this is shorthand for the type as determined by the entire matrix plus context – see (Verkuyl, 1999) for how this may be done.

Quirk et al (1985) go so far as to classify verbs into a hierarchy resulting in 11 semantic types. We wish only to make distinctions between different types of verb if the distinction leads to different temporal semantics. We will see that we need to distinguish verbs that indicate an event, e.g. *kill*, from those that indicate a non-event. We will also need to divide non-event verbs into those that are states, e.g. *like*, from those that are activities, e.g. *follow*. The reasons for our choices follow.

Events are not true over all sub-intervals of the interval in which they hold, whereas **non-events** are, cf.

(6) [*Event*] Gunner killed Ridley $\left\{ \begin{array}{c} \text{by} \\ \text{*until} \end{array} \right\}$ noon.

(7) [*Non-event*] Gunner liked Ridley $\left\{ \begin{array}{c} \text{*by} \\ \text{until} \end{array} \right\}$ noon.

In (6) the *killing* took place at some interval, most likely a matter of minutes or even hours. However, of none of the sub-intervals within this interval could it be said that the timeless proposition ⟨Gunner kill Ridley⟩ holds. This contrasts starkly with the sub-intervals in (7); in all of them it is the case that ⟨Gunner like Ridley⟩ holds.

A test for event versus non-event verbs is the acceptability or otherwise of the combination with IN or FOR governing a duration, cf. (3) with (4).

In choosing examples to illustrate the different semantics for events versus non-events, we must be careful to choose verbs, such as *kill* and *like*, which virtually require one or the other reading, rather than verbs such as *climb*, which can readily be used to indicate either an event (the achievement of having climbed) or a non-event (the act of climbing). We will use the above examples repeatedly.

We need to divide non-event verbs into those that are states and those that are activities, e.g.:

State Gunner liked Ridley for two months. $\Rightarrow$?Gunner was liking Ridley for two months.

Activity Gunner followed Ridley for two months. $\Rightarrow$ Gunner was following Ridley for two months.

The reason is that, while a progressive aspect can be used with an **activity** verb with only a small change in meaning (the activity is not terminated), when combined with a **state** verb, the result is only marginally acceptable; the meaning is changed to an activity, sometimes introducing a sense of deceit on the part of the agent. There is no temporal truth functional difference here. Rather the difference seems to be due to the need for the progressive aspect to be applied to some action, even if the action is continuous throughout the interval; this is a property that state verbs do not possess.

These three types of verb, namely event, state and activity, will be sufficient distinctions for our purpose. For the sake of comparison, Vendler's achievements and accomplishments are our events. The difference between them, for Vendler, was that accomplishments are 'extended in time', whereas achievements are not, cf.

Accomplishment Gunner wrote his report.

Achievement Gunner finished his report.

We have found no need to make this distinction as our temporal intervals can be of any duration.

Vendler's scheme has been extended by several authors. Steedman (1999) provides a good overview and a more extensive classification. It should be noted that Steedman classifies Vendler's activities as events whereas our equivalent activities we classify as non-events, since they have the sub-interval property. Also for comparison, our events are Quirk et al's (1985) punctual dynamic verbs, our state verbs are their stative verbs and our activity verbs are their durative dynamic verbs. These three top level categories include all of their 11 semantic types as special cases.

2.2 Tense

In English there are strictly only two verbal tenses: the past and the non-past or present. The past tense generally sets the `tor` to be earlier than the `tou`. The present tense has several uses. For instance, with an event it can indicate an unfolding action, with a non-event it is more likely to indicate a property that holds at the `tor` and possibly for the whole of the context interval, cf.

Event Gunner kills Ridley.

Non-event Gunner likes Ridley.

While the present can be used when the `toe` is later than the `tou`, especially with a temporal adverbial, it is the modal *will* that usually indicates the future, e.g.

Present Gunner leaves tomorrow.

Modal Gunner will leave soon.

To avoid having to talk about a past tense and a future modal, we will refer to this use of the modal *will* as the "future tense", even though in English it is not strictly a tense (Enç, 1996) and even though *will* does not always indicate that the `toe` is earlier than the `tou`.

All three tenses (past, present and future) contribute to setting the time of the main event or non-event. If there is no temporal adverbial in the sentence, then this is done by reference to the `tor` at the point where the sentence is being interpreted, as set up by the previous context, i.e. anaphorically. If there is an explicit temporal adverbial in the sentence, e.g. *yesterday, at dawn*, then the tense will pick out a unique referent for the adverbial, i.e. cataphorically, cf.

(8) Ridley arrived at dawn. [*Cataphoric*]

(9) Gunner killed him. [i.e. just after dawn; *Anaphoric*]

In this section we will be concerned with anaphoric determination of the time of the event using tense and aspect. In the following section we look at the use of prepositions to set the `toe` cataphorically.

2.2.1 Past and future tenses

Even though the future with *will* does not always behave in the same way as the past tense (Enç, 1996), e.g. in embedded clauses, we will find that the past and future tenses have the same interaction with temporal prepositions.

Events are presumed to occur just a little later than the `tor` as set by the previous sentence. As a result of interpreting the sentence, the `tor` is updated to the `toe`. We will represent a simple past or future tensed sentence describing an event, such as

(10) Gunner$\left\{\begin{array}{c}\text{killed}\\ \text{will kill}\end{array}\right\}$Ridley.

by

$$Past \models \leftarrow\!\bullet(\texttt{tou}, \bullet(\texttt{Context}, \bullet(\texttt{tor} + \epsilon, \diamond\langle \text{G kill R}\rangle))).$$

$$Future \models \bullet\!\rightarrow(\texttt{tou}, \bullet(\texttt{Context}, \bullet(\texttt{tor} + \epsilon, \diamond\langle \text{G kill R}\rangle))).$$

where, following (Pratt & Brée, 1995):

- $\bullet(t, \alpha)$ indicates that the quantified timeless proposition α holds of the time interval t, which is a unique time interval within its temporal context, e.g.

$\texttt{Context}$;

- $\leftarrow\!\!\bullet(t, \alpha)$ indicates that the quantified timeless proposition α holds of the unique time interval ending at the start of t (with the beginning of the interval set by the context);
- $\bullet\!\!\rightarrow(t, \alpha)$ indicates that the quantified timeless proposition α holds of the unique time interval beginning at the end of t (with the end of the interval set by the context);
- $\diamond\phi$ is the existential quantification of a timeless proposition ϕ over some sub-interval of the temporal context;
- ϵ is a small duration;
- $\langle \ldots \rangle$ is a timeless unquantified proposition.

For example, the formula for the past tense should be read as: there exists a unique $\texttt{tou}$, sometime before which there is a unique interval $\texttt{Context}$, within which there is a unique interval $\texttt{tor}+\epsilon$ (which is a little later than the current $\texttt{tor}$), during which there is an interval in which $\langle$Gunner kill Ridley$\rangle$ is true.

For non-events we have universal rather than existential quantification. A simple tensed sentence describing an activity, such as:

(11) Gunner $\left\{\begin{array}{l}\text{followed}\\ \text{will follow}\end{array}\right\}$ Ridley.

will be represented similarly by:

$$\left\{\begin{array}{l}\textit{Past}\\ \textit{Future}\end{array}\right\} \models \left\{\begin{array}{c}\leftarrow\!\!\bullet\\ \bullet\!\!\rightarrow\end{array}\right\} (\texttt{tou}, \bullet(\texttt{Context}, \bullet(\texttt{tor}+\epsilon, \Box\langle \text{G follow R}\rangle))).$$

where $\Box\phi$ is the universal quantification of ϕ over all sub-intervals of its temporal context, here $\texttt{tor}+\epsilon$.

Similarly, a simple tensed sentence describing a state, rather than an event, such as:

(12) Gunner $\left\{\begin{array}{l}\text{liked}\\ \text{will like}\end{array}\right\}$ Ridley.

will be represented by:

$$\left\{\begin{array}{l} \textit{Past} \\ \textit{Future} \end{array}\right\} \models \left\{\begin{array}{c} \leftarrow\!\bullet \\ \bullet\!\rightarrow \end{array}\right\} (\texttt{tou}, \bullet(\texttt{Context}, \bullet(\texttt{tor}, \Box\langle \text{G like R}\rangle))).$$

Note that we assume that $\epsilon = 0$ for state verbs.[2]

There are some well-known exceptions to these general rules which we will be ignoring. For example:

- *Will* may also be used to indicate a deduction:

  (13) Ridley will be at home by now.

- A modal in the past does not necessarily indicate a past `tor`. It may be a conditional:

  (14) Gunner should lie low for a week now.

- The past can indicate a counterfactual:

  (15) Control wishes that Gunner had been more careful.

- When the past tense is used in a clause that is part of a matrix which uses the future tense, then the past tense can indicate an event in the present, or even in the future:

  (16) "Control will be delighted when he hears that I killed you."

2.2.2 Summary

Since the present tense has several uses (Quirk et al 1985) and these differ somewhat from the way the past and future tenses are used, its interaction with temporal prepositional phrases will need to be considered separately at a later time. The semantics of the past and future tense in sentences without any aspect, temporal preposition or temporal adverbial will be represented by:

$$\left\{\begin{array}{l} \textit{Past} \\ \textit{Future} \end{array}\right\} \models \left\{\begin{array}{c} \leftarrow\!\bullet \\ \bullet\!\rightarrow \end{array}\right\} (\texttt{tou}, \bullet(\texttt{Context}, \bullet(\texttt{tor} + \epsilon, Q\phi))).$$

where:

- Q is $\diamond$ for event verbs and $\Box$ for non-event verbs,
- ϕ is the timeless proposition conveyed by the sentence,
- and $\epsilon = 0$ for state verbs.

Notation: In general tenses interact with aspects in the same way so the relation between the `tor` and the `tou`, given by the tense, will only be specified if there is ambiguity.

2.3 Aspect

The function of aspect is to set the time of an event with respect to the `tor`. Without any aspect, an event or an activity, as it is introduced, is given a time just after the `tor` (Section 2.2) and the `tor` is updated (Section 1). To put the next event or activity earlier than the `tor` is the function of the perfective aspect; to put it at the `tor` is one function of the progressive aspect. Surprisingly, the two aspects may be used in combination.

2.3.1 The perfective aspect

It is sometimes argued (e.g. by Comrie, 1985), that the perfect in English indicates a tense relative to the absolute tense set by the main verb, rather than an aspect. We prefer to follow the more traditionally grammarians, e.g. Quirk et al (1985), who use the term **perfective aspect** (rather than the more common perfect aspect) to emphasise the contrast with the progressive aspect.

We represent the perfective aspect, which sets the time of an event to be earlier than the `tor`, by embedding the existential quantification of the proposition representing the timeless meaning of the clause in $\leftarrow\!\!\bullet(\texttt{tor},\ldots)$, e.g.

$$\textit{Event}\ \text{Gunner}\left\{\begin{array}{l}\text{had}\\ \text{will have}\end{array}\right\}\text{killed Ridley:}\leftarrow\!\!\bullet(\texttt{tor},\diamond\langle\text{G kill R}\rangle),$$

$$\textit{State}\ \text{Gunner}\left\{\begin{array}{l}\text{had}\\ \text{will have}\end{array}\right\}\text{liked Ridley; }\leftarrow\!\!\bullet(\texttt{tor},\diamond\langle\text{G like R}\rangle).$$

(17) *Activity* Gunner $\left\{\begin{array}{l}\text{had}\\ \text{will have}\end{array}\right\}$ followed Ridley; $\leftarrow\!\bullet(\texttt{tor}, \diamond\langle\text{G follow R}\rangle)$.

Note that:

- the future perfective assumes a `tor` later than the `tou`. The addition of, e.g. *by tomorrow*, makes this explicit and the sentences in isolation clearer;
- with non-event verbs the perfective alters the quantifier from universal to existential;
- with an activity verb, the perfective implies that the activity is over. We have not represented this implicature.

2.3.2 The progressive aspect

The progressive aspect is used to indicate that something has a duration or is not complete. As Quirk et al (1985: 209) put it: "...there is some point of orientation from which the temporary event or non-event described by the verb can be seen to stretch into the future and into the past." The point of orientation is within the `tor`. As the extent of stretch into the future and the past is not specified, we will note only that the event or non-event holds over the whole of the `tor` interval.

With an event verb the progressive is used to ensure that what would otherwise be an event is interpreted as an activity holding in an interval which includes at least the `tor`, e.g.

Event James opened the door and looked in. Gunner was killing Ridley;
$\bullet(\texttt{tor}, \Box\texttt{prog}(\langle\text{G kill R}\rangle))$.

where $\texttt{prog}(\phi)$ is a function that turns an event into an activity, i.e. enables the proposition to hold for all subintervals of the temporal context (here the `tor`). Recall that the `tor` is an interval rather than a point in time. Here the *killing* is presumably by some slow activity such as suffocation.

As a non-event already has duration, the progressive aspect, when applied to a non-event verb, might seem to be unnecessary. But this is not so.

With an activity verb, the progressive signals that the activity takes place throughout the $\mathtt{tor}$, rather than at some small time later than the $\mathtt{tor}$, e.g.

$$\textit{Activity}\ \text{Gunner} \left\{ \begin{array}{c} \text{was} \\ \text{will be} \end{array} \right\} \text{following Ridley;}\ \bullet\,(\mathtt{tor}, \Box\mathtt{prog}(\langle \text{G follow R} \rangle)),$$

where $\mathtt{prog}$ applied to a proposition with an activity verb indicates that the activity is not complete. Note that this difference reflects the so-called 'imperfective paradox': from the progressive of an activity the activity itself holds, but from the progressive of an event, the event itself does not:

Activity Gunner was following Ridley. $\Rightarrow$ Gunner followed Ridley.

Event Gunner was killing Ridley. $\neg \Rightarrow$ Gunner killed Ridley.

With a state verb there is, indeed, no difference between the progressive aspect and the representation of the non-aspectual, as $\epsilon = 0$ already (see Section 2.2). However a progressive can be used with state verbs; not surprisingly it then usually signals some peculiarity, e.g. that there is a pretence or effort on the part of the agent:

$$\textit{State}\ \text{Gunner} \left\{ \begin{array}{l} \text{was} \\ \text{will be} \end{array} \right\} \left\{ \begin{array}{l} \text{?knowing} \\ \text{?liking} \end{array} \right\} \text{Ridley;} \bullet(\mathtt{tor}, \Box\mathtt{prog}(\langle \text{G} \left\{ \begin{array}{l} \text{know} \\ \text{like} \end{array} \right\} \text{R} \rangle)).$$

where $\mathtt{prog}$ applied to a proposition with a state verb indicates that the verb is not to be taken literally.

Note that the progressive can turn some state verbs into activities, those to which *growing to* could be added. These verbs have both a state meaning and the meaning of the activity undergone to reach the state, e.g.

$$\text{(18)}\quad \text{Gunner} \left\{ \begin{array}{l} \text{resembled} \\ \text{was resembling} \\ \text{was growing to resemble} \end{array} \right\} \text{Bond.}$$

These normally state verbs, when combined with a progressive, need to be treated as activities.

What is common to all three types of verb is that the progressive sets the $\mathtt{toe}$ to be at the $\mathtt{tor}$, rather than just after the $\mathtt{tor}$, i.e. $\epsilon = 0$. Certain special uses of the progressive (Quirk et al 1985) will not be covered:

- with *going to*, to indicate a future (in the past):

(19) Gunner was going to kill Ridley tomorrow.

- with attitude verbs, to indicate tentativeness:

(20) I was hoping to borrow some money.

(21) I was wondering if you could help me.

2.3.3 The perfect progressive aspect

The simple combination of the temporal features of the perfective (setting the $\mathtt{toe} < \mathtt{tor}$) and progressive (setting $\mathtt{toe} = \mathtt{tor}$) aspects would be contradictory. However, these two aspects are used together without contradiction, so their temporal semantics cannot be the sum of their two parts. What happens is that the progressive still has the effect of giving something a duration and being incomplete, while the perfective places this non-event earlier than the `tor`. Universal quantification at the `tor` is retained from the simple progressive.

With an event, a progressive turns the event into an activity, while the perfective puts the resulting activity earlier than the `tor`, e.g.

Event Gunner had been killing Ridley; $\leftarrow\!\!\bullet(\mathtt{tor}, \Box\mathtt{prog}(\langle \text{G kill R}\rangle))$.

We have chosen universal rather than existential quantification here, even though an event with no aspect is given existential quantification, on the grounds that the progressive turns an event into an activity (*for a while* can be added). In this example the killing would have had to be by some slow activity!

As with the simple progressive, the perfect progressive with a state verb again indicates an activity and possibly deceit on the part of the agent, e.g.

State ?Gunner$\left\{\begin{array}{c}\text{had}\\ \text{will have}\end{array}\right\}$been liking Ridley; $\leftarrow\!\!\bullet(\mathtt{tor}, \Box\mathtt{prog}(\langle \text{G like R}\rangle))$.

With an activity verb, the perfect progressive is quite natural. It is very similar to the simple perfective in that it postulates that an activity occurred earlier than the `tor`, cf. (17), so it will be represented in the same way, e.g.

(22) *Activity* Gunner$\left\{\begin{array}{c}\text{had}\\ \text{will have}\end{array}\right\}$been following R; $\leftarrow\!\!\bullet(\mathtt{tor}, \Box\mathtt{prog}(\langle \text{G follow R}\rangle))$.

Also the activity is not complete, which can be most easily seen in activities that can lead to accomplishments, cf.

(23) Gunner $\left\{\begin{array}{l}\text{cleaned}\\ \text{had cleaned}\\ \text{had been cleaning}\end{array}\right\}$ his rifle.

With a simple perfective the activity has lead to the desired accomplishment, with the perfect progressive there is an implicature that it has not yet done so.

With an activity that does not lead to an accomplishment, the simple perfective implies that the activity is over by the `tor`, whereas the perfect progressive implies that it still holds, cf.

(24) Gunner had $\left\{\begin{array}{l}\text{followed}\\ \text{been following}\end{array}\right\}$ Ridley.

Capturing this subtlety would take us beyond our present purpose of providing a simple representation of tense and aspect in order to investigate their interaction with the semantics of temporal prepositions.

2.3.4 Summary

This completes the preliminaries concerning aspect. The results are summarised in Table 1.

An aside: as the perfective aspect with an activity verb indicates that the activity is over at the `tor`, it might be thought that the perfective aspect turns an activity into an event, complementing the function of the progressive aspect in turning an event into an activity. While this is true of some activity verbs, in particular those that lead to some accomplishment, e.g.

(25) Gunner had cleaned his rifle $\left\{\begin{array}{c}\text{in}\\ \text{for}\end{array}\right\}$ five minutes.

it is not true of activity verbs in general, e.g. *cry*, let alone of state verbs. So the nice symmetry between the functions of the progressive and perfective that is suggested does not hold.

@@ Insert Table 1 here

2.4 Summary

In order to incorporate the semantics of tense and aspect into a natural language understanding program, these need to be expressed as a procedure. The procedure in Table 2 will generate the semantics of aspect given in Table 1 together with tense semantics given in Section 2.2.

@@ Insert Table 2 here

Note that the double quotes around strings indicate that the string is to be written out. There are three phases:

- a past or future tense shifts the temporal context, and thus also the `tor` away from the `tou`;
- if there is no aspect then the `toe` is moved to slightly after the `tor`;
- a perfective, if present, shifts the `toe` to be earlier than the `tor`;
- if the verb (plus context) is a non-event, or if the progressive aspect is used, then there is a universal quantification, otherwise existential quantification, of the main proposition.

This procedure does not pretend to capture all the subtleties of tense and aspect (Steedman, 1999). Our aim has been to provide a framework that is sufficient to embed the semantics of temporal prepositional phrases, to which we now turn.

3 Temporal prepositions

We turn now to the semantics of various prepositions that can govern a definite temporal interval, which we call the '**prep interval**.' We will examine three groups:

- those that fix the time of the main event to be the same as that of the interval given in the prepositional phrase: AT, ON, IN, DURING, THROUGHOUT;
- those that fix the time to be earlier or later than the prep interval: AFTER, BEFORE;
- those that fix the time to be in a range with the prep interval at one end and usually the `tor` at the other: SINCE, UNTIL, TILL, BY.

Certain temporal prepositions have not been covered as they occur infrequently with intervals and have special uses:

FOR which is used when making plans:

(26) Gunner invited Ridley for the weekend;

OVER which is an alternative to THROUGHOUT, generally one in which some activity is developing:

(27) Gunner had been growing suspicious of Ridley over the year;

THROUGH, also an alternative to THROUGHOUT, used with a constant activity:

(28) Gunner will be recording Ridley's movements through the summer;

WITHIN which is generally used with a definite duration linked to the `tor`:

(29) Gunner killed Ridley within the hour.

BETWEEN . . . AND

(30) Gunner killed Ridley between dawn and dusk.

FROM . . . TO

(31) Gunner followed Ridley from dawn to dusk.

We have also ignored any pre-modifiers, e.g. *5 minutes after*, and so have not dealt at all with AGO which only appears in this form.

In the absence of any aspect, we have chosen to place the prep time later than the `tor`. The reason for this is similar to the reason for using of $\texttt{tor} + \epsilon$ when there is no preposition. The normal expectation in a story is that time advances with each event that is reported. To place an event earlier than the `tor` it is usual to use the perfective aspect. Consider the short sequence:

(32) Gunner left the hotel in a hurry. He found Ridley in the station at 5 o'clock.

Ridley $\left\{ \begin{array}{c} * \\ \text{had} \end{array} \right\}$ arrived at 4 o'clock. He was about to leave.

After the first sentence the `tor` is the time of Gunner's leaving the hotel. It is clear that the prep time of 5 o'clock is later than this. In the third sentence the prep time is earlier than the updated `tor`=0500 and so a perfective aspect is required. After this third sentence the `tor` remains at 0500: it is at 0500 that Ridley was about to leave. Of course, if there is no `tor`, as in a story that begins:

(33) Gunner left Moscow in 1992.

then there is no restriction on the prep time.

We now consider the semantics of each of the above three groups of prepositions in the absence of any aspect in the matrix. The first group is subdivided into those which have an existential reading and THROUGHOUT, which indicates universal quantification.

3.1 AT, ON, IN and DURING

The prepositions AT, ON, IN and DURING indicate that the main proposition takes place in the interval that they govern, i.e. the prep interval. The difference between them (Brée, 1992) is of little import here, but can be summarised as:

AT is used with prep intervals that are very short, i.e. clock times, natural events, e.g. *dawn*, temporal boundaries, e.g. *beginning*, and even religious festivals, e.g. *Easter*.

ON is used for a complete day or an indefinite but qualified part of a day, e.g. *on a fine morning*;

IN is used for prep intervals longer than a day and for unqualified parts of a day, e.g. *in the morning*;

DURING is used for prep intervals of any length, except clock times; in particular it is available to introduce prep intervals that are described, not by an explicit interval, but by an event, e.g. *during the Second World War*, but it is not confined to non-temporal descriptions of prep intervals, e.g. *during 1998*.

The matrix proposition holds at some interval within the prep interval, which itself is later than the $\texttt{tor}$, e.g.

$$\textit{Event}\ \ \text{G}\left\{\begin{array}{l}\text{killed}\\ \text{will kill}\end{array}\right\}\text{R}\left\{\begin{array}{l}\text{at dawn}\\ \text{on Sunday}\\ \text{in 1992}\\ \text{during the War}\end{array}\right\};\ \bullet\!\!\rightarrow\!(\texttt{tor},\bullet(\left\{\begin{array}{l}\langle\text{dawn}\rangle\\ \langle\text{Sunday}\rangle\\ \langle\text{1992}\rangle\\ \langle\text{the War}\rangle\end{array}\right\},\diamond\langle\text{G kill R}\rangle)).$$

$$\textit{State}\ \ \text{Gunner}\left\{\begin{array}{l}\text{was}\\ \text{will be}\end{array}\right\}\text{sad on Sunday};\ \bullet\!\!\rightarrow\!(\texttt{tor},\bullet(\langle\text{Sunday}\rangle,\Box\langle\text{G sad}\rangle)).$$

$$\textit{Activity}\ \ \text{Gunner}\left\{\begin{array}{l}\text{followed}\\ \text{will follow}\end{array}\right\}\text{R on Sunday};\ \bullet\!\!\rightarrow\!(\texttt{tor},\bullet(\langle\text{Sunday}\rangle,\Box\langle\text{G follow R}\rangle)).$$

The quantification is determined by the verb type, as when there is no preposition. It might be objected that even for non-event verbs the quantifier should be existential since, for instance, there might be no claim that Gunner was sad every moment of Sunday, only that he was sad some of the time. However, non-events have the implicature, if not the truth functionality, that they hold over the whole of the prep interval, e.g. *Food was in short supply* *in the winter of 1945.* So we have chosen to retain universal quantification here.

3.2 Throughout

Whereas with AT, ON, IN and DURING quantification over the prep interval is determined by the verb type, THROUGHOUT requires universal quantification over this interval. So, with events, the progressive aspect is required as universal quantification cannot be applied to events (unless the event is generic). With non-events the progressive aspect is not required, as non-events can have durations. It cannot be used with short intervals that take AT, but religious festivals are acceptable.

$$\textit{Event}\ \ \text{Gunner}\left\{\begin{array}{l}\text{shot}\\ \text{will shoot}\end{array}\right\}\left\{\begin{array}{l}\text{*Ridley}\\ \text{rats}\end{array}\right\}\text{throughout March. }[\textit{Generic}]$$

$$\textit{State}\ \ \text{G}\left\{\begin{array}{l}\text{was}\\ \text{will be}\end{array}\right\}\text{worried throughout March; }\bullet\!\!\rightarrow(\texttt{tor}, \bullet(\langle\text{March}\rangle, \Box\langle\text{G worried}\rangle)).$$

$$\textit{Activity}\ \ \text{G}\left\{\begin{array}{l}\text{followed}\\ \text{will follow}\end{array}\right\}\text{R throughout March; }\bullet\!\!\rightarrow(\texttt{tor}, \bullet(\langle\text{March}\rangle, \Box\langle\text{G follow R}\rangle)).$$

3.3 After and Before

AFTER and BEFORE place the time of the matrix event (or non-event) later or earlier than, rather than in, the prep interval, respectively. Frequently the matrix event is assumed to be close to the prep interval, but this not necessarily the case, cf.

(34) Gunner ran off after shooting Ridley.

(35) Gunpowder was re-invented in the West after it had been invented in China.

So AFTER and BEFORE indicate a temporal range open at one end, or, more precisely, bounded by the context interval.

Once again the prep interval is later than the `tor`, as illustrated by the following example:

(36) Gunner found Ridley at dawn. He killed him $\left\{\begin{array}{c}\text{after}\\ \text{before}\end{array}\right\}$ 5 a.m.

in which the *5 a.m.* must be later than the `tor`=⟨dawn⟩. If the prep time is to be earlier than the `tor`, then the perfective aspect is required, e.g.

(37) Gunner killed Ridley at 5 a.m. He $\left\{\begin{array}{c}*\\ \text{had}\end{array}\right\}$ found him $\left\{\begin{array}{c}\text{after}\\ \text{before}\end{array}\right\}$ 4 a.m.

The range for the main proposition is that half of the time line within the `Context` interval which is on the appropriate side of the prep interval given by the AFTER/BEFORE phrase, e.g.

Event G $\left\{\begin{array}{c}\text{killed}\\ \text{will kill}\end{array}\right\}$ R $\left\{\begin{array}{c}\text{after}\\ \text{before}\end{array}\right\}$ 5 a.m.; $\bullet\!\!\to(\mathtt{tor}, \left\{\begin{array}{c}\bullet\!\!\to\\ \leftarrow\!\!\bullet\end{array}\right\}(\langle 0500\rangle, \diamond\langle \text{G kill R}\rangle)).$

State Gunner $\left\{\begin{array}{c}\text{was}\\ \text{will be}\end{array}\right\}$ sad $\left\{\begin{array}{c}\text{after}\\ \text{before}\end{array}\right\}$ the shooting;

$$\bullet\!\!\to(\mathtt{tor}, \left\{\begin{array}{c}\bullet\!\!\to\\ \leftarrow\!\!\bullet\end{array}\right\}(\mathtt{t}(\langle \text{shooting}\rangle), \Box\langle \text{G sad}\rangle)).$$

Activity Gunner $\left\{\begin{array}{c}\text{followed}\\ \text{will follow}\end{array}\right\}$ Ridley $\left\{\begin{array}{c}\text{after}\\ \text{before}\end{array}\right\}$ the shooting;

$$\bullet\!\!\to(\mathtt{tor}, \left\{\begin{array}{c}\bullet\!\!\to\\ \leftarrow\!\!\bullet\end{array}\right\}(\mathtt{t}(\langle \text{shooting}\rangle), \diamond\langle \text{G follow R}\rangle)):$$

where `t`(⟨shooting⟩) indicates the interval during which the shooting occurred.

The quantifier is determined by the verb type. Note that activity verbs are given an existential rather than the universal quantification that they would have had with no preposition.

3.4 SINCE, UNTIL and BY

While AFTER and BEFORE indicate a range of time whose beginning or ending is set by the context, SINCE, UNTIL, TILL and BY indicate an interval beginning (UNTIL, TILL, BY) or ending (SINCE) at the `tor`. This is always the case for SINCE; as a consequence it requires a perfective aspect. With UNTIL, TILL and BY, on the other hand, the beginning of the interval is the `tor` only by default; it may be some other time, sometimes made explicit using FROM, e.g.

(38) Gunner had been on tenterhooks $\left\{\begin{array}{c}\text{until}\\ \text{till}\end{array}\right\}$ then. [Beginning at the beginning of the `Context`]

(39) Ridley had been killed by then. [Beginning at the beginning of the `Context`]

(40) Ridley will be in Moscow from the end of March $\left\{\begin{array}{c}\text{until}\\ \text{till}\end{array}\right\}$ June. [Beginning at *end of March*]

As there is no discernible semantic difference between UNTIL and TILL, and TILL is less usual, it will not be used in future examples.

Temporal SINCE requires a perfective and so is unacceptable with no aspect. Quantification over the interval must be universal with UNTIL, so with an event UNTIL must be in the context of a progressive. There are no simple restrictions on the use of BY. However, with an event in the past tense, BY may or may not be acceptable, cf.:

(41) Gunner $\left\{\begin{array}{c}\text{found}\\ \text{?killed}\end{array}\right\}$ Ridley by dawn; $\left\{\begin{array}{l}\bullet\!\!\rightarrow(\texttt{tor}, \leftarrow\!\!\bullet(\langle\text{dawn}\rangle, \diamond\langle\text{G find R}\rangle))\\ ?\end{array}\right\}$.

Both *find* and *kill* are event verbs. This suggests that a distinction may be needed between different types of event verbs, such as that used by Vendler, viz. achievements and accomplishments. But both achievements and accomplishments are acceptable:

(42) Gunner $\left\{\begin{array}{c}\text{finished}\\ \text{wrote}\end{array}\right\}$ wrote the report by dawn.

The verb itself is not sufficient to make BY unacceptable. For example, embedding *kill* can make BY (at least more) acceptable:

(43) The evidence suggests that Gunner killed Ridley by dawn.

With a future tense there is no difficulty:

(44) Gunner will kill Ridley by dawn.

We leave the task of finding the restrictions on the use of BY with past tense events for another paper.

With a non-event verb, either state or activity, the non-event is true of all sub-intervals, so not only UNTIL but also BY can be used. With UNTIL the universal quantification is over the interval starting at the `tor` (by default), but with BY the interval begins at some unspecified time later than the `tor` but earlier than the prep interval:

$$\textit{State}\;\; \text{G}\left\{\begin{array}{c}\text{liked}\\ \text{will like}\end{array}\right\}\text{R}\left\{\begin{array}{c}\text{until}\\ \text{by}\end{array}\right\}1990;\ \bullet\!\!\rightarrow(\texttt{tor}, \leftarrow\!\!\bullet(\langle 1990\rangle, \left\{\begin{array}{c}\\ \bullet\!\!\rightarrow(t,\end{array}\right\}\Box\langle \text{G like R}\rangle].$$

$$\textit{Activity}\;\; \text{Gunner}\left\{\begin{array}{c}\text{followed}\\ \text{will follow}\end{array}\right\}\text{Ridley}\left\{\begin{array}{c}\text{until}\\ \text{by}\end{array}\right\}\text{dawn};$$

$$\bullet\!\!\rightarrow(\texttt{tor}, \leftarrow\!\!\bullet(\langle \text{dawn}\rangle, \left\{\begin{array}{c}\\ \bullet\!\!\rightarrow(t,\end{array}\right\}\Box\langle \text{G follow R}\rangle].$$

where ']' stands for as many right parentheses as required.

With UNTIL (but not with BY) the `tor` marks the beginning of the interval only by default. This default may be overridden using FROM:

(45) $\text{Gunner followed Ridley from dusk}\left\{\begin{array}{c}\text{until}\\ {*}\text{by}\end{array}\right\}\text{dawn};$

$$\left\{\begin{array}{l}\bullet\!\!\rightarrow(\texttt{tor}, \bullet\!\!\rightarrow(\langle \text{dusk}\rangle, \leftarrow\!\!\bullet(\langle \text{dawn}\rangle, \Box\langle \text{G follow R}\rangle))))\\ {*}\end{array}\right\}.$$

3.5 Summary

The temporal semantics of these four classes of preposition are summarised in Table 3. Note:

- The preposition interval, $\tau(\phi)$, is later than the `tor` set up by the previous context.
- The interval in which the matrix proposition, $\mu(\sigma)$, holds is set:
  - in the prep interval by AT, ON, IN, DURING and THROUGHOUT;
  - later than the prep interval by AFTER and SINCE;
  - earlier than the prep interval by all the other prepositions: BEFORE, UNTIL, BY.
- SINCE is not permitted without a perfective aspect.

- THROUGHOUT and UNTIL are the only two prepositions that require universal quantification of the matrix proposition and so are unacceptable with event verbs. AT, ON, IN, DURING and BY accept the same quantification as when there is no preposition, i.e. existential quantification for events and universal quantification for non-events. The remaining prepositions, viz: AFTER and BEFORE, allow an existential quantification not only for events but also for activities.
- BY may not occur with some event verbs in the past tense.

@@ Insert Table 3 here

The stage is now set for us to address the question: is the temporal semantics of a sentence determined by a simple summation of the semantics given by the temporal prepositions to those already given by tense and aspect, or is there an interaction?

4 Temporal prepositions in a past/future matrix

We have now established a semantics both for tense and aspect on the one hand and for the different temporal prepositions, when found in a matrix having a verb with no aspect, on the other. We now explore their combination. We look first at the use of temporal prepositions in sentences with a verb having a perfective aspect. In the next sections we turn to sentences with a verb having progressive and perfect progressive aspects.

4.1 Perfective aspect

Recall that the perfective, with no temporal preposition, forces an existential quantification of the matrix proposition, $\mu(\sigma)$, over the interval earlier than the `tor`: $\leftarrow\!\!\bullet(\texttt{tor}, \diamond\mu(\sigma))$. In a matrix with no aspect, the prep interval itself, $\tau(\phi)$, is later than the `tor`: $\bullet\!\!\rightarrow(\texttt{tor}, *(\tau(\phi), Q\mu(\sigma)))$, where $*$ is a temporal relation $(\bullet, \leftarrow\!\!\bullet, \bullet\!\!\rightarrow)$, depending on the preposition, and Q is a quantifier $(\diamond, \Box)$, depending on the verb type as well as the preposition (Table 3). In all cases we will see that the perfective takes precedence over the preposition in that the prep interval is set before the `tor` rather than later, to give: $\leftarrow\!\!\bullet(\texttt{tor}, *(\tau(\phi), Q\mu(\sigma)))$. What is of interest is the selection of the quantifier: is it determined by the verb type, the aspect or the preposition?

4.1.1 At, on, in and during

With AT, ON, IN and DURING the event or non-event is situated in the prep interval (Section 3.1):

Event Gunner $\left\{\begin{array}{l}\text{had}\\ \text{will have}\end{array}\right\}$ killed Ridley on Sunday; $\leftarrow\!\!\bullet(\texttt{tor}, \bullet(\langle\text{Sunday}\rangle, \diamond\langle\text{G kill R}\rangle))$.

State Gunner $\left\{\begin{array}{l}\text{had}\\ \text{will have}\end{array}\right\}$ been sad on Sunday; $\leftarrow\!\!\bullet(\texttt{tor}, \bullet(\langle\text{Sunday}\rangle, \diamond\langle\text{G sad}\rangle))$.

Activity G $\left\{\begin{array}{l}\text{had}\\ \text{will have}\end{array}\right\}$ followed R on Sunday; $\leftarrow\!\!\bullet(\texttt{tor}, \bullet(\langle\text{Sunday}\rangle, \diamond\langle\text{G follow R}\rangle))$.

The combination with the perfective aspect is purely additive, with existential quantification determined by the perfective aspect.[3]

4.1.2 Throughout

THROUGHOUT also indicates that the matrix event or non-event occurs in the prep interval, but now in every sub-interval (Section 3.2). With events the progressive aspect is required, so events are not acceptable with just the perfective aspect. With non-events a simple perfective puts the prep interval earlier than the `tor`:

$$\textit{State}\ \ \text{Gunner}\left\{\begin{array}{c}\text{had}\\ \text{will have}\end{array}\right\}\text{liked R throughout 1992; } \leftarrow\!\!\bullet(\mathtt{tor}, \bullet(\langle 1992\rangle, \Box\langle \text{G like R}\rangle)).$$

$$\textit{Activity}\ \ \text{G}\left\{\begin{array}{c}\text{had}\\ \text{will have}\end{array}\right\}\text{followed R throughout 1992; } \leftarrow\!\!\bullet(\mathtt{tor}, \bullet(\langle 1992\rangle, \Box\langle \text{G follow R}\rangle)).$$

Note that THROUGHOUT requires universal quantification.

4.1.3 After and before

After and before situate the matrix event or non-event later or earlier, respectively, than the prep interval (Section 3.3):

$$\textit{Event}\ \ \text{Gunner}\left\{\begin{array}{c}\text{had}\\ \text{will have}\end{array}\right\}\text{killed Ridley}\left\{\begin{array}{c}\text{after}\\ \text{before}\end{array}\right\}\text{5 a.m.;}$$

$$\leftarrow\!\!\bullet(\mathtt{tor}, \left\{\begin{array}{c}\bullet\!\!\rightarrow\\ \leftarrow\!\!\bullet\end{array}\right\}(\langle 0500\rangle, \diamond\langle \text{G kill R}\rangle)).$$

$$\textit{State}\ \ \text{Gunner}\left\{\begin{array}{c}\text{had}\\ \text{will have}\end{array}\right\}\text{been sad}\left\{\begin{array}{c}\text{after}\\ \text{before}\end{array}\right\}\text{the shooting;}$$

$$\leftarrow\!\!\bullet(\mathtt{tor}, \left\{\begin{array}{c}\bullet\!\!\rightarrow\\ \leftarrow\!\!\bullet\end{array}\right\}(\mathtt{t}(\langle \text{shooting}\rangle), \diamond\langle \text{G sad}\rangle)).$$

$$\textit{Activity}\ \ \text{Gunner}\left\{\begin{array}{c}\text{had}\\ \text{will have}\end{array}\right\}\text{followed Ridley}\left\{\begin{array}{c}\text{after}\\ \text{before}\end{array}\right\}\text{the shooting;}$$

$$\leftarrow\!\!\bullet(\mathtt{tor}, \left\{\begin{array}{c}\bullet\!\!\rightarrow\\ \leftarrow\!\!\bullet\end{array}\right\}(\mathtt{t}(\langle \text{shooting}\rangle), \diamond\langle \text{G follow R}\rangle)).$$

Note that the quantification is determined by the perfective aspect.

4.1.4 Since, until and by

Recall that SINCE places the matrix (non-)event after the prep interval but before the `tor`, while UNTIL and BY place it after the `tor` but before the prep interval (Section 3.4).

As the perfective aspect places the event earlier than the `tor`, and both UNTIL and BY with no aspect indicate an interval beginning at the `tor` we would expect neither to be acceptable. However, UNTIL, just with non-events, and BY, just with events, can mark the end of an interval whose beginning is set by the `Context`:

$$\textit{Event}\ \ \text{Gunner}\left\{\begin{array}{c}\text{had}\\ \text{will have}\end{array}\right\}\text{killed Ridley}\left\{\begin{array}{c}\text{since}\\ \text{by}\\ {}^{*}\text{until}\end{array}\right\}\text{dawn;}$$

$$\left\{\begin{array}{l}\leftarrow\!\bullet(\mathtt{tor},\left\{\begin{array}{c}\bullet\!\!\rightarrow\\ \leftarrow\!\bullet\end{array}\right\}(\langle\text{dawn}\rangle,\diamond\langle\text{G kill R}\rangle)).\\ *\end{array}\right\}$$

$$\textit{State}\ \ \text{Gunner}\left\{\begin{array}{c}\text{had}\\ \text{will have}\end{array}\right\}\text{liked Ridley}\left\{\begin{array}{c}\text{since}\\ \text{until}\\ {}^{*}\text{by}\end{array}\right\}\text{1992;}$$

$$\leftarrow\!\bullet(\mathtt{tor},\left\{\begin{array}{c}\bullet\!\!\rightarrow\\ \leftarrow\!\bullet\\ *\end{array}\right\}(\langle 1992\rangle,\Box\langle\text{G like R}\rangle)).$$

$$\textit{Activity}\ \ \text{Gunner}\left\{\begin{array}{c}\text{had}\\ \text{will have}\end{array}\right\}\text{followed Ridley}\left\{\begin{array}{c}\text{since}\\ \text{until}\\ {}^{*}\text{by}\end{array}\right\}\text{dawn;}$$

$$\leftarrow\!\bullet(\mathtt{tor},\left\{\begin{array}{c}\bullet\!\!\rightarrow\\ \leftarrow\!\bullet\\ *\end{array}\right\}(\langle\text{dawn}\rangle,\Box\langle\text{G follow R}\rangle)).$$

Note that the quantification is determined by the verb type.

With the future tense the beginning of the `Context` is later than the `tou`, $\models \bullet\!\!\rightarrow(\mathtt{tou},\bullet(\mathtt{Context},\bullet\!\!\rightarrow(\mathtt{tor},\ldots)))$, and so with BY an event that may have occurred earlier than the `tou` is generally indicated by making the matrix conditional using *if ... not*, e.g.

(46) Gunner will have killed Ridley by dawn, if he hasn't done so already.

There is an alternative reading for BY. Rather than the `tor` being updated after the matrix is processed, the `tor` is first updated to the prep interval and then the matrix event is placed earlier:

(47) By dawn, Gunner had killed Ridley; $\mathtt{tor} \Leftarrow \langle\text{dawn}\rangle; \leftarrow\!\bullet(\mathtt{tor},\diamond\langle\text{G kill R}\rangle)$.

This phenomenon takes us beyond the scope of this paper.

Note that:

- With SINCE, the quantification of the matrix proposition is existential for events but universal for non-events.
- For UNTIL and BY, when there is no aspect the beginning of the interval in which the matrix event may occur is normally the `tor`. However, the perfective sets the prep interval to be earlier than the `tor`, so the beginning of the interval in which the matrix proposition holds is set instead by the `Context`, but only for non-events with UNTIL and only for events with BY.

4.1.5 Summary

The interaction of the perfective aspect with different prepositions depends on the type of the verb, as shown in Table 4, which summarises the details given above. Note:

- The the prep interval is set earlier than the `tor`, following the perfective aspect (Table 1).
- The temporal relation between the matrix interval and the prep interval is identical to that found with no aspect (Table 3).
- For most prepositions, quantification is existential, irrespective of the type of verb, which is consistent with the perfective aspect (Table 1). However:
  - with SINCE quantification is determined by the type of verb, as was the case with the other prepositions when there was no aspect. Maybe this is because temporal SINCE requires a perfective.
  - THROUGHOUT and UNTIL require universal quantification as usual.
- BY is acceptable with events but not with non-events (which were acceptable with no aspect).

@@ Insert Table 4 here

4.2 Progressive aspect

We turn now to considering the interaction between the progressive aspect and temporal prepositions. Recall that one function of the progressive aspect is to indicate that a proposition holds at the `tor` rather than some time later (Section 2.3.2):

(48) $\bullet(\mathtt{tor}, \Box\mathtt{prog}(\mu(\sigma)))$.

On the other hand a temporal preposition with no aspect introduces a prep interval that is **after** the `tor` (Section 3). The progressive aspect does not affect this, as illustrated by the following sequence in which *1205* is acceptable, as it is later than the previous `tor` of *1200*, but *1130* is not acceptable:

(49) Gunner arrived in Moscow at noon. At $\left\{\begin{array}{c}\text{1205}\\ \text{*1130}\end{array}\right\}$ he was looking for Ridley when he suffered a heart attack.

Note also that the `tor` is updated to a time within the matrix state, e.g. the *heart attack* took place during the *looking*. Compare this with no aspect:

(50) *At 1205, Gunner looked for Ridley when he suffered a heart attack.

which is unacceptable because the AT phrase and the WHEN clause have the same function: to fix the `toe`.

The progressive of a state verb is unnecessary; it is frequently interpreted as deceit on the part of the agent (Section 2.3.2). This is also the case when a temporal prepositional phrase is introduced.

4.2.1 AT, ON, IN and DURING

AT/ON/IN/DURING in a progressive matrix set the time of the non-event resulting from applying the progressive to within the prep interval (cf Section 3.1). An issue arises as to whether the prep interval is after the `tor` or the $\texttt{tor}$ is within the prep interval, cf.:

(51) Gunner was killing R on Sunday; $\left\{ \begin{array}{l} \bullet\!\!\rightarrow(\texttt{tor}, \bullet(\langle\text{Sunday}\rangle, \diamond\texttt{prog}(\langle\text{G kill R}\rangle))). \\ \bullet(\langle\text{Sunday}\rangle, \bullet(\texttt{tor}, \Box\texttt{prog}(\langle\text{G kill R}\rangle))). \end{array} \right\}$

Recall that

(52) Gunner was killing Ridley; $\bullet(\texttt{tor}, \Box\texttt{prog}(\langle\text{G kill R}\rangle))$.

Note also that if a *when* clause is added to (51) then the *when*, which normally refers to the $\texttt{tor}$, is the interval in which the *killing* took place rather than the whole of the *Sunday*. This suggests that we choose the $\texttt{tor}$ within the prep interval, i.e. $\bullet(\langle\text{Sunday}\rangle, \bullet(\texttt{tor}, \Box\texttt{prog}(\langle\text{G kill R}\rangle)))$. However, under a normal flow of time *Sunday* should be later than the previous $\texttt{tor}$, cf.:

(53) Gunner arrived at 5 a.m. He was killing Ridley at $\left\{ \begin{array}{c} 6 \\ {}^{*}4 \end{array} \right\}$, when ...

This suggests that we need to note both the old and the new $\texttt{tor}$:

(54) $\bullet\!\!\rightarrow(\texttt{tor}, \bullet(\langle\text{Sunday}\rangle, \bullet(\texttt{tor}', \Box\texttt{prog}(\langle\text{G kill R}\rangle))))$,

where $\texttt{tor}'$ is the new updated $\texttt{tor}$. So in general we have:

Event G$\left\{ \begin{array}{c} \text{was} \\ \text{will be} \end{array} \right\}$killing R on Sunday; $\bullet\!\!\rightarrow(\texttt{tor}, \bullet(\langle\text{Sunday}\rangle, \bullet(\texttt{tor}', \Box\texttt{prog}(\langle\text{G kill R}\rangle))))$.

State ?$\left\{ \begin{array}{c} \text{was} \\ \text{will be} \end{array} \right\}$being sad on Sunday; $\bullet\!\!\rightarrow(\texttt{tor}, \bullet(\langle\text{Sunday}\rangle, \bullet(\texttt{tor}', \Box\texttt{prog}(\langle\text{G sad}\rangle))))$.

Activity Gunner$\left\{ \begin{array}{c} \text{was} \\ \text{will be} \end{array} \right\}$following Ridley on Sunday;
$\bullet\!\!\rightarrow(\texttt{tor}, \bullet(\langle\text{Sunday}\rangle, \bullet(\texttt{tor}', \Box\texttt{prog}(\langle\text{G follow R}\rangle))))$.

Note how the progressive aspect applied to a state verb introduces a note of deceit and, applied to an activity verb, prevents completion (Section 2.3.2).

4.2.2 Throughout

Throughout gives a universal quantification over the entire prep interval, which again is later than the $\texttt{tor}$ (cf Section 3.2). There is no need to include an updated $\texttt{tor}$:

Event G$\left\{ \begin{array}{c} \text{was} \\ \text{will be} \end{array} \right\}$killing R throughout March; $\bullet\!\!\rightarrow(\texttt{tor}, \bullet(\langle\text{March}\rangle, \Box\texttt{prog}(\langle\text{G kill R}\rangle)))$.

State ?G$\left\{\begin{array}{c}\text{was}\\ \text{will be}\end{array}\right\}$liking R throughout March; $\bullet\!\!\rightarrow(\texttt{tor}, \bullet(\langle\text{March}\rangle, \Box\texttt{prog}(\langle\text{G like R}\rangle))).$

Activity Gunner$\left\{\begin{array}{c}\text{was}\\ \text{will be}\end{array}\right\}$following Ridley throughout March;

$\bullet\!\!\rightarrow(\texttt{tor}, \bullet(\langle\text{March}\rangle, \Box\texttt{prog}(\langle\text{G follow R}\rangle))).$

4.2.3 After and before

After and before place the matrix (non-)event later or earlier than the prep interval (cf Section 3.3). Again the tor is updated to a new tor′ that is after/before the prep interval, respectively:

Event Gunner $\left\{\begin{array}{c}\text{was}\\ \text{will be}\end{array}\right\}$killing Ridley $\left\{\begin{array}{c}\text{after}\\ \text{before}\end{array}\right\}$ the tip-off;

$\bullet\!\!\rightarrow(\texttt{tor}, \left\{\begin{array}{c}\bullet\!\!\rightarrow\\ \leftarrow\!\!\bullet\end{array}\right\}(\texttt{t}(\langle\text{tip-off}\rangle), \bullet(\texttt{tor}', \Box\texttt{prog}(\langle\text{G kill R}\rangle)))).$

State ?Gunner$\left\{\begin{array}{c}\text{was}\\ \text{will be}\end{array}\right\}$liking Ridley $\left\{\begin{array}{c}\text{after}\\ \text{before}\end{array}\right\}$ that;

$\bullet\!\!\rightarrow(\texttt{tor}, \left\{\begin{array}{c}\bullet\!\!\rightarrow\\ \leftarrow\!\!\bullet\end{array}\right\}(\langle\text{that time}\rangle, \bullet(\texttt{tor}', \Box\texttt{prog}(\langle\text{G `like' R}\rangle)))).$

Activity Gunner$\left\{\begin{array}{c}\text{was}\\ \text{will be}\end{array}\right\}$crying$\left\{\begin{array}{c}\text{after}\\ \text{before}\end{array}\right\}$the shooting;

$\bullet\!\!\rightarrow(\texttt{tor}, \left\{\begin{array}{c}\bullet\!\!\rightarrow\\ \leftarrow\!\!\bullet\end{array}\right\}(\texttt{t}(\langle\text{shooting}\rangle), \bullet(\texttt{tor}', \Box\texttt{prog}(\langle\text{G cry}\rangle)))).$

The past tense sentences can also be given a future intent reading, in which the tor is not updated to the time of the main event. The sentence then conveys that the actor, here Gunner, has an intention to carry out an act, e.g. *killing*, at a later time. This reading is the same as in:

(55) Gunner was going to kill Ridley$\left\{\begin{array}{c}\text{after}\\ \text{before}\end{array}\right\}$the tip-off.

Also a case could be made that the prep interval may occur earlier than, rather than after, the tor, e.g.

(56) Ridley found Gunner. He was crying after the shooting.

We leave these two possibilities aside for a future investigation.

4.2.4 SINCE, UNTIL and BY

Recall that SINCE requires a perfective aspect for a temporal interpretation and so is not acceptable with a progressive aspect (Section 3.4).

UNTIL is a universal quantifier and so normally requires a non-event verb and cannot be used in the context of an event verb. Here, however, the progressive aspect turns an event into an activity and so UNTIL can be used. Just as with THROUGHOUT there is no need for an updated $\texttt{tor}'$ to be included:

$$\textit{Event}\ \text{Gunner}\left\{\begin{array}{c}\text{was}\\ \text{will be}\end{array}\right\}\text{killing Ridley}\left\{\begin{array}{c}\text{until}\\ \text{by}\end{array}\right\}\text{dawn;}$$

$$\bullet\!\!\rightarrow(\texttt{tor}, \leftarrow\!\!\bullet(\langle\text{dawn}\rangle, \left\{\begin{array}{c} \\ \bullet\!\!\rightarrow(t,\end{array}\right\} \Box\texttt{prog}(\langle\text{G kill R.}\rangle].$$

$$\textit{State}\ \text{?Gunner}\left\{\begin{array}{c}\text{was}\\ \text{will be}\end{array}\right\}\text{liking Ridley}\left\{\begin{array}{c}\text{until}\\ \text{by}\end{array}\right\}\text{dawn;}$$

$$\bullet\!\!\rightarrow(\texttt{tor}, \leftarrow\!\!\bullet(\langle\text{dawn}\rangle, \left\{\begin{array}{c} \\ \bullet\!\!\rightarrow(t,\end{array}\right\} \Box\texttt{prog}(\langle\text{G like R.}\rangle].$$

$$\textit{Activity}\ \text{Gunner}\left\{\begin{array}{c}\text{was}\\ \text{will be}\end{array}\right\}\text{following R}\left\{\begin{array}{c}\text{until}\\ \text{by}\end{array}\right\}\text{dawn;}$$

$$\bullet\!\!\rightarrow(\texttt{tor}, \leftarrow\!\!\bullet(\langle\text{dawn}\rangle, \left\{\begin{array}{c} \\ \bullet\!\!\rightarrow(t,\end{array}\right\} \Box\texttt{prog}(\langle\text{G follow R}\rangle].$$

where t is an unbound time in the context, and ']' indicates that all open left parentheses should be closed

4.2.5 Summary

These observations on the interaction of prepositions and the progressive aspect are drawn together in Table 5. Note:

- The progressive aspect turns an event into an activity (Table 1), so that both THROUGHOUT and UNTIL, which require universal quantification, are acceptable with events.
- The temporal relation between the tor and the prep interval is identical

to that found with no aspect (Table 3).

- Quantification of the matrix proposition is determined by the progressive (Table 1) but over an updated `tor`.

@@ Insert Table 5 here

4.3 Perfect progressive aspect

Finally we turn to the interaction between temporal prepositions and the perfect progressive aspect. Recall that the combination of the progressive and perfective aspects combines their effects, giving an event a duration and placing this earlier than the `tor` (Section 2.3.3):

(57) $\leftarrow\!\!\bullet(\mathtt{tor}, \diamond\mathtt{prog}(\mu(\sigma)))$

As the perfect progressive of a state verb is unnecessary, it is frequently interpreted as deceit on the part of the agent (Section 2.3.3). This is still so when a temporal prepositional phrase is introduced.

Mostly the perfect progressive is the simple addition of the perfective and the progressive aspects. So when the progressive sets the new `tor′` it is to a time earlier than the present `tor`.

4.3.1 AT, ON, IN and DURING

$$\textit{Event}\ \ \text{Gunner}\left\{\begin{array}{c}\text{had}\\ \text{will have}\end{array}\right\}\text{been killing Ridley on Sunday;}$$

$$\leftarrow\!\!\bullet(\mathtt{tor}, \bullet(\langle\text{Sunday}\rangle, \bullet(\mathtt{tor}', \Box\mathtt{prog}(\langle\text{G kill R}\rangle))))).$$

$$\textit{State}\ \ \text{?Gunner}\left\{\begin{array}{c}\text{had}\\ \text{will have}\end{array}\right\}\text{been being sad on Sunday;}$$

$$\leftarrow\!\!\bullet(\mathtt{tor}, \bullet(\langle\text{Sunday}\rangle, \bullet(\mathtt{tor}', \Box\mathtt{prog}(\langle\text{G sad}\rangle))))).$$

Activity Gunner $\left\{\begin{array}{c}\text{had}\\ \text{will have}\end{array}\right\}$ been following Ridley on Sunday;

$$\leftarrow\!\!\bullet(\mathtt{tor}, \bullet(\langle\text{Sunday}\rangle, \bullet(\mathtt{tor}', \Box\mathtt{prog}(\langle\text{G follow R}\rangle))))).$$

4.3.2 Throughout

Event Gunner $\left\{\begin{array}{c}\text{had}\\ \text{will have}\end{array}\right\}$ been killing Ridley throughout March;

$$\leftarrow\!\!\bullet(\mathtt{tor}, \bullet(\langle\text{March}\rangle, \Box\mathtt{prog}(\langle\text{G kill R}\rangle))).$$

State ?Gunner $\left\{\begin{array}{c}\text{had}\\ \text{will have}\end{array}\right\}$ been liking Ridley throughout March;

$$\leftarrow\!\!\bullet(\mathtt{tor}, \bullet(\langle\text{March}\rangle, \Box\mathtt{prog}(\langle\text{G like R}\rangle))).$$

Activity Gunner $\left\{\begin{array}{c}\text{had}\\ \text{will have}\end{array}\right\}$ been following Ridley throughout March;

$$\leftarrow\!\!\bullet(\mathtt{tor}, \bullet(\langle\text{March}\rangle, \Box\mathtt{prog}(\langle\text{G follow R}\rangle))).$$

4.3.3 After and before

Event Gunner $\left\{\begin{array}{c}\text{had}\\ \text{will have}\end{array}\right\}$ been killing Ridley $\left\{\begin{array}{c}\text{after}\\ \text{before}\end{array}\right\}$ 5 a.m.;

$$\leftarrow\!\!\bullet(\mathtt{tor}, \left\{\begin{array}{c}\bullet\!\!\rightarrow\\ \leftarrow\!\!\bullet\end{array}\right\}(\langle 0500\rangle, \bullet(\mathtt{tor}', \Box\mathtt{prog}(\langle\text{G kill R}\rangle))))).$$

State ?Gunner $\left\{\begin{array}{c}\text{had}\\ \text{will have}\end{array}\right\}$ been liking Ridley $\left\{\begin{array}{c}\text{after}\\ \text{before}\end{array}\right\}$ the shooting;

$$\leftarrow\!\!\bullet(\mathtt{tor}, \left\{\begin{array}{c}\bullet\!\!\rightarrow\\ \leftarrow\!\!\bullet\end{array}\right\}(\langle\text{shooting}\rangle, \bullet(\mathtt{tor}', \Box\mathtt{prog}(\langle\text{G like R}\rangle))))).$$

Activity Gunner $\left\{\begin{array}{c}\text{had}\\ \text{will have}\end{array}\right\}$ been following Ridley $\left\{\begin{array}{c}\text{after}\\ \text{before}\end{array}\right\}$ the shooting;

$$\leftarrow\!\!\bullet(\mathtt{tor}, \left\{\begin{array}{c}\bullet\!\!\rightarrow\\ \leftarrow\!\!\bullet\end{array}\right\}(\mathtt{t}(\langle\text{shooting}\rangle), \bullet(\mathtt{tor}', \Box\mathtt{prog}(\langle\text{G follow R}\rangle))))).$$

4.3.4 Since, until and by

The perfect progressive aspect can be used with since, not surprisingly as since indicates an interval ending at the `tor` (required by the perfective).

UNTIL, which, by default, indicates an interval starting at the `tor`, can also be used. The interval ends at the prep interval introduced by UNTIL, which is set earlier (by the perfective aspect) rather than later than the `tor`. The start of the interval is determined by the `Context`. On the other hand, the use of the perfect progressive with BY is unacceptable. This is not surprising as BY is unacceptable with perfective non-event verbs and the progressive ensures that even events are to be considered as activities.

$$\textit{Event}\ \text{Gunner}\left\{\begin{array}{l}\text{had}\\ \text{will have}\end{array}\right\}\text{been killing Ridley}\left\{\begin{array}{l}\text{since}\\ \text{until}\\ \text{*by}\end{array}\right\}\text{dawn;}$$

$$\left\{\begin{array}{l}\leftarrow\!\!\bullet(\mathtt{tor},\left\{\begin{array}{c}\bullet\!\!\rightarrow\\ \leftarrow\!\!\bullet\end{array}\right\}(\langle\text{dawn}\rangle,\Box\mathtt{prog}(\langle\text{G kill R}\rangle))).\\ *\end{array}\right.$$

$$\textit{State}\ \text{Gunner}\left\{\begin{array}{l}\text{had}\\ \text{will have}\end{array}\right\}\text{been liking Ridley}\left\{\begin{array}{l}\text{since}\\ \text{until}\\ \text{by*}\end{array}\right\}\text{1992;}$$

$$\left\{\begin{array}{l}\leftarrow\!\!\bullet(\mathtt{tor},\left\{\begin{array}{c}\bullet\!\!\rightarrow\\ \leftarrow\!\!\bullet\end{array}\right\}(\langle 1992\rangle,\Box\langle\text{G `like' R}\rangle)).\\ *\end{array}\right.$$

$$\textit{Activity}\ \text{Gunner}\left\{\begin{array}{l}\text{had}\\ \text{will have}\end{array}\right\}\text{been following Ridley}\left\{\begin{array}{l}\text{since}\\ \text{until}\\ \text{*by}\end{array}\right\}\text{dawn;}$$

$$\left\{\begin{array}{l}\leftarrow\!\!\bullet(\mathtt{tor},\left\{\begin{array}{c}\bullet\!\!\rightarrow\\ \leftarrow\!\!\bullet\end{array}\right\}(\langle\text{dawn}\rangle,\Box\langle\text{G follow R}\rangle)).\\ *\end{array}\right.$$

4.3.5 Summary

These observations on the interaction between temporal prepositions and the perfect progressive aspect are drawn together in Table 6. Note:

- The temporal relation between the interval in which the matrix occurs and the `tor` is identical to that found with prepositions with no aspect (Table 3).

- The perfect part of the perfect progressive puts the prep interval earlier than the `tor` (Table 1), overriding the preposition in a sentence with no aspect (which puts the prep interval later than the `tor`).
- The progressive part of the perfect progressive turns an event into an activity (Table 1).
- The quantification of the matrix proposition is universal as with the simple progressive aspect (Table 3).
- By is not acceptable because the perfective itself is unacceptable with non-events and the progressive turns even events into non-events.

@@ Insert Table 6 here

@@ Insert Table 7 (landscape) about here

5 Summary

The above analysis is brought together in Table 7. Each column of this table shows the interaction of the preposition with aspect. For each group of prepositions, the semantics for event and non-event verbs are both given. In a few cases there is a difference between state and activity verbs which is shown in the footnotes.

When there is no aspect and no temporal preposition, the interval is set close to the `tor`. The introduction of a temporal preposition moves the interval in which the main proposition holds to a time set by the prep interval given in the prepositional phrase, which is itself after the `tor`. Most prepositions have different effects; those that have the same effect, e.g. AT, ON, IN and DURING, generally take different classes of noun phrase; UNTIL and TILL, however, are indistinguishable in use:

At/on/in/during/throughout fix the main interval to be the same as the prep interval $\tau(\phi)$, with either universal quantification (THROUGHOUT) or quantification determined by the type and aspect of the verb (AT, ON, IN, DURING).

After/before fix the main interval to be later/earlier than $\tau(\phi)$.

Since fixes the interval to start at the end of $\tau(\phi)$ and end at `tor`; it requires a perfective aspect to do so.

Until/till/by fix the interval to end at $\tau(\phi)$ and to start either at the `tor`, by default (UNTIL), or at some sub-interval between the `tor` and the prep interval (BY), with universal quantification.

A perfective aspect moves the interval in question to be earlier than the `tor`. With SINCE, this shift is required, so the perfective aspect is always required with SINCE. UNTIL (TILL), which by default indicates an interval beginning with the `tor` when there is no aspect, and BY which indicates an interval after the `tor`, might be expected not to take a perfect(-progress)ive aspect. In fact UNTIL just with non-events and BY just with events then indicate an interval, with its beginning point set to the start of the `Context` rather than to the `tor`.

The progressive aspect turns events into activities, i.e. there is no completion of the event. When combined with a state verb, there is a sense of action on the part of the agent, transforming the state into an activity and generally giving a sense of deceit on the part of the agent. The progressive with an activity verb only has the effect of indicating that the activity still holds at the updated `tor`, i.e. the `tor` after the sentence has been processed. It retains this function when combined with temporal prepositions. With AT, ON, IN, DURING, AFTER and BEFORE the `tor` is first updated to an interval set by the preposition, and then the progressive requires universal quantification over this updated `tor`. With the prepositions that require universal quantification, viz: THROUGHOUT and UNTIL, and with BY, this updating is unnecessary.

The combination of the perfective and progressive aspects both sets the interval to be earlier than the `tor` and forces events to be interpreted as activities. In general the combination also does this when used with temporal prepositions. BY, which is only acceptable with the perfective if the verb is an event, is unacceptable with the prefect progressive as the progressive turns even events into non-events.

With past and future tenses, the way the semantics of aspect and of the temporal prepositional phrase combine is:

1. The tense sets the context and thus the `tor` to being before or after the `tou`:

$$\models \left\{ \begin{array}{c} \leftarrow\!\bullet \\ \bullet\!\rightarrow \end{array} \right\} (\mathtt{tou}, \bullet(\mathtt{Context}, \ldots$$

The `toe` is then set in relation to the `tor`:

- if there is a perfective, then to be earlier (whether or not there is a temporal preposition): $\leftarrow\!\bullet(\mathtt{tor}, \ldots;$

- if no temporal preposition nor aspect is present, then to be at or just after: $\bullet(\texttt{tor}+\epsilon,\ldots;$
- otherwise, to being after: $\bullet\!\!\rightarrow\!(\texttt{tor},\ldots;$

2. If there is a temporal preposition, then its temporal constraint is now introduced, together with the interval signalled by its noun phrase.

3. In addition:

- With progressives, for all prepositions except SINCE, UNTIL, BY and THROUGHOUT, the quantification is to be over the `tor` updated to be within the context set by the preposition: $\bullet(\texttt{tor}',\ldots$
- For BY an unbounded interval t later than the `tor` is introduced so that quantification is over the interval between t and the prep interval: $\bullet\!\!\rightarrow\!(t,\ldots.$[4]

4. Then the appropriate quantifier is added:[5]

- if there is a progressive aspect then $\Box$;
- if the temporal preposition is THROUGHOUT or UNTIL, then $\Box$;
- if there is a perfective aspect then $\diamond$;
- if the temporal preposition is AFTER or BEFORE and the verb is an activity, then $\diamond$;
- if the verb is a non-event then $\Box$;
- otherwise $\diamond$.

5. If there is a progressive aspect, its effect is now set to operate on the matrix proposition.

6. Finally the matrix proposition is inserted.

This procedure is shown in Table 8.

@@ Insert Table 8 here

The combination of the effect of tense and aspect on the one hand (1, 2, 5, 6) and the temporal prepositional phrase on the other (3, 4, 5) are mostly additive. In setting the `toe` relative to the `tor` (2), prepositions place the `toe` to be later than the `tor` rather than at or just after the `tor`, but this is hardly an interaction.

However, the main interactions are:

- Quantification is generally determined by the aspect, when present, and by the type of verb otherwise, except that:
  - THROUGHOUT and UNTIL require universal quantification,
  - AFTER and BEFORE require existential quantification with activities.
- Temporal SINCE can only occur with a perfective aspect, as was known. The reason is that quantification with SINCE is always over an interval ending at the `tor`.
- Temporal BY can only take a perfective aspect with (some) events. As the progressive turns an event into an activity, perfect progressives do not take BY. The reason is that quantification is always over an interval that is later than the `tor`.
- With the prepositions AT, ON, IN, DURING, AFTER and BEFORE, but not with THROUGHOUT, UNTIL and BY, the progressive requires that the `tor` be updated to an interval as indicated by the preposition. The universal quantification is then over this updated `tor`. The reason is that THROUGHOUT, UNTIL and BY force universal quantification.

Notes

(1) Note that the `tor` and the `toe` may be on opposite sides of the `tou`. This overcomes Cumrie's (1985) objection to Reichenbach's system.

(2) This is in line with ter Meulen(1995), but not with Steedman (1999) who suggests that 'context' should determine ϵ. We incorporate context into the decision of whether a verb is being used to describe an event or a non-event.

(3) Actually universal quantification might be called for with state verbs. This is an open question.

(4) When quantification is existential this step makes no semantic difference and may be omitted.

(5) Note that these rules are ordered, the first one that is acceptable is taken. The format is slightly different from that given in Table 8, but the effect is the same.

References

Brée, D.S. 1992. "Words for time." In *Time, action and cognition*, F. Macar, V. Pouthas and W. Friedman (eds), 337–348. Dordrecht, NL: Kluwer.

Comrie, B. 1985. *Tense.* Cambridge, UK: Cambridge University Press.

Enç, M. 1996. "Tense and modality." In *The Handbook of contemporary semantic theory*, S Lappin (ed), 345-358. Oxford, UK: Blackwells.

Meulen, A. G. B. ter, 1995. *Representing time in natural language.* Cambridge, Mass: MIT Press.

Pratt, I.E. and Brée, D.S. 1995. "An approach to the semantics of some English temporal constructions." *Proceedings of the Seventeenth Cognitive Science Conference*, 118-123. New Jersey: Erlbaum.

Quirk, R., Greenbaum, S., Leech, G. and Svartvik, J. 1985. *A Comprehensive grammar of the English language.* London, UK: Longmans.

Steedman, M. 1999. "Temporality." In *Handbook of logic and language*, J. van Bentham and A. ter Meulen (eds), 895-938. Amsterdam, NL: Elsevier.

Vendler, Z. 1957. "Verbs and times." *The Philosophical Review* 66:143-160.

Verkuyl, H. J. 1999. *Aspectual issues: studies on time and quantity.* Stanford, CA: Center for the Study of Language and Information.

Table 1: Temporal semantics for the aspects

Aspect	-	Progressive
-	$\bullet(\mathtt{tor}+\epsilon, \diamond\mu(\sigma))^{\dagger}$	$\bullet(\mathtt{tor}, \Box\mathtt{prog}(\mu(\sigma)))$
Perfective	$\leftarrow\!\!\bullet(\mathtt{tor}, \diamond\mu(\sigma))^{\ddagger}$	$\leftarrow\!\!\bullet(\mathtt{tor}, \Box\mathtt{prog}(\mu(\sigma)))$

$\mu(\sigma)$	The timeless unquantified proposition given by the sentence σ.
$\bullet(\mathtt{tor}, \alpha)$	Proposition α holds in time interval $\mathtt{tor}$.
$\leftarrow\!\!\bullet(\mathtt{tor}, \alpha)$	Proposition α holds from the beginning of the context up to the unique interval which is the $\mathtt{tor}$.
$\mathtt{prog}(\phi)$	A function that turns an event ϕ into an activity, that with a state verb gives an implicature of deceit on the part of the agent and with an activity verb an implicature that there is no accomplishment.
$\dagger$	If the verb is a non-event, then $\Box$ instead of $\diamond$; if the verb is a state, then $\epsilon = 0$.
$\ddagger$	If the verb is an activity that can lead to an accomplishment, then there is an implicature that there is an accomplishment.

Table 2: Procedure for determining the temporal semantics of a sentence without a temporal preposition

$\mu(\Sigma)$ "$\models$";

  case tense(σ): % Set the `tor` relative to the `tou`

    past "$\leftarrow\!\!\bullet$(`tou`,";

    future "$\bullet\!\!\rightarrow$(`tou`,";

  esac;

  "$\bullet$(`Context`,";

  if perfective?(σ) *then* "$\leftarrow\!\!\bullet$" *else* " $\bullet$ "; % Set the `toe` relative to the `tor`

  "(`tor`";

  if $\neg$(perfective?(σ) $\vee$ progressive?(σ) $\vee$ state?(σ)) *then* " $+\,\epsilon$";

  ",";

  if ($\neg$event?(σ) $\vee$ progressive?(σ)) $\wedge$ $\neg$perfective?(σ) *then* "$\Box$" *else* " $\diamond$ ";

  if progressive?(σ) *then* "`prog`("; % Now the progressive operator

  "$\mu(\sigma)$"]; % and finish off with the matrix.

LEGEND

Inputs:		Functions:
Σ is a sentence	$\mu(\Sigma)$	returns the proposition found in Σ
σ is the matrix of Σ	tense(σ)	returns the tense in σ

	Boolean functions:
perfective?(σ)	is true iff σ has a perfective aspect
progressive?(σ)	is true iff σ has a progressive aspect
event?(σ)	is true iff σ indicates an event
state?(σ)	is true iff σ indicates a state verb as opposed to an activity
]	output as many right parentheses as necessary.

Table 3: Temporal semantics for temporal preposition phrases ϕ in a matrix σ with an event, state or activity verb in the past or future tense, having no aspect

Preposition	Event	State	Activity
none	$\bullet(\mathtt{tor}+\epsilon, \diamond\mu(\sigma))$	$\bullet(\mathtt{tor}, \Box\mu(\sigma))$	$\bullet(\mathtt{tor}+\epsilon, \Box\mu(\sigma))$
AT/ON/IN/ DURING	$\bullet\!\!\rightarrow(\mathtt{tor}, \bullet(\tau(\phi), \diamond\mu(\sigma)))$	$\bullet\!\!\rightarrow(\mathtt{tor}, \bullet(\tau(\phi), \Box\mu(\sigma)))$	$\bullet\!\!\rightarrow(\mathtt{tor}, \bullet(\tau(\phi), \Box\mu(\sigma)))$
THROUGHOUT	*	$\bullet\!\!\rightarrow(\mathtt{tor}, \bullet(\tau(\phi), \Box\mu(\sigma)))$	$\bullet\!\!\rightarrow(\mathtt{tor}, \bullet(\tau(\phi), \Box\mu(\sigma)))$
AFTER	$\bullet\!\!\rightarrow(\mathtt{tor}, \bullet\!\!\rightarrow(\tau(\phi), \diamond\mu(\sigma)))$	$\bullet\!\!\rightarrow(\mathtt{tor}, \bullet\!\!\rightarrow(\tau(\phi), \Box\mu(\sigma)))$	$\bullet\!\!\rightarrow(\mathtt{tor}, \bullet\!\!\rightarrow(\tau(\phi), \diamond\mu(\sigma)))$
BEFORE	$\bullet\!\!\rightarrow(\mathtt{tor}, \leftarrow\!\!\bullet(\tau(\phi), \diamond\mu(\sigma)))$	$\bullet\!\!\rightarrow(\mathtt{tor}, \leftarrow\!\!\bullet(\tau(\phi), \Box\mu(\sigma)))$	$\bullet\!\!\rightarrow(\mathtt{tor}, \leftarrow\!\!\bullet(\tau(\phi), \diamond\mu(\sigma)))$
SINCE	*	*	*
UNTIL	*	$\bullet\!\!\rightarrow(\mathtt{tor}, \leftarrow\!\!\bullet(\tau(\phi), \Box\mu(\sigma)))^{\dagger}$	$\bullet\!\!\rightarrow(\mathtt{tor}, \leftarrow\!\!\bullet(\tau(\phi), \Box\mu(\sigma)))^{\dagger}$
BY	$\bullet\!\!\rightarrow(\mathtt{tor}, \leftarrow\!\!\bullet(\tau(\phi), \diamond\mu(\sigma)))^{\ddagger}$	$\bullet\!\!\rightarrow(\mathtt{tor}, \leftarrow\!\!\bullet(\tau(\phi), \bullet\!\!\rightarrow(t, \Box\mu(\sigma))))$	$\bullet\!\!\rightarrow(\mathtt{tor}, \leftarrow\!\!\bullet(\tau(\phi), \bullet\!\!\rightarrow(t, \Box\mu(\sigma))))$

$\mu(\sigma)$	The proposition given by the matrix σ.
$\tau(\phi)$	The interval indicated by the temporal prepositional phrase ϕ.
$\bullet(t, \alpha)$	Proposition α holds in the unique time interval t.
$\bullet\!\!\rightarrow(t, \alpha)$	Proposition α holds from the unique time t up the interval marking the end of the context.
$\leftarrow\!\!\bullet(t, \alpha)$	Proposition α holds from the beginning of the context up to the unique time t.
t	is any interval within the context, here between `tor` and $\tau(\phi)$.
$*$	Unacceptable.
$\dagger$	The `tor` is by default.
$\ddagger$	In the past tense, some event verbs are unacceptable in some contexts.

Table 4: Temporal semantics for preposition phrases ϕ in a matrix σ with an event or non-event verbs in the past or future tense, having a perfective aspect

Preposition	Event	Non-event
none	$\leftarrow\!\!\bullet(\mathtt{tor}, \diamond\mu(\sigma))$	$\leftarrow\!\!\bullet(\mathtt{tor}, \diamond\mu(\sigma))$
AT/ON/IN/DURING	$\leftarrow\!\!\bullet(\mathtt{tor}, \bullet(\tau(\phi), \diamond\mu(\sigma)))$	$\leftarrow\!\!\bullet(\mathtt{tor}, \bullet(\tau(\phi), \diamond\mu(\sigma)))$
THROUGHOUT	*	$\leftarrow\!\!\bullet(\mathtt{tou}, \bullet(\tau(\phi), \Box\mu(\sigma)))$
AFTER	$\leftarrow\!\!\bullet(\mathtt{tor}, \bullet\!\!\rightarrow(\tau(\phi), \diamond\mu(\sigma)))$	$\leftarrow\!\!\bullet(\mathtt{tor}, \bullet\!\!\rightarrow(\tau(\phi), \diamond\mu(\sigma)))$
BEFORE	$\leftarrow\!\!\bullet(\mathtt{tor}, \leftarrow\!\!\bullet(\tau(\phi), \diamond\mu(\sigma)))$	$\leftarrow\!\!\bullet(\mathtt{tor}, \leftarrow\!\!\bullet(\tau(\phi), \diamond\mu(\sigma)))$
SINCE	$\leftarrow\!\!\bullet(\mathtt{tor}, \bullet\!\!\rightarrow(\tau(\phi), \diamond\mu(\sigma)))$	$\leftarrow\!\!\bullet(\mathtt{tou}, \bullet\!\!\rightarrow(\tau(\phi), \Box\mu(\sigma)))$
UNTIL	*	$\leftarrow\!\!\bullet(\mathtt{tor}, \leftarrow\!\!\bullet(\tau(\phi), \Box\mu(\sigma)))$
BY	$\leftarrow\!\!\bullet(\mathtt{tor}, \leftarrow\!\!\bullet(\tau(\phi), \diamond\mu(\sigma)))$	*

$\mu(\sigma)$ The proposition given by the matrix σ.

$\tau(\phi)$ The interval indicated by the temporal prepositional phrase ϕ.

$\bullet(t, \alpha)$ Proposition α holds in the unique time interval t.

$\bullet\!\!\rightarrow(t, \alpha)$ Proposition α holds from the unique time t up the interval marking the end of the context.

$\leftarrow\!\!\bullet(t, \alpha)$ Proposition α holds from the beginning of the context up to the unique time t.

$*$ Unaccaptable.

Table 5: Temporal semantics for preposition phrases ϕ in a matrix σ with any verb in the past or future tense, having progressive aspect

Preposition	Any verb
none	$\bullet(\texttt{tor}, \Box\texttt{prog}(\mu(\sigma)))$
AT/ON/IN/DURING	$\bullet\!\!\rightarrow(\texttt{tor}, \bullet(\tau(\phi), \bullet(\texttt{tor}', \Box\texttt{prog}(\mu(\sigma)))))$
THROUGHOUT	$\bullet\!\!\rightarrow(\texttt{tor}, \bullet(\tau(\phi), \Box\texttt{prog}(\mu(\sigma))))$
AFTER	$\bullet\!\!\rightarrow(\texttt{tor}, \bullet\!\!\rightarrow(\tau(\phi), \bullet(\texttt{tor}', \Box\texttt{prog}(\mu(\sigma)))))$
BEFORE	$\bullet\!\!\rightarrow(\texttt{tor}, \leftarrow\!\!\bullet(\tau(\phi), \bullet(\texttt{tor}', \Box\texttt{prog}(\mu(\sigma)))))$
SINCE	$*$
UNTIL	$\bullet\!\!\rightarrow(\texttt{tor}, \leftarrow\!\!\bullet(\tau(\phi), \Box\texttt{prog}(\mu(\sigma))))$
BY	$\bullet\!\!\rightarrow(\texttt{tor}, \leftarrow\!\!\bullet(\tau(\phi), \bullet\!\!\rightarrow(t, \Box\texttt{prog}\mu(\sigma)))))$

$\mu(\sigma)$ The proposition given by the matrix σ.

$\tau(\phi)$ The interval indicated by the temporal prepositional phrase ϕ.

$\bullet(t, \alpha)$ Proposition α holds in the unique time interval t.

$\bullet\!\!\rightarrow(t, \alpha)$ Proposition α holds from the unique time t up the interval marking the end of the context.

$\leftarrow\!\!\bullet(t, \alpha)$ Proposition α holds from the beginning of the context up to the unique time t.

$\texttt{prog}(\phi)$ A function that turns an event ϕ into an activity, that with a state verb gives an implicature of deceit on the part of the agent and with an activity verb an implicature that there is no accomplishment.

$\texttt{tor}'$ The updated $\texttt{tor}$.

t is an unbound time in the context.

$*$ Unaccaptable.

Table 6: Temporal semantics for preposition phrases ϕ in a matrix σ with any verb in the past or future tense, having perfect progressive aspect

Preposition	Any verb
none	$\leftarrow\!\!\bullet(\mathtt{tor}, \Box\mathtt{prog}(\mu(\sigma)))$
AT/ON/IN/DURING	$\leftarrow\!\!\bullet(\mathtt{tor}, \bullet(\tau(\phi), \bullet(\mathtt{tor}', \Box\mathtt{prog}(\mu(\sigma)))))$
THROUGHOUT	$\leftarrow\!\!\bullet(\mathtt{tor}, \bullet(\tau(\phi), \Box\mathtt{prog}(\mu(\sigma))))$
AFTER	$\leftarrow\!\!\bullet(\mathtt{tor}, \bullet\!\!\rightarrow(\tau(\phi), \bullet(\mathtt{tor}', \Box\mathtt{prog}(\mu(\sigma)))))$
BEFORE	$\leftarrow\!\!\bullet(\mathtt{tor}, \leftarrow\!\!\bullet(\tau(\phi), \bullet(\mathtt{tor}', \Box\mathtt{prog}(\mu(\sigma)))))$
SINCE	$\leftarrow\!\!\bullet(\mathtt{tor}, \bullet\!\!\rightarrow(\tau(\phi), \Box\mathtt{prog}(\mu(\sigma))))$
UNTIL	$\leftarrow\!\!\bullet(\mathtt{tor}, \leftarrow\!\!\bullet(\tau(\phi), \Box\mathtt{prog}(\mu(\sigma))))$
BY	$*$

$\mu(\sigma)$ The proposition given by the matrix σ.

$\tau(\phi)$ The interval indicated by the temporal prepositional phrase ϕ.

$\bullet(t, \alpha)$ Proposition α holds in the unique time interval t.

$\bullet\!\!\rightarrow(t, \alpha)$ Proposition α holds from the unique time t up the interval marking the end of the context.

$\leftarrow\!\!\bullet(t, \alpha)$ Proposition α holds from the beginning of the context up to the unique time t.

$\mathtt{prog}(\phi)$ A function that turns an event ϕ into an activity, that with a state verb gives an implicature of deceit on the part of the agent and with an activity verb an implicature that there is no accomplishment.

$\mathtt{tor}'$ The updated $\mathtt{tor}$.

$*$ Unaccaptable.

Table 7: Temporal semantics for Event (E) or Non-event (Ẽ) verbs, within $\models [\leftarrow\!\bullet \text{or} \bullet\!\!\rightarrow](\mathtt{tou}, \bullet(\mathtt{Context}, \ldots))$

		Aspect:			
Preposition	V	None	Perfective	Progressive	Perfect progressive
none	E	$\bullet(\mathtt{tor}+\epsilon, \diamond\mu(\sigma))$	$\leftarrow\!\bullet(\mathtt{tor}, \diamond\mu(\sigma))$	$\bullet(\mathtt{tor}, \Box\mathtt{prog}(\mu(\sigma)))$	$\leftarrow\!\bullet(\mathtt{tor}, \Box\mathtt{prog}(\mu(\sigma)))$
	Ẽ	$\bullet(\mathtt{tor}+\epsilon, \Box\mu(\sigma))^{\dagger}$	$\leftarrow\!\bullet(\mathtt{tor}, \diamond\mu(\sigma))$	$\bullet(\mathtt{tor}, \Box\mathtt{prog}(\mu(\sigma)))$	$\leftarrow\!\bullet(\mathtt{tor}, \Box\mathtt{prog}(\mu(\sigma)))$
AT/ON/IN/	E	$\bullet\!\!\rightarrow(\mathtt{tor}, \bullet(\tau(\phi), \diamond\mu(\sigma)))$	$\leftarrow\!\bullet(\mathtt{tor}, \bullet(\tau(\phi), \diamond\mu(\sigma)))$	$\bullet\!\!\rightarrow(\mathtt{tor}, \bullet(\tau(\phi), \bullet(\mathtt{tor}', \Box\mathtt{prog}(\mu(\sigma)))))$	$\leftarrow\!\bullet(\mathtt{tor}, \bullet(\tau(\phi), \bullet(\mathtt{tor}', \Box\mathtt{prog}(\mu(\sigma))))))$
DURING	Ẽ	$\bullet\!\!\rightarrow(\mathtt{tor}, \bullet(\tau(\phi), \Box\mu(\sigma)))$	$\leftarrow\!\bullet(\mathtt{tor}, \bullet(\tau(\phi), \diamond\mu(\sigma)))$	$\bullet\!\!\rightarrow(\mathtt{tor}, \bullet(\tau(\phi), \bullet(\mathtt{tor}', \Box\mathtt{prog}(\mu(\sigma)))))$	$\leftarrow\!\bullet(\mathtt{tor}, \bullet(\tau(\phi), \bullet(\mathtt{tor}', \Box\mathtt{prog}(\mu(\sigma)))))$
THROUGHOUT	E	*	*	$\bullet\!\!\rightarrow(\mathtt{tor}, \bullet(\tau(\phi), \Box\mathtt{prog}(\mu(\sigma))))$	$\leftarrow\!\bullet(\mathtt{tor}, \bullet(\tau(\phi), \Box\mathtt{prog}(\mu(\sigma))))$
	Ẽ	$\bullet\!\!\rightarrow(\mathtt{tor}, \bullet(\tau(\phi), \Box\mu(\sigma)))$	$\leftarrow\!\bullet(\mathtt{tor}, \bullet(\tau(\phi), \Box\mu(\sigma)))$	$\bullet\!\!\rightarrow(\mathtt{tor}, \bullet(\tau(\phi), \Box\mathtt{prog}(\mu(\sigma))))$	$\leftarrow\!\bullet(\mathtt{tor}, \bullet(\tau(\phi), \Box\mathtt{prog}(\mu(\sigma))))$
AFTER	E	$\bullet\!\!\rightarrow(\mathtt{tor}, \bullet\!\!\rightarrow(\tau(\phi), \diamond\mu(\sigma)))$	$\leftarrow\!\bullet(\mathtt{tor}, \bullet\!\!\rightarrow(\tau(\phi), \diamond\mu(\sigma)))$	$\bullet\!\!\rightarrow(\mathtt{tor}, \bullet\!\!\rightarrow(\tau(\phi), \bullet(\mathtt{tor}', \Box\mathtt{prog}(\mu(\sigma)))))$	$\leftarrow\!\bullet(\mathtt{tor}, \bullet\!\!\rightarrow(\tau(\phi), \bullet(\mathtt{tor}', \Box\mathtt{prog}(\mu(\sigma)))))$
	Ẽ	$\bullet\!\!\rightarrow(\mathtt{tor}, \bullet\!\!\rightarrow(\tau(\phi), \Box\mu(\sigma)))^{\ddagger}$	$\leftarrow\!\bullet(\mathtt{tor}, \bullet\!\!\rightarrow(\tau(\phi), \diamond\mu(\sigma)))$	$\bullet\!\!\rightarrow(\mathtt{tor}, \bullet\!\!\rightarrow(\tau(\phi), \bullet(\mathtt{tor}', \Box\mathtt{prog}(\mu(\sigma)))))$	$\leftarrow\!\bullet(\mathtt{tor}, \bullet\!\!\rightarrow(\tau(\phi), \bullet(\mathtt{tor}', \Box\mathtt{prog}(\mu(\sigma))))$
BEFORE	E	$\bullet\!\!\rightarrow(\mathtt{tor}, \leftarrow\!\bullet(\tau(\phi), \diamond\mu(\sigma)))$	$\leftarrow\!\bullet(\mathtt{tor}, \leftarrow\!\bullet(\tau(\phi), \diamond\mu(\sigma)))$	$\bullet\!\!\rightarrow(\mathtt{tor}, \leftarrow\!\bullet(\tau(\phi), \bullet(\mathtt{tor}', \Box\mathtt{prog}(\mu(\sigma)))))$	$\leftarrow\!\bullet(\mathtt{tor}, \leftarrow\!\bullet(\tau(\phi), \bullet(\mathtt{tor}', \Box\mathtt{prog}(\mu(\sigma))))))$
	Ẽ	$\bullet\!\!\rightarrow(\mathtt{tor}, \leftarrow\!\bullet(\tau(\phi), \Box\mu(\sigma)))^{\ddagger}$	$\leftarrow\!\bullet(\mathtt{tor}, \leftarrow\!\bullet(\tau(\phi), \diamond\mu(\sigma)))$	$\bullet\!\!\rightarrow(\mathtt{tor}, \leftarrow\!\bullet(\tau(\phi), \bullet(\mathtt{tor}', \Box\mathtt{prog}(\mu(\sigma)))))$	$\leftarrow\!\bullet(\mathtt{tor}, \leftarrow\!\bullet(\tau(\phi), \bullet(\mathtt{tor}', \Box\mathtt{prog}(\mu(\sigma)))))$
SINCE	E	*	$\leftarrow\!\bullet(\mathtt{tor}, \bullet\!\!\rightarrow(\tau(\phi), \diamond\mu(\sigma)))$	*	$\leftarrow\!\bullet(\mathtt{tor}, \bullet\!\!\rightarrow(\tau(\phi), \Box\mathtt{prog}(\mu(\sigma))))$
	Ẽ	*	$\leftarrow\!\bullet(\mathtt{tor}, \bullet\!\!\rightarrow(\tau(\phi), \Box\mu(\sigma)))$	*	$\leftarrow\!\bullet(\mathtt{tor}, \bullet\!\!\rightarrow(\tau(\phi), \Box\mathtt{prog}(\mu(\sigma))))$
UNTIL/	E	*	*	$\bullet\!\!\rightarrow(\mathtt{tor}, \leftarrow\!\bullet(\tau(\phi), \Box\mathtt{prog}(\mu(\sigma))))$	$\leftarrow\!\bullet(\mathtt{tor}, \leftarrow\!\bullet(\tau(\phi), \Box\mathtt{prog}(\mu(\sigma))))$
TILL	Ẽ	$\bullet\!\!\rightarrow(\mathtt{tor}, \leftarrow\!\bullet(\tau(\phi), \Box\mu(\sigma)))^{\dagger\dagger}$	$\leftarrow\!\bullet(\mathtt{tor}, \leftarrow\!\bullet(\tau(\phi), \Box\mu(\sigma)))$	$\bullet\!\!\rightarrow(\mathtt{tor}, \leftarrow\!\bullet(\tau(\phi), \Box\mathtt{prog}(\mu(\sigma))))$	$\leftarrow\!\bullet(\mathtt{tor}, \leftarrow\!\bullet(\tau(\phi), \Box\mathtt{prog}(\mu(\sigma))))$
BY	E	$\bullet\!\!\rightarrow(\mathtt{tor}, \leftarrow\!\bullet(\tau(\phi), \diamond\mu(\sigma)))^{\ddagger\ddagger}$	$\leftarrow\!\bullet(\mathtt{tor}, \leftarrow\!\bullet(\tau(\phi), \diamond\mu(\sigma)))$	$\bullet\!\!\rightarrow(\mathtt{tor}, \leftarrow\!\bullet(\tau(\phi), \bullet\!\!\rightarrow(t, \Box\mathtt{prog}(\mu(\sigma)))))$	*
	Ẽ	$\bullet\!\!\rightarrow(\mathtt{tor}, \leftarrow\!\bullet(\tau(\phi), \bullet\!\!\rightarrow(t, \Box\mu(\sigma))))$	*	$\bullet\!\!\rightarrow(\mathtt{tor}, \leftarrow\!\bullet(\tau(\phi), \bullet\!\!\rightarrow(t, \Box\mathtt{prog}(\mu(\sigma)))))$	*

$\mu(\sigma)$ The timeless unquantified proportion from the matrix σ.

$\tau(\phi)$ The interval indicated by the temporal prepositional phrase ϕ.

$\bullet(t, \alpha)$ Proposition α holds in the unique time interval t.

$\bullet\!\!\rightarrow(t, \alpha)$ Proposition α holds from the unique time t up the interval marking the end of the context.

$\leftarrow\!\bullet(t, \alpha)$ Proposition α holds from the beginning of the context up to the unique time t.

$\mathtt{prog}(\phi)$ A function that turns an event ϕ into an activity, that with a state verb gives an implicature of deceit on the part of the agent and with an activity verb an implicature that there is no accomplishment.

$\mathtt{tor}'$ the updated value of $\mathtt{tor}$.

t is an unbound time in the context.

† If the verb is a state, then $\epsilon = 0$.

‡ If the verb is an activity, then $\Box$ is replaced by $\diamond$.

* Unacceptable.

†† The $\mathtt{tor}$ is by default.

‡‡ In the past tense some event verbs are unacceptable in some contexts.

Table 8: Procedure for the temporal semantics of all sentences

$\mu(\Sigma) = if \quad (\pi(\phi) = \text{SINCE} \wedge \neg\text{perfective?}(\sigma)) \vee$ % Exceptions

$\quad (\pi(\phi) = \text{BY} \wedge \text{perfective?}(\sigma) \wedge (\text{state?}(\sigma) \vee \text{progressive?}(\sigma)))$ *then* "$*$"

else "$\models$";

case tense(σ): % Set the `tor` relative to the `tou`

past "$\leftarrow\!\bullet$(`tou`,";

future "$\bullet\!\rightarrow$(`tou`,";

esac;

"$\bullet$(`Context`,";

if perfective?(σ) *then* "$\leftarrow\!\bullet$" % Set the `toe` relative to the `tor`

else if $\phi =$'' *then* "$\bullet$" *else* "$\bullet\!\rightarrow$";

"(`tor`";

if $\phi =$ '' $\wedge\, \neg$perfective?(σ) $\wedge\, \neg$progressive?(σ) *then* "$+\,\epsilon$";

",";

case $\pi(\phi)$: % Set up the prepositional constraint

AT|ON|IN|DURING|THROUGHOUT "$\bullet$";

AFTER|SINCE "$\bullet\!\rightarrow$";

BEFORE|UNTIL|BY "$\leftarrow\!\bullet$";

esac;

"($\tau(\phi)$)," % and add the prep interval

if $\neg(\pi(\phi) =$ THROUGHOUT|SINCE|UNTIL|BY$) \wedge$ progressive?(σ)

then "$\bullet$ (`tor′`,"; % update `tor` first

if $\pi(\phi) =$ BY *then* "$\bullet\!\rightarrow(t,$"; % t any time between `tor` and prep interval

case $\pi(\phi)$ % Select the quantifier

THROUGHOUT|UNTIL *if* progressive?(σ) $\vee\, \neg$event?(σ)

then "$\Box$" *else* "$*$";

AFTER|BEFORE *if* progressive?(σ) $\vee$ state?(σ) $\wedge\, \neg$perfective?(σ))

then "$\Box$" *else* "$\diamond$";

T *if* progressive?(σ) $\vee\, (\neg$event?(σ) $\wedge\, \neg$perfective?(σ))

then "$\Box$" *else* "$\diamond$";

esac;

if progressive?(σ) *then* "`prog(`";

"$\mu(\sigma)$"]; % and finish off with the matrix.

LEGEND

Inputs:

Σ is a sentence

σ is the matrix of Σ

ϕ is the temporal phrase in Σ

Functions:

$\mu(\sigma)$	returns the proposition found in σ
$\pi(\phi)$	returns the temporal preposition in ϕ
$\tau(\phi)$	returns the time found in ϕ
tense(σ)	returns the tense in σ

Boolean functions:

perfective?(σ)	is true iff σ has a perfective aspect
progressive?(σ)	is true iff σ has a progressive aspect
event?(σ)	is true iff σ indicates an event
state?(σ)	is true iff σ indicates a state verb
]	output as many right parentheses as necessary.