The Expressive Power of the English Temporal Preposition System

Ian Pratt and **David Brée**
Artificial Intelligence Group
Department of Computer Science,
University of Manchester
Manchester M13 9PL
United Kingdom

1 Introduction

Sentences involving temporal prepositions number among our simplest and most natural expressions of temporal location and extent:

(1) Sue worked on the letter *until* 10 o'clock

(2) Bill will post the parcels *by* 10 o'clock

(3) Charles has sent me email *within* the last 10 minutes.

Altogether, there are eighteen or so temporal prepositions in English, depending on exactly how you count them. The temporal prepositions considered here are *before*, *after*, *since*, *until*, *by*, *at*, *for*, *in*, *within*, *on*, *during*, *through*, *throughout*, *over*, *from ... to*, *between ... and* and *ago*. The last of these, *ago*, is normally classified as an adverb rather than a preposition, but, as we will see, fits neatly into the temporal prepositional system. There are a number of related prepositions such as *about* and *around* which can have a temporal function, but which we ignore here.

One of the noteworthy features of temporal prepositions is that, in general, they are not embedded one within the other. Thus

(4) *Sue wasn't working on the letter *by* 10 o'clock *until* 10 o'clock

(5) *Charles had sent me electronic mail *within* the last 5 minutes *until* 10 o'clock

count, for most competent speakers of English, as nonsense. Examples where two temporal prepositions can work together, as in

(6) *In* five minutes, David will have been working in his office *for* 6 hours

are the exception rather than the rule. In the Brown corpus of American English [10], which has a total of 52,126 sentence, about 10% (4,894) include at least one preposition used temporally. Only 366 (7.5%) of these sentences, i.e. less than 1% of the corpus, have two or more prepositions used temporally. Only two sentences have more than two temporal prepositions:[1]

(f32:020) Many years later (*on* August 3, 1915), Lucy Upton wrote Winslow's daughter soon to be graduated from Smith College: "While I love botany which, after dabbling in *for* years, I studied according to the methods of that day exactly forty years *ago* in a summer school, it must be fascinating to take up zoology in the way you are doing.

(p09:067) And the hours were six-thirty *in* the morning *until* eleven *at* night *on* Saturdays and *during* sales, ...

In f32:020 we see the most common situation: the temporally used prepositions (in *italics*) are not in the same clause. In p09:067 we see how temporal prepositions, when there is more than one within a clause, have a hierarchical structure rather than a direct interaction: the *in* and the *at* qualify the two

[1] code numbers refer to the sub-corpus and the sequential number of the sentence within that sub-corpus

clock times, *until* builds a cyclic period between these times, which in turn is restricted by the *on* and the *during*.

This general lack of iterative use, combined with the limited number of temporal prepositions available to start with, suggests that the expressive power of the temporal preposition system is limited. That is, within the space of logically possible assertions concerning the temporal distribution of states and events, prepositions give us access to only a very limited subspace. The main burden of this paper is to identify this subspace and to explain how, exactly, the English temporal propositions span it.

The approach does not make use of the well-known temporal relationships proposed by James Allen [1]. His system provided a means of representing all the possible temporal orderings between two events in time, in particular when they overlapped in some way, e.g. one starting and finishing before the other. In English this relationship is **not** indicated by the prepositions but rather by explicit references to *the beginning/start of* and to *the end/finish of* such periods. In English temporal prepositions serve not only to order two events but also to indicate their absolute time duration and their actual time of occurrence relative to the time of reference or utterance of the discourse, neither of which are included in Allen's system.

2 Temporal functions

This section illustrates the flavour of the analysis we propose by means of simple examples.

Consider the sentences:

(7) Bill posted the parcel *between* 9 o'clock *and* 10 o'clock.

(8) Sue worked on the letter *from* 9 o'clock *to* 10 o'clock.

Sentence (7) reports an event—namely, Bill's posting the parcel—and locates that event as having occurred *sometime* within the interval [9:00,10:00]. Sentence (8) also reports an event—namely, Sue's working on the letter—but locates that event as having occurred *throughout* that interval.

Following common practice in semantics (e.g. Richards [16]), we take (7) and (8) to have, as significant constituents, the tenseless sentences

(9) Bill post the parcel

(10) Sue work on the letter

respectively, which receive truth-values relative to intervals of time. Thus (9) is true over an interval J just in case Bill posts the parcel over that interval; likewise, (10) is true over an interval J just in case Sue works on the letter over that interval, and so on. We will have more to say presently on what it means for a tenseless sentence to be *true over* an interval; but for the present, let us take this notion as given.

On this approach, it is natural to give the truth-conditions of (7) and (8) as, respectively:

(11) There exists an interval J wholly contained within the interval [9:00, 10:00], such that (Bill post the parcel) is true over J

(12) For all intervals J wholly contained within the interval [9:00, 10:00], (Sue work on the letter) is true over J.

And we might write these truth-conditions symbolically as

(13) $\exists J(J \subset [9{:}00, 10{:}00]\ \&\ (\text{Bill post the parcel})(J))$

(14) $\forall J(J \subset [9{:}00, 10{:}00] \rightarrow (\text{Sue work on the letter})(J))$

thus viewing tenseless sentences as one-place predicates whose arguments range over time intervals. To be sure, there are alternative approaches to the semantics of tensed sentences to the one taken here.[2] However, the basic framework adopted here should not necessarily be understood as a rejection of these alternatives. It is merely that we have to work within some framework or other, and ours, as we shall see, has the virtue of simplicity for the topic at hand. But we expect that the conclusions presented below can probably be translated—with varying degrees of effort—into the frameworks favoured by a number of approaches to natural language semantics. So, those who think they have an argument against the interval-based framework adopted here should be able to reformulate what they find in this paper in their preferred terms.

Generalizing our analysis of (7) and (8), the temporal prepositional constructions *between ... and* and *from ... to* can be seen as functioning so as to map a tenseless sentence ϕ onto the propositions:

(15) $\exists J(J \subset [t_1, t_2] \ \ \& \ \ \phi(J))$

(16) $\forall J(J \subset [t_1, t_2] \ \rightarrow \ \phi(J))$

respectively, where t_1 and t_2 are the prepositional arguments. We shall call forms (15) and (16) *temporal functions*—that is: functions by which an underlying tenseless sentence ϕ is mapped to a proposition. Our goal in this paper is precisely to specify the range of temporal functions which the prepositional system makes available.

The temporal functions (15) and (16) express restricted existential and universal quantification over intervals. That is, they have the *general forms*:

(17) $\exists J(J \subset I \ \ \& \ \ \phi(J))$

(18) $\forall J(J \subset I \rightarrow \phi(J))$

where I is a time interval determined (in these cases) by the arguments to the prepositions. We call temporal functions having form (17) *existential* temporal functions, and those having form (18) *universal* temporal functions. The interval I, over which the quantification ranges, we call the *reference interval* of the temporal function.

In giving the semantics of temporal prepositions in terms of operations they perform on underlying tenseless sentences, we need to distinguish between tenseless sentences that report a *completed* event from those that report an *ongoing process*. Such aspectual distinctions are familiar and widely accepted in semantics, following Vendler [17], who differentiated between the four *aspectual classes* of activities, achievements, accomplishments and states. Less widely accepted are Vendler's specific proposals as to the number and nature of the different aspectual classes. (See, for example, Herweg [7], and Lascarides [11], for their own treatments.) But for the purposes of accounting for the semantics of temporal prepositions, the following minimal distinction suffices.

We suppose that some tenseless sentences, which describe 'ongoing' process- or state-types, have the property that whenever they are true over an interval I, they are true over every subinterval of I. We call these *non-completion sentences*. We suppose in addition that other tenseless sentences, which describe 'completed' event-types, have the property that whenever they are true over an interval I, they are false over some subinterval of I. We call these *completion sentences*. Note that the aspectual distinctions made here are

[2] Some writers, for example, have taken tensed sentences to quantify over *events* (e.g. Parsons [14]), or over events and *time-points*, depending on the type of sentence (Herweg [7]). And among those who adopt the interval-approach, there is sometimes disagreement on which intervals, exactly, given tenseless sentences should be evaluated at (see Lascarides [11], where the discussion hinges on just this question).

the minimal ones required for presenting a semantics of temporal prepositions. We do not mean to argue that there might be no other reason to define additional aspectual classes satisfying stronger requirements.

3 The group-I temporal functions

In the previous section, we proposed that the temporal prepositions *between ... and* and *from ... to* should be seen as having temporal functions of the forms:

(17) $\exists J(J \subset I \ \& \ \phi(J))$

(18) $\forall J[J \subset I \rightarrow \phi(J))$

respectively, where I, the so-called reference interval, is fixed directly by the arguments to those prepositions. In this section, we examine a group of temporal prepositions which also express temporal functions of this form, but where the reference interval is fixed *indexically* or *anaphorically*.

The prepositions *since*, *by*, *until*, *within*, *in* and *for*, when used with appropriate verb-tense and -aspect, can express temporal functions of forms (17) and (18) with any of the eight reference intervals:

$[t, \mathrm{TOU}]$, $[\mathrm{TOU}\text{-}t, \mathrm{TOU}]$,

$[t, \mathrm{TOR}]$, $[\mathrm{TOR}\text{-}t, \mathrm{TOR}]$,

$[\mathrm{TOU}, t]$, $[\mathrm{TOU}, \mathrm{TOU} + t]$,

$[\mathrm{TOR}, t]$, $[\mathrm{TOR}, \mathrm{TOR} + t]$,

where t is the argument to the temporal preposition, TOU the time of utterance, and TOR the reference time of the discourse. These reference intervals can be identified by their position on three dimensions of variation: indexical/anaphorical, forward-looking/ backward-looking and absolute/relative.

Indexicals have one end of the reference interval fixed at the time of utterance. The tense in this case cannot be past. Anaphoricals have one end of their reference interval fixed by the time of reference of the discourse, so their tense cannot be present. Further tense restrictions are placed by the existential/universal feature of the function. We do not go into these in detail.

The absolute use occurs when the argument to the preposition is a time on the time axis, e.g. *6 o'clock*. The relative use is when this argument is a temporal duration, e.g. *one hour*. This duration is used as an offset from the time of utterance/reference in determining the reference interval, I.

Whether an existential or a universal function is intended is indicated by an aspect of the matrix clause. If it is progressive, then the function is universal.

The direction is indicated by another aspect of the matrix clause. If it is perfect, then the function is backward-looking; if not, it is forward looking.

The reference intervals, I, for the backward-looking functions have their upper bound fixed at the time of utterance (TOU) or reference (TOR). Their lower bound is determined by the argument to the preposition, t, either absolutely, or by an offset relative to the upper bound. For the reference intervals for forward-looking functions this is reversed: their *lower* bound is fixed by the time of utterance or reference and their *upper bound* is fixed by t, either absolutely or relatively.

Example sentences of each function, i.e. Absolute or Relative, Backwards or Forwards, indexical or anaphorical and Universal or Existential, are:

(ABiU) Sue has been working *since* 6 o'clock.

(ABiE) Sue has cried once *since* 6 o'clock.

(ABaU) Sue had/(will have) been working *since* 6 o'clock.

(ABaE) Sue had cried once *since* 6 o'clock.

(AFiU) Sue is/(will be) working *until* 6 o'clock.

(AFiE) Sue will call *by* 6 o'clock.

(AFaU) Sue worked/(would be working) *until* 6 o'clock.

(AFaE) Sue called/(would call) *by* 6 o'clock.

(RBiU) Sue has been working *for* a week.

(RBiE) Sue has the best score *in* 3 days.

(RBaU) Sue had/(will have) been working *for* a week.

(RBaE) Sue had the best score *in* 3 days.

(RFiU) Sue is/(will be) working *for* a week.

(RFiE) Sue will call *within* an hour.

(RFaU) Sue would be working *for* a week.

(RFaE) Sue would call *within* an hour.

As can be seen, backward-looking indexicals are not happily classified as existentials. They are generally used, e.g. in the Brown corpus, to give a frequency of occurrence, as in ABiE and ABaE, or to pick out an extreme value, as in RBiE and RBaE, in a time interval.

The rules for the interpretation of English sentences involving propositions in this usage are summarized in table 1. The permitted combination of tense and aspect, both perfective and progressive, are taken from the above examples. Note that the past+future corresponds to the use of *would*, as in RFaU and RFaE above. By way of illustration, the mapping of these functions onto the time axis is depicted in figure 1.

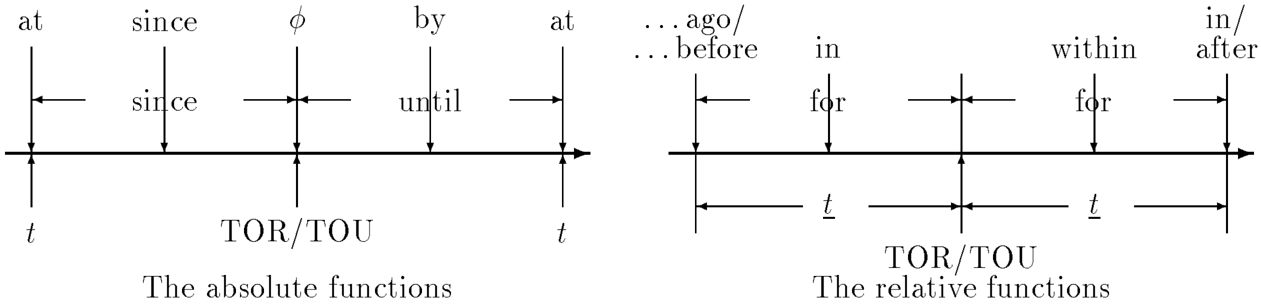

Figure 1: The absolute and relative functions in groups I and II

relative/ absolute	forward/ backward	indexical/ anaphorical	reference interval I	existential/ universal on J	prepos- ition	tense	per- fective	pro- gressive
absolute	backward	indexical	$[t, \mathrm{TOU}]$	universal existential	*since*	present	Y	Y N
		anaphorical	$[t, \mathrm{TOR}]$	universal existential	*since*	past/fut past	Y	Y N
	forward	indexical	$[\mathrm{TOU}, t]$	universal existential	*until* *by*	pres/fut future	N	Y N
		anaphorical	$[\mathrm{TOR}, t]$	universal existential	*until* *by*	past/ future	N	Y N
relative	backward	indexical	$[(\mathrm{TOU} - \underline{t}), \mathrm{TOU}]$	universal existential	*for* *in*	present	Y	Y N
		anaphorical	$[(\mathrm{TOR} - \underline{t}), \mathrm{TOR}]$	universal existential	*for* *in*	past/fut past	Y	Y N
	forward	indexical	$[\mathrm{TOU}, (\mathrm{TOU} + \underline{t})]$	universal existential	*for* *within*	pres/fut future	N	Y N
		anaphorical	$[\mathrm{TOR}, (\mathrm{TOR} + \underline{t})]$	universal existential	*for* *within*	past+ future	N	Y N

Table 1: The group-I temporal functions: $(\exists/\forall)J(J \subset I \ \& \ \phi(J))$.

TOU is the time of utterance

TOR is the time of reference

t is the argument to the preposition phrase when it is a time

$\underline{t}$ is the argument to the preposition phrase when it is a duration.

relative/ absolute	forward/ backward	indexical/ anaphorical	reference interval I	$\exists/\forall$ on J	prepos- ition	tense	per- fective	pro- gressive
absolute	backward		$[(t-\varepsilon, t+\varepsilon)]$	$\forall$ $\exists$	*at*	past	N N/Y	Y N
	forward		$[(t-\varepsilon, t+\varepsilon)]$	$\forall$ $\exists$	*at*	present/ future	N	Y N
relative	backward	indexical	$[(\text{TOU-}\underline{t}\text{-}\varepsilon, \text{ TOU-}\underline{t}+\varepsilon)]$	$\forall$ $\exists$	*ago*	past	N	Y N
		anaphorical	$[(\text{TOR-}\underline{t}\text{-}\varepsilon, \text{ TOR-}\underline{t}+\varepsilon)]$	$\forall$ $\exists$	*before*	past	Y	Y N
	forward	indexical	$[(\text{TOU+}\underline{t}\text{-}\varepsilon, \text{ TOU+}\underline{t}+\varepsilon)]$	$\forall$ $\exists$	*in*	future pres/fut	N	Y N
		anaphorical	$[(\text{TOR+}\underline{t}\text{-}\varepsilon, \text{ TOR+}\underline{t}+\varepsilon)]$	$\forall$ $\exists$	*after*	past+ future	N	Y N

Table 2: The group-II temporal functions: $(\exists/\forall)J(J \subset I \;\&\; \phi(J))$.

TOU is the time of utterance — t is the argument to the preposition phrase when it is a time

TOR is the time of reference — $\underline{t}$ is the argument to the preposition phrase when it is a duration

ε is a small duration.

4 The group-II temporal functions

Various temporal prepositions, including *at*, *in*, *after*, *before* and *ago* (usually classed as an adverb) can be used to express temporal functions of the by now familiar forms (17) and (18) but where the reference interval I is of negligible temporal extension. These temporal functions are thus used to *locate* events and states in time rather than to report on their duration.

The reference interval centres around a point which is given either absolutely or relatively. In the latter case, the function may be determined relative to the TOU (indexical) or the TOR (anaphorical), and may be fixed by adding (forward-looking) or subtracting (backward-looking) the offset.

Even though the reference interval is negligible, it is possible for there to be universal quantification. Again, universal quantification is indicated by the progressive aspect.

Only one of the prepositions, *at*, has an absolute temporal function, either existential or universal. When the argument of the preposition is earlier than the time of utterance, then the past tense is used, when later, a non-past tense. The other prepositions cover times relative to the time of utterance or reference. As for group-I functions, they can be either backward or forward-looking. However, unlike group-I functions, a different preposition is used with a time of utterance (*ago, in*) than with a time of reference (*before, after*).

Examples of the group-II functions, either Absolute or Relative, Backward or Forward-looking, indexical or anaphorical and Universal or Existential are:

(AB.U) We were working *at* 2 o'clock.

(AB.E) We (had) finished *at* 2 o'clock.

(AF.U) We are/(will be) working *at* 2 o'clock.

(AF.E) We (will) finish *at* 2 o'clock.

(RBiU) We were laughing three hours *ago*.

(RBiE) We stopped three hours *ago*.

(RBaU) We had been laughing three days *before*.

(RBaE) They had stopped three days *before*.

(RFiU) We will be laughing *in* three hours.

(RFiE) They (will) stop *in* three hours.

(RFaU) The trains would be running *after* three days.

(RFaE) They would stop *after* three days.

Note that the perfect aspect is used with the backward-looking anaphoricals (BaE and BaU) but, surprisingly, not necessarily with the indexicals (BiE and BiU).

The results are summarized in table 2 and again depicted in figure 1.

5 The group-III temporal functions

Under this group we understand existential and universal temporal functions with reference intervals [START, t] or [t, END], where t is the time supplied by the prepositional argument and START and END are contextually supplied parameters indicating the start- and end-times of the temporal universe of discourse. That is, the group-III temporal functions are:

(19) $\exists J(J \subset [\mathrm{START}, t] \;\&\; \phi(J))$

(20) $\forall J(J \subset [\mathrm{START}, t] \;\rightarrow\; \phi(J))$

(21) $\exists J(J \subset [t,\mathrm{END}] \;\&\; \phi(J))$

(22) $\forall J(J \subset [t,\mathrm{END}] \;\rightarrow\; \phi(J))$.

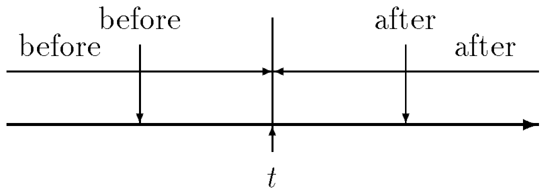

Figure 2: The group-III temporal functions

We have already met certain uses of *until*, *by* and *at* with the perfective aspect, in which we took the reference interval to be [START, t]. However, the main prepositions expressing the group-III temporal functions are *before* and *after*. Both can be used existentially and universally:

(23) Tim died *before/after* the explosion.

(24) Sue worked *before/after* her marriage.

The mapping of these prepositions onto the time axis is depicted in figure 2.

6 The group-IV temporal functions

This group contains just two temporal functions of the general forms (17) and (18), where the reference interval I is given directly by a pair of arguments to the prepositions. That is, the group-IV temporal functions are:

(25) $\exists J(J \subset [t_1, t_2] \ \ \& \ \ \phi(J))$.

(26) $\forall J(J \subset [t_1, t_2] \ \ \rightarrow \ \ \phi(J))$.

We have already met prepositions expressing these temporal functions: *between ... and* and *from ... to*, since they were used in section 2 to introduce the general approach taken here.

(27) Tim died *between* 5 *and* 6 o'clock.

(28) Sue worked *from* dawn *to* dusk.

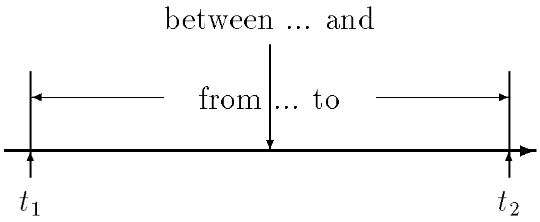

Figure 3: The group-IV temporal functions

Group	reference interval I	$\exists/\forall$ on J	preposition
III	[START, t]	$\forall/\exists$	*before*
	[t, END]	$\forall/\exists$	*after*
IV	$[t_1, t_2]$	$\forall$	*from... to*
		$\exists$	*between... and*
V	$[t]$	$\forall$	*throughout/for/through/over*
		$\exists$	*in/on/during*

Table 3: The groups III, IV and V temporal functions: $(\exists/\forall)J(J \subset I \& \phi(J))$.
t is the argument to the preposition phrase
t_1 and t_2 are the arguments to a double preposition.

7 The group-V temporal functions

This group also contains just two temporal functions of the form (17) and (18), where the reference interval I is given directly as the argument to the preposition. Several temporal prepositions can be used to express the group-V universal function: *throughout, for, through, over*.

(29) Judy was working *throughout* the day.

(30) Judy is at home *for* Christmas.

(31) Judy survived *through* the winter.

(32) Judy worked *over* the summer.

In, on and *during* express the group-V existential function:

(33) Judy worked best *in* the morning.

(34) Judy worked *on* Sunday.

(35) Judy worked hardest *during* examinations.

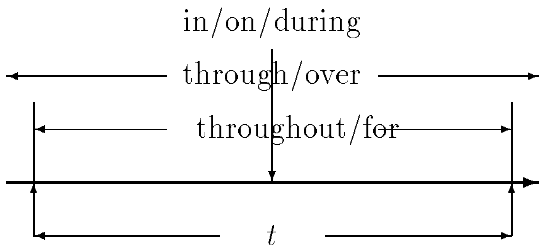

Figure 4: The group V temporal functions

The differences in use encountered in the Brown corpus between *throughout, for, through* and *over* on the one hand and *in, on* and *during* on the other are discussed in Brée *et al.* [4].

8 The floating temporal functions

Leaving aside some doubtful cases (particularly concerning the preposition *over*), we have so far considered temporal functions belonging to one of two categories: the existential functions, which allow one to say that something is true over some subinterval J of a given reference-interval I, and the universal functions, which allow one to say that something is true over all subintervals J of a given reference-interval I. We now turn to a group of temporal functions for which only the duration of the subinterval is fixed, not its location in time: the *floating* functions. Prepositions expressing functions in this group include *for*, *within*, *in* and *over*.

The floating functions also fall into the two categories existential and universal. We begin with an oft-noted ambiguity in *for*-sentences. The sentence

(36) Sue has worked *for* one hour

can be used to say that Sue was working throughout the interval stretching backward one hour from the TOU. In that case, we give (36) truth-conditions:

(37) $\forall K(K \subset [TOU, TOU - 1 \text{ hr}] \rightarrow$ (Sue be working on the letter)$(K))$.

But (36) can also be used to say that Sue spent a period of one hour sometime in the past working on the letter. In which case, plausible truth-conditions would be, by analogy with (37),

(38) $\exists K(K \subset [START, TOU]$ & $\text{dur}(K) = 1\text{hr}$ & $\forall J(J \subset K \rightarrow$ (Sue be working on the letter)$(J)))$

where $\text{dur}(K)$ is a function that returns the duration of interval K. Thus, *for*, on this reading, has a temporal function of the form:

(39) $\exists K(K \subset I \;\; \& \;\; \text{dur}(K) = t \;\; \& \;\; \forall J(J \subset K \rightarrow \phi(J)))$

where I is, in this case, the interval [START, TOU]. It is as if the reference interval in form (18) has been allowed to float.[3] So we might say that temporal functions having form (39) are *floating universal* functions.

The sentence

(40) Charles will solve the problem *within* one hour

is also ambiguous. It can be used in a discourse to say that Charles will solve the problem sometime in the interval stretching forward one hour from the TOU. In that case, we give (40) truth-conditions:

(41) $\exists K(K \subset [TOU, TOU + 1 \text{ hr}]$ & (Charles solve the problem)$(K))$.

But (40) can also be used to say that Charles will solve the problem sometime in the future, taking not more than one hour to do so. In which case, plausible truth-conditions would be

[3] Actually, this use of *for* is complicated by the fact that the intervals over which the event in question is said to have been taking place can sometimes be *summed*: that is, (36) can be taken to be true if, e.g. Sue worked on the letter over three periods of twenty minutes each. We ignore this feature of *for*, noting it as a phenomenon which does not fit neatly into the framework developed here.

(42) $\exists K(K \subset [TOU, END]$ & dur(K)=1 hr & $\exists J(J \subset K$ & (Charles solve the problem)$(J)))$

Thus, *within*, on this reading, has a temporal function of the form:

(43) $\exists K(K \subset I$ & dur$(K) = t$ & $\exists J(J \subset K$ & $\phi(J)))$

where I is, in this case, the interval [TOU, END]. We say that temporal functions having form (43) are *floating existential* functions.

Examples of the floating use that are Backward- or Forward-looking, Universal or Existential and indexical (or anaphoric), are:

(BUi) Judy (has) worked for one hour yesterday.

(BUi) The premium was/(has been) paid over 3 years.

(BEi) Judy (has) solved the problem in one hour.

(BEi) Judy (has) solved the problem within one hour.

(FUi) Judy will work for one hour tomorrow.

(FUi) The premium will be paid over 3 years.

(FEi) Judy will solve the problem in one hour.

(FEi) Judy will solve the problem within one hour.

(.Ui) Judy works each day for 10 hours.

(BUa) Judy had worked for one hour already.

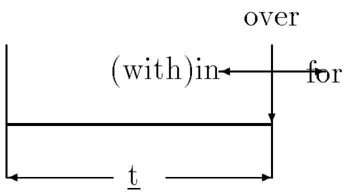

Figure 5: Floating temporal functions

reference interval I	$\exists/\forall$ on J	preposition	tense	perfective
[START, TOR]/ [START, TOU]	$\forall$	*for/ over*	present past	Y Y/N
	$\exists$	*in within*	present past	Y Y/N
[TOR, START]/ [TOU, START]	$\forall$	*for/ over*	present/ future	N Y/N
	$\exists$	*in/ within*	present future	Y Y/N

Table 4: The floating temporal functions: $\exists K(K \subset I$ & dur$(K) = t$ & $(\exists/\forall)J(J \subset K$ & $\phi(J)))$
TOR is the time of reference
TOU is the time of utterance
t is the argument to the preposition phrase

We see that *for* and *over* indicate a universal floating function whereas *in* and *within* indicate an existential floating function. The differences between these pairs is discussed in Brée *et al.* [4].

The backward/forward-looking distinction is carried by the tense or perfect aspect as is usual: past tense or perfect aspect indicating backward-looking, future tense indicating forward-looking. The present tense indicates a universal time interval, i.e. I is [START, END]. The tense also indicates whether the interval I is bounded by the time of utterance, as in most of the above examples, or by the time of reference, as in the last example BUa. The difference between indexical and anaphoric use is again carried by the tense and aspect as normally, so we do not consider it further here.

The rules for the floating temporal function are given in table 4 and given some depiction in figure 5.

9 Conclusion

In this paper, we chart the expressive power of the English temporal preposition system by determining the forms of the temporal functions—functions mapping underlying tenseless sentences onto propositions—which those prepositions can express. We distinguish just four such forms, namely:

(44) $\exists J(J \subset I \ \ \& \ \phi(J))$

(45) $\forall J(J \subset I \rightarrow \phi(J))$

(46) $\exists K(K \subset I \ \& \ \mathrm{dur}(K) = t$
$\ \& \ \exists J(J \subset K \ \& \ \phi(J)))$

(47) $\exists K(K \subset I \ \& \ \mathrm{dur}(K) = t$
$\ \& \ \forall J(J \subset K \rightarrow \phi(J)))$.

We have shown how the parameters I and t are fixed in a number of ways, using, as well as the prepositional arguments, indexical, anaphorical and other contextual parameters. We distinguish five groups of temporal functions having forms (44) and (45). These are: 16 group-I functions, where one of the bounds on the reference interval I is fixed at either the TOR or the TOU; 12 group-II functions in which the reference interval I is some sort of interval straddling a time point specified either absolutely or relative to the TOU or TOR; 4 group-III functions in which one bound of the reference interval is either the start or the end of the temporal universe of discourse; 2 group-IV functions in which the endpoints of the reference interval are given directly by a pair of arguments; and 2 group-V functions in which the reference interval is given by a single argument. In total, then, we have 36 temporal functions of forms (44) and (45)—that is: 2 temporal forms, each with 18 ways of specifying the reference interval I.

We have seen that not all these 36 cases are equally easy to specify; in particular backward-looking existentials in group-I are awkward. Also there is more than one preposition for the group-V functions, indicating that some of these carry additional non-temporal information.

In addition, we have distinguished a final group of 8 floating functions having forms (46) and (47)—each with a 4 ways of specifying I.

We have investigated how temporal prepositions, by combining with tense and aspect, span this logical space and we have explained how the well-known restrictions on the use of temporal prepositions with underlying tenseless sentences of various aspectual classes arise.

References

[1] Allen, James "Towards a general theory of action and time" *AI Journal*, 23(2), 1984.

[2] Brée, D. S. "Words for Time" in Macar, Pouthas and Friedman [12]

[3] Brée, D. S., R. A. Smit and J.P. van Werkhoven "Translating Temporal Prepositions between Dutch and English", *Journal of Semantics*, 7, pp. 1–51.

[4] Brée, D. S., Allel Feddag and Ian Pratt "Towards a formalisation of the semantics of some temporal prepositions" *Time and Society*, 2(2), 1993, pp. 219–240.

[5] Dowty, David, R. "The effects of Aspectual Class on the Temporal Structure of Discourse: Semantics or Pragmatics?", *Linguistics and Philosophy*, 9(1), 1989, pp. 37–61.

[6] Van Eynde, Frank "Towards a Dynamic and Compositional Treatment of temporal Expressions" in *Proceedings, Eighth Amsterdam Colloquium*

[7] Herweg, Michael "A Critical Examination of Two Classical Approaches to Aspect" *Journal of Semantics*, 8, 1991, pp. 363–402.

[8] Hinrichs, Erhard "Temporal Anaphora in Discourses of English", *Linguistics and Philosophy*, 9(1), 1989, pp. 63–82.

[9] Hornstein, Norbert *As Time Goes by: Tense and Universal Grammar*, Cambridge, MA: MIT Press 1990.

[10] Kučera, H., and W.N. Francis *Computational analysis of present-day American English*, Providence, RI: Brown University Press, 1967.

[11] Lascarides, Alex "The progressive and the imperfective paradox", *Synthese* 87(3), 1991, pp. 401–448.

[12] Macar, F., V. Pouthas and W. J. Friedman *Time, Action and Cognition: Towards Bridging the Gap*, NATO ASI Series D, vol. 66, Dordrecht: Kluwer, 1992.

[13] Mittwoch, Anita "Aspects of English aspect: on the interaction of perfect, progressive and durational phrases", *Linguistics and Philosophy*, 11(2), 1988, pp. 203–254.

[14] Parsons, Terence "The progressive in English", *Linguistics and Philosophy*, 12(2), 1989, pp. 213–241.

[15] Rice, Sally, A: "Polysemy and Lexical Representation: the case of three English Prepositions", *Proceedings of the fourteenth annual conference of the cognitive science society*, Hillsdale, NJ: Lawrence Earlbaum, 1992.

[16] Richards, Barry, Inge Bethke, Jaap van der Does and John Oberlander *Temporal representation and inference*, London: Academic Press, 1989.

[17] Vendler, Zeno *Linguistics and Philosophy*, Ithaca: Cornell University Press, 1967