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Abstract

In this paper we investigate the compositional semantics of temporal preposition phrases in isolated English sentences, with particular emphasis on their quantificational role. Our theory covers temporal preposition phrases with noun-phrase, sentential and preposition-phrase complements, and accounts naturally for quantification-restrictions and structural ambiguities occurring in sentences with multiple temporal preposition phrases, phenomena which, we argue, have not been adequately treated in the literature. One feature which contributes greatly to the uniformity of our theory is the use of *generalized temporal quantifiers* to serve as meanings for temporal noun phrases, temporal preposition phrases and sentences. This feature requires some changes to the usual semantics of sentences and their components.

1 Introduction

In this paper, we aim at a systematic and formal account of the semantics of temporal prepositions (TPs) and temporal preposition phrases (TPPs), as they occur in sentences such as:

(1) Mary kissed John during every meeting

(2) Jane arrived after the meeting on Wednesday

(3) John telephoned Jane 5 minutes before Mary arrived.

Most research to date on the formal semantics of temporal expressions in natural languages has focused on tense and aspect,[1] with relatively little research devoted to TPs. The locus classicus on the semantics of TPs is still Dowty [7], though several partial accounts are often to be found in semantic theories whose main focus lies elsewhere.[2]

The present account is motivated by two well-known observations, which, we claim, the literature to-date fails to treat adequately. The first observation is that preposition phrases generally, and TPPs in particular, create semantic contexts with respect to which quantification in other noun phrases is constrained. Here is a temporal example:

(4) All the lectures were given by Professor Jones on Tuesday.

This sentence is ambiguous: it could mean that all the lectures (in the domain of discourse) were given by Professor Jones and on Tuesday; or it could mean that all the lectures that were on Tuesday were given by Professor Jones (on Tuesday). Here is a non-temporal example:

(5) All the students were talking in lecture theatre A.

Again, maybe all the students in the domain of discourse were in lecture theatre A and talking; or maybe all the students who were in lecture theatre A were talking (in lecture theatre A).

Of particular interest in this paper is a similar quantification-restriction phenomenon occurring with multiple preposition phrases. Consider, for example, the sentence

(6) Mary fell asleep during every lecture one Monday.

Sentence (6) cannot naturally be interpreted as implying that Mary fell asleep during every lecture and that, furthermore, every lecture occurred on a Monday. Rather, the quantification in every lecture is

[1] References are too numerous to list here; see a recent survey in [24]

[2] See, for example, Alshawi [2], Crouch and Pullman [5], Hinrichs [13], Hwang and Schubert [16], Mittwoch [20], Richards *et al.* [22].

restricted to those lectures occurring on some Monday. Note incidentally that this phenomenon cannot be explained away by supposing that lecture one Monday is a single phrasal constituent, since

(7) Mary fell asleep one Monday during every lecture

is an acceptable, if stylistically inferior, paraphrase.

We aim to provide a semantics for temporal prepositions in which such quantification-restriction arises as a natural consequence. In particular, we shall demonstrate how the correct truth-conditions are assigned to sentences (6) and (7). Our strategy will be to take the meaning of a temporal noun phrase to be a *temporal generalized quantifier* (TGQ), a natural extension of the classical generalized quantifier introduced in Barwise and Cooper [3]. A major advantage of our semantics is the elegant account for cascaded TPP modifications in sentences like

(8) Mary kissed John during every meeting one day in January.

We claim that these cascades are not handled correctly by existing approaches.

The second motivating observation concerns the variety of grammatical categories with which TPs interact. Thus, some TPs take noun phrase, preposition-phrase or sentential complements, e.g.:

(9) John worked on the proposal until {Monday/after the meeting/Jane arrived}.[3]

Furthermore, most TPPs can modify (at least) both noun-phrase and verb-phrase constituents, a fact which gives rise to familiar ambiguities of prepositional attachment. For example,

(10) Mary remembered the meeting on Tuesday

is ambiguous: maybe the remembered meeting was the one to have occurred on Tuesday (on Tuesday modifies the noun phrase meeting); or maybe the remembering of the meeting occurred on Tuesday (on Tuesday modifies the verb phrase remembered the meeting).

We aim to provide a semantics for temporal prepositions able to accommodate these multiple-category interactions. In doing so, we insist for example, (i) that the sentence Jane arrived have the same meaning whether it appears on its own or as a complement to a temporal preposition as in (9); (ii) that the preposition until have the same meaning for all three cases in (9); and (iii) that the TPP on Tuesday have the same meaning whether it modifies noun- or verb phrases. Our strategy will be to assign temporal noun phrases, temporal preposition phrases, and sentences a single type of meaning: the TGQ. We will show in the course of the paper how this proposal leads to a unified account of the semantics of temporal prepositions in a wide variety of grammatical contexts.

To achieve these aims, we must complicate the usual semantics of simple sentences and their components. The order of presentation is as follows. First, we deal with temporally-unmodified sentences. We start with sentences where the verb-arguments are unquantified (we refer to such sentences as *simple* sentences), and then consider the effect of verb-argument quantification. This sets the stage for expressing the dependency of noun-meanings and verb-meanings on time intervals. We then pass to temporal modification of sentences[4] by means of one or more TPPs. We consider first TPPs with simple noun-phrase complements, passing to complements of other categories, and complements which are themselves modified by TPPs.

The meaning derivations introduce some operations in the λ-calculus which are different to ordinary function application. In a companion paper [8], we show how to derive the meaning of sentences containing TPPs using *logical deduction* within a *glue-language*, in the spirit of the syntax-semantics

[3] Arguably, other complements are possible as well as in, e.g. Stir the soup until thick; however, we do not cover such cases here, which we regard as elliptical.

[4] On most accounts, it is standardly the verb phrases that are being temporally-modified; this issue will be discussed below.

interface which has recently been developed within the *LFG* [17] framework in [6]. One particular advantage we find in the glue-language approach is the ability to refer freely to components of a formula—particularly its variables—rather than having to rely on the strict order of reference to variables imposed by the λ-calculus (in β-reductions). This avoids the need for our additional operations.

2 The general semantic framework

We express meanings in a variant of Montague's *Intensional Logic (IL)* (actually, in the extensional fragment of IL, since we do not consider intensional phenomena in this paper). A lucid presentation of the formalism can be found in [9]. In the present paper, we use SMALL CAPITAL font for the IL relations and constants corresponding to the obvious English words. For example, STUDENT(x) denotes the property picked out by the common noun student, and JOHN denotes the person named by John. The modification of IL we need is the introduction of a new basic type **i**, of temporal intervals.[5] The interpretation of this type in models is *fixed*, expressing the temporal ontology assumed here, namely, intervals of the real line. Interval-based temporal ontology is by now well established; see, for example, [1]. We use I, J to range over temporal intervals. One could do without this type-extension by regarding temporal intervals as ordinary entities of type **e** (**e** for *entity*). However, in that case, one would need to resort to selectional restrictions in order to explain why (1) is a good sentence, while the similarly typed (11) is normally unacceptable.

(11) * Mary kissed John during every book.

We find the presentation by means of the extra type **i** much clearer, and use it in the sequel.

The additional type **i** interacts also with other types in accordance with our intended interpretation of temporal expressions. Thus, propositions are viewed as depending on temporal intervals, and are assigned the type **(i,t)**, instead of their more usual type **t** (**t** for *truth-value*). In general, propositions (and their components) are evaluated with regard to a *time of interest* (*toi*), the determination of which is discourse-driven. The temporal-interval argument of a proposition originates in the lexical meanings of verbs, and is modified and restricted by constructs like tense, aspect, temporal adverbs and TPPs. We concentrate here on the latter. We believe that other indexical modifications, e.g., by means of locative PPs, can be similarly handled, but we make no attempt to justify this belief in the present paper.

We shall make frequent use of two semantic operations, to which we refer as *pseudo-application*, denoted by $({}_1\ldots)_1$ and $({}_2\ldots)_2$, respectively, defined as follows. Given a functional expression $\lambda y_1 \ldots \lambda y_m[\psi(y_1,\ldots,y_m)]$ (where y_1 is of type $(\tau,\mathbf{t})$, for some type τ, and $m \geq 1$), and an argument expression of the form $\lambda x_1 \ldots \lambda x_n[\phi(x_1,\ldots,x_n)]$ (where x_1 is of type τ, and $n \geq 1$), we define

(12) $\lambda y_1 \ldots \lambda y_m[\psi(y_1,\ldots,y_m)]({}_1\lambda x_1 \ldots \lambda x_n[\phi(x_1,\ldots,x_n)])_1 =_{\mathrm{def}}$
$\lambda y_2 \ldots \lambda y_m \lambda x_2 \ldots \lambda x_n[\psi(\lambda x_1[\phi(x_1,\ldots,x_n)], y_2,\ldots,y_m)]$.

(13) $\lambda y_1 \ldots \lambda y_m[\psi(y_1,\ldots,y_m)]({}_2\lambda x_n \ldots \lambda x_1[\phi(x_1,\ldots,x_n)])_2 =_{\mathrm{def}}$
$\lambda x_n \ldots \lambda x_2 \lambda y_2 \ldots \lambda y_m[\psi(\lambda x_1[\phi(x_1,\ldots,x_n)], y_2,\ldots,y_m)]$.

In this paper, we avoid syntactic issues as far as possible. Where we do assume a particular phrase-structure, we do so largely for the sake of definiteness: the essentials of our account could easily be adapted to suit competing syntactic theories. If π is a phrase of syntactic category C, we use the notation $[\![_{\mathrm{C}}\pi]\!]$ to denote its meaning.

[5] This expedient was also proposed by Dowty [7], p. 326.

3 The semantics of temporally-unmodified sentences

This section sets the scene for the main contribution of the paper in section 4. Much of the material it contains will be familiar to readers versed in Montague semantics; however, we draw attention to the 'double-indexing' of temporal nouns (especially the role of the sub-interval relation) and the somewhat unfamiliar treatment of sentence meanings.

3.1 The meaning of noun phrases

In this paper, we draw a sharp distinction between *temporal nouns* and *non-temporal* nouns. Temporal nouns are those which can serve, directly or indirectly, to pick out a interval of time; non-temporal nouns are those which cannot. The temporal nouns include event-denoting nouns like meeting or vacation, as well as calendrical nouns like Monday or 1997; the non-temporal nouns include many proper nouns like Henry, as well as type- or state-identifying common nouns like student or book. A rough test for distinguishing the two kinds is that temporal nouns can figure in TPP-complements, while non-temporal nouns, being devoid of temporal connotation, cannot. Thus, for example, we have after a meeting and by Monday, but (?) during Henry and (?) after a student. Here as elsewhere, of course, the flexibility of natural language makes a hard-and-fast distinction impossible. On the one hand, some temporal prepositions, especially until and by, can sound strained with non-calendrical temporal nouns, thus: (?) by the meeting and (?) until the accident. On the other hand, nearly all non-temporal nouns can be endowed with a temporal sense, as it were by courtesy, thus: after Henry (= after Henry died) and before that book (= before that book was published). However, these issues are orthogonal to the concerns of this paper, and we assume the distinction between temporal and non-temporal nouns to be a sharp one.

Let us first review the standard account of the semantics for non-temporal nouns and non-temporal noun phrases. On this account, non-temporal nouns—henceforth Ns—denote first-order λ-expressions, e.g.

(14) $[\![_{\mathrm{N}}\textsf{book}]\!] = \lambda x[\textsc{book}(x)]$

(15) $[\![_{\mathrm{N}}\textsf{student}]\!] = \lambda x[\textsc{student}(x)]$

where the type of x is $\mathbf{e}$. Determiners, by contrast, are mapped to second-order relations, e.g.

(16) $[\![_{\mathrm{Det}}\textsf{every}]\!] = \lambda P\lambda Q[\mathbf{every}(P,Q)] =_{\mathrm{def}} \lambda P\lambda Q[\forall x(P(x)\rightarrow Q(x))]$

(17) $[\![_{\mathrm{Det}}\textsf{a}]\!] = \lambda P\lambda Q[\mathbf{a}(P,Q)] =_{\mathrm{def}} \lambda P\lambda Q[\exists x(P(x)\wedge Q(x))]$

(18) $[\![_{\mathrm{Det}}\textsf{the}]\!] = \lambda P\lambda Q[\mathbf{the}(P,Q)] =_{\mathrm{def}} \lambda P\lambda Q[\exists!x(P(x))\wedge\exists x(P(x)\wedge Q(x))]$,

where the type of x is $\mathbf{e}$, and the type of P, Q is $(\mathbf{e,t})$. Non-temporal noun phrases—henceforth NPs—are then interpreted as generalized quantifiers, computed by applying the meaning of the determiner to the meaning of the noun, for example:

(19) $[\![_{\mathrm{NP}}\textsf{the book}]\!] = [\![_{\mathrm{Det}}\textsf{the}]\!]([\![_{\mathrm{N}}\textsf{book}]\!]) = \lambda P[\mathbf{the}(\lambda z[\textsc{book}(z)], P)]$.[6]

(20) $[\![_{\mathrm{NP}}\textsf{every student}]\!] = [\![_{\mathrm{Det}}\textsf{every}]\!]([\![_{\mathrm{N}}\textsf{student}]\!]) =$
$\lambda P[\mathbf{every}(\lambda z[\textsc{student}(z)], P)]$.

In general, we denote by $\mathcal{R}_{\mathbf{Q}}$ the expression $\lambda Q\lambda P[\mathbf{Q}(Q,P)]$.

We turn now to the interpretation of temporal nouns and temporal noun phrases. In order to explain the semantics for temporal nouns proposed in this paper, we draw attention to a difficulty that

[6] The Russellian interpretation of **the** can be easily replaced by more current approach to definiteness, based on anaphoric reference and familiarity. We keep to the Russellian view only for uniformity of presentation.

arises when quantification is restricted to contexts created by preposition phrases. For instance, consider the sentences:

(21) Mary attended every meeting on Monday

(22) On Monday, Mary attended every meeting

Here, the most natural reading of sentence (21), and the only possible reading of sentence (22), restricts universal quantification to the meetings occurring on Mondays. Moreover, this restriction of quantification is not confined to subcategorized verb-arguments, but also applies to complements of other TPPs. For example, in the equivalent sentences

(23) Mary telephoned John during every meeting on Monday

(24) Mary telephoned John on Monday during every meeting,

the meetings in question are taken to be those on Monday, not all meetings in the time of interest.

To accommodate this phenomenon, we complicate the meanings of temporal nouns—henceforth TNs. We provisionally take the meaning of meeting to be a relation holding between meetings and a time-interval within which those meetings are constrained to occur, thus:

(25) $[\![_{\mathrm{TN}}\textsf{meeting}]\!] = \lambda x \lambda I[\textsc{meeting}(x) \wedge \mathrm{time}(x) \subseteq I]$.

(We slightly revise this proposal below.) Here, the variable I, of type $\mathbf{i}$, represents the temporal context with respect to which the noun meeting is to be interpreted, and $\mathrm{time}(x)$ is a function of type $(\mathbf{e}, \mathbf{i})$, denoting the occurrence time-interval of the event x. How, exactly, this mechanism allows the meanings of sentences such as (23) and (24) to be computed is detailed in section 4. For the present, we merely note that, on this (provisional) proposal, a meaning-assignment to a TN is of the form:

(26) $[\![_{\mathrm{TN}}\textsf{n}]\!] = \lambda x \lambda I[\textsc{n}(x) \wedge \mathrm{time}(x) \subseteq I]$.

One or two simplifications will make the presentation in the sequel easier to follow. First, we restrict verb-complements to contain only non-temporal nouns, with temporal nouns confined to the complements of TPPs. (This restriction rules out sentences (21) and (22), but not sentences (23) and (24)). Second, having restricted temporal nouns to occur within TPPs, we might as well assume the first argument of a TPP to have type $\mathbf{i}$ rather than $\mathbf{e}$, since the temporal preposition will effect such a coercion anyway (thus: during the meeting means during the time of the meeting). Hence, for example, we henceforth take the meaning of meeting to be given not by (25), but rather:

(27) $[\![_{\mathrm{TN}}\textsf{meeting}]\!] = \lambda J \lambda I[\textsc{meeting}(J) \wedge J \subseteq I]$.

We stress that this second move is really a technical device to increase the readability of formulae. We certainly do not mean to claim that meeting denotes a set of time-intervals.

Similarly, calendrical TNs are interpreted directly over time-intervals, though again with an additional argument to handle the temporal-context phenomenon alluded to above. For example, we have

(28) $[\![_{\mathrm{TN}}\textsf{Monday}]\!] = \lambda J \lambda I[\textsc{monday}(J) \wedge J \subseteq I]$.

More generally, a meaning-assignment to a TN will no longer be of the form (26), but rather:

(29) $[\![_{\mathrm{TN}}\textsf{n}]\!] = \lambda J \lambda I[\textsc{n}(J) \wedge J \subseteq I]$.

Having settled upon a general form for the meanings of TNs, we now turn to temporal noun phrases—henceforth, TNPs. We propose that the meaning of a TNPs is obtained by *pseudo-applying* (using $(_1 \ldots)_1$) the meaning of its determiner to the meaning of the corresponding TN. For example, on this proposal, the meaning of every Monday is

(30) $$\begin{aligned}[\![_{\mathrm{TNP}}\textsf{every Monday}]\!] &= [\![_{\mathrm{Det}}\textsf{every}]\!](_1[\![_{\mathrm{TN}}\textsf{Monday}]\!])_1 \\ &= \lambda P \lambda I[\mathbf{every}(\lambda J[\textsc{monday}(J) \wedge J \subseteq I], P)].\end{aligned}$$

We can think of this as the property of being a set of intervals containing all Mondays within a given interval. Similarly, the meaning of a/the meeting is

(31) $[\![_{\mathrm{TNP}}\textsf{a/the meeting}]\!] = \lambda P \lambda I[\mathbf{a/the}(\lambda J[\textsc{meeting}(J) \wedge J \subseteq I], P)]$.

We call these TNP-meanings *temporal generalized quantifiers* (TGQs). Formally, a TGQ is a function of type $((\mathbf{i}, \mathbf{t}) \times \mathbf{i}, \mathbf{t})$. Thus, we propose that a meaning-assignment to a TNP have the form:

(32) $[\![_{\mathrm{TNP}}\textsf{qn}]\!] = [\![_{\mathrm{Det}}\textsf{q}]\!]({}_1[\![_{\mathrm{TN}}\textsf{n}]\!])_1 = \lambda P \lambda I[\mathbf{Q}(\lambda J[\textsc{n}(J) \wedge J \subseteq I], P)]$.

The utility of such meaning-assignments will become clear as the paper proceeds.

One final caution before we proceed. The restriction of noun phrase quantification by preposition phrases elsewhere in the sentence, as illustrated by sentences (21)–(24), is certainly not confined to the temporal dimension. Spatial and pseudo-spatial preposition phrases display similar behaviour. Thus, for example,

(33) Every element is nonzero in the third column of the matrix

does not assert that every element anywhere is nonzero, and moreover, is so in the third row of the matrix, but rather, that every element *which is in the third row of the matrix* is nonzero (period). In our opinion, this phenomenon makes the account of non-temporal nouns proposed above ultimately untenable, because it is unable to account for the kinds of prepositional quantification-restriction in sentences such as (33). However, for the sake of perspicuity, we concentrate in this paper exclusively on quantification-restriction due to *temporal* PPs. We contend that non-temporal quantification-restriction can be treated similarly, but we make no attempt here to justify this contention.

3.2 The meaning of verb phrases

We view verbs here as expressing relations among two collections of arguments, $v(\overline{x})(\overline{z})$. The arguments in $\overline{x}$ are the "usual" arguments, for which the verb subcategorizes in the syntax, having the usual grammatical functions of subject, direct object, oblique object, etc. The arguments $\overline{z}$ represent *indexical* arguments, such as time, space etc. These arguments are represented by variables that are λ-bound in the lexical meaning of a verb, to be further restricted by suitable PPs (and in other ways). Here we confine our attention to *temporal* indexing.

An important lexical property of verbs that interacts closely with TPPs is their *aspectual class*, an issue extensively studied in the literature. To simplify the presentation here, we assume a very coarse distinction between sentences denoting *events* and those denoting *states*. Basically, events correspond to predicates which hold of intervals, but never of any overlapping intervals; whereas states correspond to predicates which hold at time points. To say that a state holds over an interval is to say that it holds over all time points in that interval. (Thus, if a state holds over an interval, it necessarily holds over all subintervals thereof.) In terms of the traditional Vendler classification of *Aktionsarten*, our events correspond to the traditional categories of accomplishments and achievments, and states correspond to the traditional categories of states and activities. Thus, we are using *state* in a non-standard way.[7] The strategy of treating events and states differently in roughly this respect was argued for by Herweg in [12]. We identify time points with intervals of the form $[t, t]$. Whether a sentence is state-reporting or event-reporting depends on not only on the main verb, but also on the subject and verb-complements (see, for example, Krifka [18], Verkuyl [27], White [28]). For our purposes, however, we may assume aspectual class to depend only on the verb, so that some verbs, such as, e.g. kiss, are *eventive*, while others, such as, e.g., sleep, are *stative* (in our terminology). We concentrate first on eventive verbs,

[7] There are many presentations of the Vendler classification; see, e.g. ter Meulen [25]. Other, more complex accounts can be found in, e.g. Moens and Steedman [21], Smith [23] or ter Meulen [26].

deferring the derivation of the meanings of sentences with stative verbs, and their TPP-modification, to section 5.

The meanings of eventive verbs take two temporal arguments: one representing a temporal context and the other, the actual interval of occurrence of the event within this context. On this view, transitive verbs are assigned type $(\mathbf{e},(\mathbf{e},(\mathbf{i},(\mathbf{i},\mathbf{t}))))$, and intransitive verbs are assigned type $(\mathbf{e},(\mathbf{i},(\mathbf{i},\mathbf{t})))$. We thus end up with the following general meaning-forms for transitive, respectively, intransitive verbs:

(34) $[\![_{\mathrm{V_t}}\mathsf{v}]\!] = \lambda y\lambda x\lambda J\lambda I[\mathrm{V}(x,y)(J) \wedge J \subseteq I]$.

(35) $[\![_{\mathrm{V_i}}\mathsf{v}]\!] = \lambda x\lambda J\lambda I[\mathrm{V}(x)(J) \wedge J \subseteq I]$.

For example, the lexical meaning of the transitive verb kiss is

(36) $[\![_{\mathrm{V_t}}\mathsf{kiss}]\!] = \lambda y\lambda x\lambda J\lambda I[\textsc{kiss}(x,y)(J) \wedge J \subseteq I]$.

The intuitive interpretation of (36) is a relation holding between y, x, J and I just in case x kisses y over a subinterval J of some temporal context I. Note that the IL relational constant KISS itself is of type $((\mathbf{e}\times\mathbf{e}),(\mathbf{i},\mathbf{t}))$, i.e., it depends only on one temporal argument, corresponding, intuitively, to the occurrence time of the kiss. Similarly, the lexical meaning of the intransitive verb fail is

(37) $[\![_{\mathrm{V_i}}\mathsf{fail}]\!] = \lambda x\lambda J\lambda I[\textsc{fail}(x)(J) \wedge J \subseteq I]$.

The meaning of a VP headed by a transitive verb is obtained by pseudo-applying (using $(_1 \ldots)_1$) the meaning of the object to the meaning of the verb. This produces a meaning of the form $\lambda x\lambda J\lambda I[\mathrm{V}(x)(J) \wedge J \subseteq I]$, which is of the same type as the meaning of an intransitive verb. For example, for the VP kissed John, taking the meaning of John to be $\lambda P[P(\textsc{john})]$, we get

(38) $$\begin{aligned}[\![_{\mathrm{VP}}\mathsf{kissed\ John}]\!] &= [\![_{\mathrm{NP}}\mathsf{John}]\!](_1[\![_{\mathrm{V}}\mathsf{kissed}]\!])_1\\ &= \lambda x\lambda J\lambda I[\textsc{kiss}(x,\textsc{john})(J) \wedge J \subseteq I].\end{aligned}$$

Note that, for intransitive verbs v, $[\![_{\mathrm{V_i}}\mathsf{v}]\!] = [\![_{\mathrm{VP}}\mathsf{v}]\!]$. Note also the similarity in form between $[\![_{\mathrm{TN}}...]\!]$, and $[\![_{\mathrm{VP}}...]\!]$, differing only in the presence of a subject argument x. This similarity is strongly exploited later.

Next, consider VPs with subcategorized quantified verb-arguments (but still without temporal modification), such as

(39) interviewed a/the student.

By the above considerations, the meaning of the transitive verb interviewed is

(40) $[\![_{\mathrm{V_t}}\mathsf{interviewed}]\!] = \lambda y\lambda x\lambda J\lambda I[\textsc{interview}(x,y)(J) \wedge J \subseteq I]$.

The respective meanings of the NPs a/the student are

(41) $[\![_{\mathrm{NP}}\mathsf{a/the\ student}]\!] = \lambda P[\mathbf{a/the}(\lambda z[\textsc{student}(z)], P)]$.

Pseudo-applying the object meaning to the verb meaning yields

(42) $$\begin{aligned}&[\![_{\mathrm{VP}}\mathsf{interviewed\ a/the\ student}]\!] =\\ &[\![_{\mathrm{NP}}\mathsf{a/the\ student}]\!](_1[\![_{\mathrm{V}}\mathsf{interviewed}]\!])_1 =\\ &\lambda x\lambda J\lambda I[\mathbf{a/the}(\ \lambda y_1[\textsc{student}(y_1)],\\ &\qquad\qquad \lambda y_2[\textsc{interview}(x,y_2)(J) \wedge J \subseteq I])].\end{aligned}$$

3.3 The meaning of sentences

Sentences have two meanings: *determined* meanings and *undetermined* meanings. The nature of this distinction, and the need to recognize it, will become clear below. We reserve the notation $[\![_{\mathrm{S}}...]\!]$ for undetermined meanings and $[\![_{\hat{\mathrm{S}}}...]\!]$ for determined meanings.

Consider the simple sentence:

(43) Mary kissed John

consisting of the subject $[_{\mathrm{NP}}$Mary$]$ and verb phrase $[_{\mathrm{VP}}$ kissed John$]$. The undetermined sentence meaning is obtained by pseudo-applying the subject meaning to the meaning of the VP, thus:

(44) $[\![_{\mathrm{S}}\text{Mary kissed John}]\!] = [\![_{\mathrm{NP}}\text{Mary}]\!](_1[\![_{\mathrm{VP}}\text{kissed John}]\!])_1 =$
$\lambda J \lambda I[\textsc{kiss}(\textsc{mary}, \textsc{john})(J) \wedge J \subseteq I]$.

In other words, the sentence-subject is treated, on this approach, exactly like like the verb-complements. Generalizing, we note that the form of an S-meaning assignment is:

(45) $[\![_{\mathrm{S}}\text{s}]\!] = \lambda J \lambda I[\textsc{s}(J) \wedge J \subseteq I)]$.

The reader should compare this form with the form (29) of meaning-assignments to TNs.

We now present the transformation which we refer to as *(temporal) determination*, which introduces a quantification on the occurrence time. In general, this transformation is applied to an undetermined sentence meaning to yield determined sentence meaning. Determination is achieved by pseudo-applying (using $(_1 ...)_1$) a *schematic* quantifier $\mathcal{R}_{\mathbf{Q}}$ to the sentence meaning, the identity of which depends on whether the sentence forms a main clause or is the complement of a TP. For main-clause meanings of sentences, we will always take $\mathbf{Q} = \mathbf{a}$. (We will encounter other cases in section 4.6.) Determining the S-meaning (44), where $\mathbf{Q}$ is taken as $\mathbf{a}$, yields:

(46) $[\![_{\hat{\mathrm{S}}}\text{Mary kissed John}]\!] =$
$\mathcal{R}_{\mathbf{a}}(_1[\![_{\mathrm{S}}\text{Mary kissed John}]\!])_1 =$
$\mathcal{R}_{\mathbf{a}}(_1\lambda J \lambda I[\textsc{kiss}(\textsc{mary}, \textsc{john})(J) \wedge J \subseteq I])_1 =$
$\lambda P \lambda I[\mathbf{a}(\lambda J[\textsc{kiss}(\textsc{mary}, \textsc{john})(J) \wedge J \subseteq I], P)]$.

For the sentence John failed, the same transformation yields

(47) $[\![_{\hat{\mathrm{S}}}\text{John failed}]\!] = \mathcal{R}_{\mathbf{a}}(_1[\![_{\mathrm{S}}\text{John failed}]\!])_1 =$
$\lambda P \lambda I[\mathbf{a}(\lambda J[\textsc{fail}(\textsc{john})(J) \wedge J \subseteq I], P)]$.

Generalizing, we note that the form of an Ŝ-meaning assignment is:

(48) $[\![_{\hat{\mathrm{S}}}\text{s}]\!] = \mathcal{R}_{\mathbf{Q}}(_1[\![_{\mathrm{S}}\text{s}]\!])_1 = \lambda P \lambda I[\mathbf{Q}(\lambda J[\textsc{s}(J) \wedge J \subseteq I], P)]$.

The reader should compare this form with the form (32) of meaning-assignments to TNPs. The introduction of the quantifier $\mathbf{Q}$ through temporal determination is analogous to the quantification introduced by the transition from an TN to a TNP. Determination of sentence-meanings produces a TGQ in the same way as applying a determiner to the meaning of a TN. The difference is that, in English, (T)NPs can have an overt, syntactically realized determiner, whereas determination of sentence-meanings is not—or at least arguably not—syntactically realized.

In order to get the intended meaning of (43), a finalization is needed, by which P is replaced by $\lambda J[\textsc{true}]$ ($\textsc{true}$ being the property of intervals holding for every interval). The result is

(49) $\lambda I[\mathbf{a}(\lambda J[\textsc{kiss}(\textsc{mary}, \textsc{john})(J) \wedge J \subseteq I], \textsc{true})]$,

which can be simplified to

(50) $\lambda I[\exists J[\textsc{kiss}(\textsc{mary}, \textsc{john})(J) \wedge J \subseteq I]]$.

We now turn to assigning meanings to sentences with quantified subjects and verb-complements. Existential or definite quantification is handled straightforwardly. Consider, for example:

(51) Mary interviewed a/the student.

The derivation of the determined meaning of (51) is obtained by subject incorporation of $\lambda P[P(\text{MARY})]$ into the VP meaning (39), and then determination (with $\mathbf{Q} = \mathbf{a}$).

(52) $[\![_{\hat{\mathrm{S}}}\textsf{Mary interviewed a/the student}]\!] =$
$\mathcal{R}_{\mathbf{a}}({}_1[\![_{\mathrm{NP}}\textsf{Mary}]\!]({}_1[\![_{\mathrm{VP}}\textsf{interviewed a/the student}]\!])_1)_1 =$
$\lambda P\lambda I[\mathbf{a}(\lambda J[\mathbf{a/the}(\ \lambda y_1[\text{STUDENT}(y_1)],$
$\lambda y_2[\text{INTERVIEW}(\text{MARY}, y_2)(J) \wedge J \subseteq I])],$
$P)].$

However, universally quantified subjects and verb-complements present a difficulty. Consider

(53) Mary interviewed every student.

In contrast to (51), this sentence has two non-equivalent readings, generated by scope ambiguity between the determination quantifier and the object quantifier. This ambiguity does not arise in (51) because existential quantifiers commute. The first, and more prominent, reading is that, within the toi, several interviewing events (one event per each student) took place, each event with its own, possibly different, occurrence time (depending on the student). This reading occurs when the object quantifier scopes over the determination quantifier. A second, less salient, reading is of a "cumulative event" of interviewing of all the students at the same (occurrence) time within the toi. This reading occurs when the determination quantifier scopes over the object quantifier. The need for this second reading comes from sentences like

(54) The department chairman was astonished when Mary interviewed every student.

The derivation of the secondary meaning proceeds as for sentence (51). The meaning of the NP every student is

(55) $[\![_{\mathrm{NP}}\textsf{every student}]\!] = \lambda P[\mathbf{every}(\lambda z[\text{STUDENT}(z)], P)].$

Combining the object with the verb by pseudo-application yields

(56) $[\![_{\mathrm{VP}}\textsf{interviewed every student}]\!] =$
$[\![_{\mathrm{NP}}\textsf{every student}]\!]({}_1[\![_{\mathrm{V}}\textsf{interviewed}]\!])_1 =$
$\lambda x\lambda J\lambda I[\mathbf{every}(\ \lambda y_1[\text{STUDENT}(y_1)],$
$\lambda y_2[\text{INTERVIEW}(x, y_2)(J) \wedge J \subseteq I])].$

Pseudo-application of the subject-meaning $\lambda P[P(\text{MARY})]$ to (56) yields the undetermined sentence meaning

(57) $[\![_{\mathrm{S}}\textsf{Mary interviewed every student}]\!] =$
$[\![_{\mathrm{NP}}\textsf{Mary}]\!]({}_1[\![_{\mathrm{V}}\textsf{interviewed every student}]\!])_1 =$
$\lambda J\lambda I[\mathbf{every}(\ \lambda y_1[\text{STUDENT}(y_1)],$
$\lambda y_2[\text{INTERVIEW}(\text{MARY}, y_2)(J) \wedge J \subseteq I])].$

And determination by pseudo-applying $\mathcal{R}_{\mathbf{a}}$ to (57) yields

(58) $[\![_{\hat{\mathrm{S}}}\textsf{Mary interviewed every student}]\!]_2 =$
$\lambda P\lambda I[\mathbf{a}(\lambda J[\mathbf{every}(\lambda y_1[\text{STUDENT}(y_1)],$
$\lambda y_2[\text{INTERVIEW}(\text{MARY}, y_2)(J) \wedge J \subseteq I])],$
$P)].$

To generate the primary reading of (53), we resort to the Montagovian substitution procedure that first produces an undetermined sentence meaning using a vacuous object it (in the form of a free variable), and then substitutes the "real" quantified object. We ignore here Montague's strict numbering of pronouns and their corresponding free variables, and just assume that whenever needed, a fresh free variable is supplied. The meaning of it is the GQ

(59) $[\![_{\mathrm{NP}}\textsf{it}]\!] = \lambda P[P(u)],$

where u is a fresh free variable. Pseudo-applying $[\![_{\mathrm{NP}}\textsf{it}]\!]$ to $[\![_{\mathrm{V_t}}\textsf{interviewed}]\!]$ produces

(60) $[\![_{\mathrm{VP-gap}}\textsf{interviewed it}]\!] =$
$\lambda P[P(u)]({}_1\lambda y\lambda x\lambda J\lambda I[\textsc{interview}(x,y)(J)\wedge J\subseteq I])_1 =$
$\lambda x\lambda J\lambda I[\textsc{interview}(x,u)(J)\wedge J\subseteq I]$

as the meaning of the "gappy"-VP interviewed it. Note that (60) still has the free variable u. Then, $\lambda P[P(\textsc{mary})]$ is pseudo-applied to (60), producing the undetermined sentence meaning

(61) $[\![_{\mathrm{S-gap}}\textsf{Mary interviewed it}]\!] =$
$\lambda P[P(\textsc{mary})]({}_1\lambda x\lambda J\lambda I[\textsc{interview}(x,u)(J)\wedge J\subseteq I])_1 =$
$\lambda J\lambda I[\textsc{interview}(\textsc{mary},u)(J)\wedge J\subseteq I]$.

Next, we determine (60) by pseudo-applying $\mathcal{R}_{\mathbf{a}}$, obtaining

(62) $[\![_{\hat{\mathrm{S}}-\mathrm{gap}}\textsf{Mary interviewed it}]\!] =$
$\lambda P\lambda I[\mathbf{a}(\lambda J[\textsc{interview}(\textsc{mary},u)(J)\wedge J\subseteq I],P)]$.

Again, note that (62) has a free variable, u. Now we can use Montague's substitutional rule and pseudo-apply the meaning of every student to the u-abstraction of (62), to obtain

(63) $[\![_{\hat{\mathrm{S}}}\textsf{Mary interviewed every student}]\!]_1 =$
$[\![_{\mathrm{NP}}\textsf{every student}]\!]({}_1\lambda u[[\![_{\hat{\mathrm{S}}-\mathrm{gap}}\textsf{Mary interviewed it}]\!]])_1 =$
$\lambda P\lambda I[\mathbf{every}(\ \lambda y_1[\textsc{student}(y_1)],$
$\quad\lambda y_2[\mathbf{a}(\lambda J[\textsc{interview}(\textsc{mary},y_2)(J)\wedge J\subseteq I],$
$\quad\quad P)])]$.

This is the required primary reading of (53), where the existential quantifier on the occurrence time of individual interview-events falls within the scope of the universal quantifier on students.

To summarize the above derivations,

(64) $[\![_{\hat{\mathrm{S}}}\textsf{Mary interviewed every student}]\!]_1 =$
$[\![_{\mathrm{NP}}\textsf{every student}]\!]({}_1\lambda u[\mathcal{R}_{\mathbf{a}}({}_1[\![_{\mathrm{NP}}\textsf{Mary}]\!]({}_1[\![_{\mathrm{NP}}\textsf{it}]\!]({}_1[\![_{\mathrm{V_t}}\textsf{interviewed}]\!])_1)_1)_1])_1$.

(65) $[\![_{\hat{\mathrm{S}}}\textsf{Mary interviewed every student}]\!]_2 =$
$\mathcal{R}_{\mathbf{a}}({}_1[\![_{\mathrm{NP}}\textsf{Mary}]\!]({}_1[\![_{\mathrm{NP}}\textsf{every student}]\!]({}_1[\![_{\mathrm{V_t}}\textsf{interviewed}]\!])_1)_1)_1$

When the subject is quantified, we again have an ambiguity due to the determination quantification. Thus,

(66) Every student failed

has also two readings. The primary reading reports the occurence of a collection of failing-events, one per student, each event having its own, possibly different, occurrence time (subintervals of the toi). The secondary meaning is of a collective event of (simultaneous) failure of all students (e.g., in an examination), with one occurence time only (subinterval of the toi). The secondary meaning is needed for sentences like

(67) The professor was upset when every student failed.

A similar ambiguity has been pointed out in [14]. Routine calculation yields:

(68) $[\![_{\hat{\mathrm{S}}}\textsf{Every student failed}]\!]_1 =$
$[\![_{\mathrm{NP}}\textsf{every student}]\!]({}_1\lambda u[\mathcal{R}_{\mathbf{a}}({}_1[\![_{\mathrm{S-gap}}\textsf{it failed}]\!])_1])_1 =$
$\lambda P\lambda I[\mathbf{every}(\lambda x_1[\textsc{student}(x_1)],$
$\quad\lambda x_2[\mathbf{a}(\lambda J[\textsc{fail}(x_2)(J)\wedge J\subseteq I],$
$\quad\quad P)])]$.

(69) $[\![_{\hat{\mathrm{S}}}\textsf{Every student failed}]\!]_2 =$
$\mathcal{R}_{\mathbf{a}}({}_1[\![_{\mathrm{S}}\textsf{Every student failed}]\!])_1 =$
$\lambda P\lambda I[\mathbf{a}(\lambda J[\mathbf{every}(\lambda x_1[\textsc{student}(x_1)],$

$\lambda x_2[\text{FAIL}(x_2)(J) \wedge J \subseteq I])],$
$P)].$

If more than one verb complement is quantified, the usual scope ambiguity is present. Thus,

(70) A professor interviewed every student

has the following three derivations. One reading is given by

(71) $[\![_{\hat{S}}\text{A professor interviewed every student}]\!]_1 =$
$[\![_{NP}\text{A professor}]\!](_1\lambda u[\mathcal{R}_{\mathbf{a}}(_1[\![_{NP}\text{it}]\!](_1$
$[\![_{NP}\text{every student}]\!](_1[\![_{V_t}\text{interview}]\!])_1)_1)_1])_1 =$
$\lambda P \lambda I[\mathbf{a}(\lambda x_1[\text{PROFESSOR}(x_1)],$
$\lambda x_2[\mathbf{a}(\lambda J[\mathbf{every}(\lambda y_1[\text{STUDENT}(y_1)],$
$\lambda y_2[\text{INTERVIEW}(x_2, y_2)(J) \wedge J \subseteq I])],$
$P)])].$

This collective reading means that there is some professor, who interviewed collectively every student (during one occurence time J, a subinterval of the toi). A second reading is given by

(72) $[\![_{S}\text{A professor interviewed every student}]\!]_2 =$
$[\![_{NP}\text{a professor}]\!](_1\lambda v[[\![_{NP}\text{every student}]\!](_1$
$\lambda u[\mathcal{R}_{\mathbf{a}}(_1[\![_{NP}\text{it}]\!]_2(_1[\![_{NP}\text{it}]\!]_1(_1[\![_{V_t}\text{interview}]\!])_1)_1)_1])_1])_1 =$
$\lambda P \lambda I[\mathbf{a}(\lambda x_1[\text{PROFESSOR}(x_1)],$
$\lambda x_2[\mathbf{every}(\lambda y_1[\text{STUDENT}(y_1)],$
$\lambda y_2[\mathbf{a}(\lambda J[\text{INTERVIEW}(x_2, y_2)(J) \wedge J \subseteq I],$
$P)])])].$

This reading means that there is some professor, who interviewed every student separately, at a possibly different occurence time (all subintervals of the toi). Here $[\![\text{it}]\!]_1$ and $[\![\text{it}]\!]_2$ use different free variables, say u and v, respectively. A third reading is given by

(73) $[\![_{S}\text{A professor interviewed every student}]\!]_3 =$
$[\![_{NP}\text{every student}]\!](_1\lambda v[\mathcal{R}_{\mathbf{a}}(_1[\![_{NP}\text{a professor}]\!](_1[\![_{NP}\text{it}]\!]_1(_1[\![_{V_t}\text{interview}]\!])_1)_1)_1])_1 =$
$\lambda P \lambda I[\mathbf{every}(\lambda x_1[\text{STUDENT}(x_1)],$
$\lambda x_2[\mathbf{a}(\lambda J[\mathbf{a}(\lambda y_1[\text{PROFESSOR}(y_1)],$
$\lambda y_2[\text{INTERVIEW}(x_2, y_2)(J) \wedge J \subseteq I])],$
$P)])].$

This reading means that, for every student, there is some professor that interviewed that student at some occurrence time. Summarizing these derivations, we see that there are the following freely-applicable operations used: determination, pseudo-application of subject-meaning and pseudo-application of object-meaning. Applying these operations in any other order than in the three derivations presented above yields a result equivalent to one of the obtained results. We will encounter yet another multitude of such derivations in the next section.

4 Temporal modification by temporal preposition phrases

4.1 Temporal modification of simple sentences

We now turn to sentences with temporal modification by means of TPPs. Here, as before, nouns within TPPs are assumed to be temporal nouns, while nouns in verb-arguments are assumed to be non-temporal nouns. Consider the sentences:

(74) Mary kissed John

(75) Mary kissed John during the meeting

(76) Mary kissed John during the meeting one day

(77) Mary kissed John during the meeting one day in January.

Sentence (74) states that Mary kissed John over some sub-interval of the toi. We agreed in section 3.3 that its (determined) meaning be given by the λ-expression:

(78) $[\![_{\hat{\mathrm{S}}}\text{Mary kissed John}]\!] =$
$\lambda P \lambda I_0[\mathbf{a}(\lambda J_0[\textsc{kiss}(\textsc{mary}, \textsc{john})(J_0) \wedge J_0 \subseteq I_0], P)]$.

The level of indexing on the temporal variables reflects the level of TPP modification, as will become clear soon. Sentence (75) states[8] that there is a unique sub-interval within the toi over which a meeting occurred, and that Mary kissed John over a sub-interval of *that* interval. Hence we should assign (75) the determined meaning:

(79) $[\![_{\hat{\mathrm{S}}}\text{Mary kissed John during the meeting}]\!] =$
$\lambda P \lambda I_1[\mathbf{a}(\lambda J_0[\mathbf{the}(\lambda J_1[\textsc{meeting}(J_1) \wedge J_1 \subseteq I_1],$
$\lambda I_0[\textsc{kiss}(\textsc{mary}, \textsc{john})(J_0) \wedge J_0 \subseteq I_0])],$
$P)]$.

Note the level of indexing: the new toi is I_1, and J_1 coincides with I_0, containing J_0, the actual occurrence time of the kissing event.

Likewise, sentence (76) asserts that, for some day within the toi, a unique meeting occurred on that day, over some sub-interval of which Mary kissed John. So, sentence (76) should be assigned the determined meaning:

(80) $[\![_{\hat{\mathrm{S}}}\text{Mary kissed John during the meeting one day}]\!] =$
$\lambda P \lambda I_2[\mathbf{a}(\lambda J_0[\mathbf{a}(\lambda J_2[\textsc{day}(J_2) \wedge J_2 \subseteq I_2],$
$\lambda I_1[\mathbf{the}(\lambda J_1[\textsc{meeting}(J_1) \wedge J_1 \subseteq I_1],$
$\lambda I_0[\textsc{kiss}(\textsc{mary}, \textsc{john})(J_0) \wedge J_0 \subseteq I_0])])],$
$P)]$.

Although there is no overt temporal preposition in the TPP one day, we have basically the same pattern as before: the determiner contributes the main quantifier, and there is an implicit restriction of further quantification to subintervals of the intervals over which the main quantifier ranges. So, for our purposes, we suppose that there is a covert temporal preposition in the TPP one day, e.g., on, which is not syntactically realized. Finally, by parity of treatment, sentence (77) should be assigned the determined meaning:

(81) $[\![_{\hat{\mathrm{S}}}\text{Mary kissed John during the meeting one day in January}]\!] =$
$\lambda P \lambda I_3[\mathbf{a}(\lambda J_0[\mathbf{the}(\lambda J_3[\textsc{january}(J_3) \wedge J_3 \subseteq I_3],$
$\lambda I_2[\mathbf{a}(\lambda J_2[\textsc{day}(J_2) \wedge J_2 \subseteq I_2],$
$\lambda I_1[\mathbf{the}(\lambda J_1[\textsc{meeting}(J_1) \wedge J_1 \subseteq I_1],$
$\lambda I_0[\textsc{kiss}(\textsc{mary}, \textsc{john})(J_0) \wedge$
$J_0 \subseteq I_0])])])],$
$P)]$.

The reader can check that (81) gives the intuitively correct truth-condition. Again, there is no overt determiner in the TPP in January; but semantically, it is as if a definite article were present—something like: *in the unique January within the toi.* So, for our purposes, we suppose that there is a a covert definite arcticle which is not syntactically realized. An important feature of these derivations is the "pull-out" of the innermost occurrence time J_0 to the top level. This feature will prove crucial in section 4.7.

[8] In this paper, presuppositions will be assimilated to truth-conditions in the obvious (e.g. Russellian) way. This strategy avoids complications irrelevant to the treatment of temporal prepositions.

We now turn to the derivation of these truth-conditions. On the account proposed here, a TPP such as during the meeting contributes to the truth conditions of simple sentences in which it occurs by pseudo-applying (using $(_2 \ldots)_2$) a function to the meaning of the (undetermined) S it qualifies, returning another S-meaning as value. Some readers may be surprised that we pseudo-apply the TPP-meaning to the S-meaning rather than to the VP-meaning, since, syntactically the preposition phrase is most naturally be taken to attach to the verb phrase rather than the whole sentence.[9] Our strategy reflects the fact that quantification in both sentence-subject and verb-complements can sometimes take narrower scope than quantification in TPP-phrases, so that, from a semantic point of view, there is no reason to treat the sentence-subject and verb-complements differently. The precise mechanisms for dealing with scope ambiguities will be explained below, when we consider sentences with quantified subjects and verb-complements.

Specifically, we propose:

(82) $[\![_{\text{TPP}}\textsf{during the meeting}]\!] = \lambda P \lambda I[\mathbf{the}(\lambda J[\textsc{meeting}(J) \wedge J \subseteq I], P)]$.

To see how this function works, we compute (after renaming I and J to I_1, J_1, respectively, so that the index tracks the level of TPP-modification)

(83)
$$
\begin{aligned}
&[\![_{\text{S}}\textsf{Mary kissed John during the meeting}]\!] = \\
&[\![_{\text{TPP}}\textsf{during the meeting}]\!](_2[\![_{\text{S}}\textsf{Mary kissed John}]\!])_2 = \\
&\lambda P \lambda I_1[\mathbf{the}(\lambda J_1[\textsc{meeting}(J_1) \wedge J_1 \subseteq I_1], P)](_2 \\
&\quad \lambda J_0 \lambda I_0[\textsc{kiss}(\textsc{mary}, \textsc{john})(J_0) \wedge J_0 \subseteq I_0])_2 = \\
&\lambda J_0 \lambda I_1[\lambda P[\mathbf{the}(\lambda J_1[\textsc{meeting}(J_1) \wedge J_1 \subseteq I_1], P)](\\
&\qquad\qquad \lambda I_0[\textsc{kiss}(\textsc{mary}, \textsc{john})(J_0) \wedge J_0 \subseteq I_0])] = \\
&\lambda J_0 \lambda I_1[\mathbf{the}(\lambda J_1[\textsc{meeting}(J_1) \wedge J_1 \subseteq I_1], \\
&\qquad\qquad \lambda I_0[\textsc{kiss}(\textsc{mary}, \textsc{john})(J_0) \wedge J_0 \subseteq I_0])]
\end{aligned}
$$

and after determination, the meaning (79) of (75) is obtained. Generalizing, we prepose that TPP-meanings be taken to be TGQs, just like TNP-meanings and $\hat{\text{S}}$-meanings. We defer the derivation of these TPP-meanings until section 4.2.

We now proceed to the TPP one day (which we may if we wish take to have a covert temporal preposition). We propose the meaning:

(84) $[\![_{\text{TPP}}\textsf{one day}]\!] = \lambda P \lambda I[\mathbf{a}(\lambda J[\textsc{day}(J) \wedge J \subseteq I], P)]$.

We now continue as before, pseudo-applying this TPP-meaning to the S-meaning (83). We get (after renaming I and J to I_2, J_2, respectively)

(85)
$$
\begin{aligned}
&[\![_{\text{S}}\textsf{Mary kissed John during the meeting one day}]\!] = \\
&[\![_{\text{TPP}}\textsf{one day}]\!](_2[\![_{\text{S}}\textsf{Mary kissed John during the meeting}]\!])_2 = \\
&\lambda P \lambda I_2[\mathbf{a}(\lambda J_2[\textsc{day}(J_2) \wedge J_2 \subseteq I_2], P)](_2 \\
&\quad \lambda J_0 \lambda I_1[\mathbf{the}(\lambda J_1[\textsc{meeting}(J_1) \wedge J_1 \subseteq I_1], \\
&\qquad\qquad \lambda I_0[\textsc{kiss}(\textsc{mary}, \textsc{john})(J_0) \wedge J_0 \subseteq I_0])])_2 = \\
&\lambda J_0 \lambda I_2[\mathbf{a}(\lambda J_2[\textsc{day}(J_2) \wedge J_2 \subseteq I_2] \\
&\qquad \lambda I_1[\mathbf{the}(\lambda J_1[\textsc{meeting}(J_1) \wedge J_1 \subseteq I_1], \\
&\qquad\qquad \lambda I_0[\textsc{kiss}(\textsc{mary}, \textsc{john})(J_0) \wedge J_0 \subseteq I_0])])]
\end{aligned}
$$

which, after determination , yields the correct meaning (80) for (76).

Similarly, by interpreting in January as having a covert quantifier the, i.e.,

(86) $[\![_{\text{TPP}}\textsf{in January}]\!] = \lambda P \lambda I[\mathbf{the}(\lambda J[\textsc{January}(J) \wedge J \subseteq I], P)]$

and pseudo-applying it to the S-meaning (85), we obtain, after determination, the correct meaning (81).

[9]For a discussion of the effect of PP-attachment on truth-conditions, see Hitzemann [15].

In dealing with sentences (75)–(77), we pseudo-applied the TPP-meanings to an S-meaning, and only then applied determination to yield the final Ŝ-meaning. But this policy fails for sentences with universal quantification within a TPP, such as

(87) Mary kissed John every day.

Assuming, by analogy with (84),

(88) $[\![_{\mathrm{TPP}}\text{every day}]\!] = \lambda P \lambda I[\mathbf{every}(\lambda J[\textsc{day}(J) \wedge J \subseteq I], P)]$,

and proceeding as before, we get the wrong meaning, namely:

(89) $(*)\ [\![_{\hat{\mathrm{S}}}\text{Mary kissed John every day}]\!] =$
$$\lambda P \lambda I_1[\mathbf{a}(\lambda J_0[\mathbf{every}(\lambda J_1[\textsc{day}(J_1) \wedge J_1 \subseteq I_1], \lambda I_0[\textsc{kiss}(\textsc{mary}, \textsc{john})(J_0) \wedge J_0 \subseteq I_0])], P)].$$

This reading—assuming the usual finalization by putting $P = \lambda J[\textsc{true}]$—implies that there is an interval J_0, such that every day contains J_0. This is a degenerate reading, because it is automatically false if there is more than one day within the toi.

To get the right meaning for (87), the TPP-quantifier must scope higher than the determination quantifier. Accordingly, we propose that $[\![_{\mathrm{TPP}}\text{every day}]\!]$ be pseudo-applied to the *determined* meaning, (78), to get

(90) $[\![_{\hat{\mathrm{S}}}\text{Mary kissed John every day}]\!] =$
$$[\![_{\mathrm{TPP}}\text{every day}]\!](_2[\![_{\hat{\mathrm{S}}}\text{Mary kissed John}]\!])_2 =$$
$$\lambda P' \lambda I_1[\mathbf{every}(\lambda J_1[\textsc{day}(J_1) \wedge J_1 \subseteq I_1], P')(_2\ \lambda P \lambda I_0[\mathbf{a}(\lambda J_0[\textsc{kiss}(\textsc{mary}, \textsc{john})(J_0) \wedge J_0 \subseteq I_0], P)]])_2 =$$
$$\lambda P \lambda I_1[\mathbf{every}(\lambda J_1[\textsc{day}(J_1) \wedge J_1 \subseteq I_1], \lambda I_0[\mathbf{a}(\lambda J_0[\textsc{kiss}(\textsc{mary}, \textsc{john})(J_0) \wedge J_0 \subseteq I_0], P)])].$$

Of course, having obtained (90), we can proceed in the normal way to obtain, e.g.

(91) $[\![_{\hat{\mathrm{S}}}\text{Mary kissed John every day in January}]\!] =$
$$[\![_{\mathrm{TPP}}\text{in January}]\!](_2[\![_{\hat{\mathrm{S}}}\text{Mary kissed John every day}]\!])_2 =$$
$$\lambda P \lambda I_2[\mathbf{the}(\lambda J_2[\textsc{january}(J_2) \wedge J_2 \subseteq I_2], \lambda I_1[\mathbf{every}(\lambda J_1[\textsc{day}(J_1) \wedge J_1 \subseteq I_1], \lambda I_0[\mathbf{a}(\lambda J_0[\textsc{kiss}(\textsc{mary}, \textsc{john})(J_0) \wedge J_0 \subseteq I_0], P)])])].$$

Notice how the correct restriction on the universal quantification in every day to the days in January is automatic on this account.

We could have employed the derivation strategy of (90)—i.e. pseudo-applying the TPP-meaning to the Ŝ-meaning—on sentence (75). If so, we would have obtained:

(92) $[\![_{\hat{\mathrm{S}}}\text{Mary kissed John during the meeting}]\!] =$
$$[\![_{\mathrm{TPP}}\text{during the meeting}]\!](_2[\![_{\hat{\mathrm{S}}}\text{Mary kissed John}]\!])_2 =$$
$$\lambda P \lambda I_2[\mathbf{the}(\lambda J_1[\textsc{meeting}(J_1) \wedge J_1 \subseteq I_1], \lambda I_0[\mathbf{a}(\lambda J_0[\textsc{kiss}(\textsc{mary}, \textsc{john})(J_0) \wedge J_0 \subseteq I_0], P)])]$$

which is equivalent to (80). That is, for sentence (75), we can pseudo-apply the TPP *either* before *or* after temporal determination.

Generalizing, TPPs with universally-quantified complements must be allowed to pseudo-apply *after* determination in order to produce the correct quantifier-scoping; TPPs with existentially or definitely quantified complements, by contrast, may be pseudo-applied either before or after determination, because the quantifiers involved commute. The reader may at this stage wonder why we then allow TPPs to pseudo-apply before determination at all; the answer will emerge when we consider TPPs whose complements are themselves modified by TPPs. For the present, we simply decree that TPP-meanings may be pseudo-applied before or after determination, and we assume that we have a method for filtering out degenerate meanings such as (89). We remark in passing that, since S- and Ŝ-meanings are logically of different types, allowing the meanings of preposition phrases to be pseudo-applied to both types of meanings amounts to a sort of polymorphism. That this is possible at all is implicit in the definition of psuedo-application in (13), which imposes no restrictions on the types of the x_i for $i > 1$.

When several TPPs modify a single verb phrase, the order in which their meanings are combined is constrained by commonsense knowledge rather than lexical order. For example, we have

(93) $[\![_{\hat{S}}\textsf{Mary kissed John one day during the meeting}]\!] =$
$$\begin{array}{l}\lambda P\lambda I_2[\mathbf{a}(\lambda J_0[\mathbf{a}(\lambda J_2[\textsc{day}(J_2)\wedge J_2 \subseteq I_2],\\ \qquad\qquad \lambda I_1[\mathbf{the}(\lambda J_1[\textsc{meeting}(J_1)\wedge J_1 \subseteq I_1],\\ \qquad\qquad\qquad \lambda I_0[\textsc{kiss}(\textsc{mary},\textsc{john})(J_0)\wedge J_0 \subseteq I_0])])],\\ \qquad P)],\end{array}$$

that is, the same truth-condition as (80). The preference for this order arises merely from the assumption that meetings fit into days and not the other way 'round. Of course, if the meetings in question last several days, then we would have:

(94) $[\![_{\hat{S}}\textsf{Mary kissed John one day during the meeting}]\!] =$
$[\![_{\hat{S}}\textsf{Mary kissed John during the meeting one day}]\!] =$
$$\begin{array}{l}\lambda P\lambda I_2[\mathbf{a}(\lambda J_0[\mathbf{the}(\lambda J_2[\textsc{meeting}(J_2)\wedge J_2 \subseteq I_2],\\ \qquad\qquad \lambda I_1[\mathbf{a}(\lambda J_1[\textsc{day}(J_1)\wedge J_1 \subseteq I_1],\\ \qquad\qquad\qquad \lambda I_0[\textsc{kiss}(\textsc{mary},\textsc{john})(J_0)\wedge J_0 \subseteq I_0])])],\\ \qquad P)].\end{array}$$

And if it was unclear whether meetings fitted into days or vice versa, both meanings would be possible. In the sequel we assume that all orderings of TPPs modifying a single phrase are possible, with commonsense and calendrical knowledge determining scoping. Of course, this assumption is certainly a simplification, since there is a clear preference to order TPPs from 'small' to 'large', and totally scrambled orders such as every day in January one week seem unacceptable. However, we have nothing more to add about this complication.

The most important lesson of this section is the crucial role played by the double-indexing of temporal nouns combined with the presence of the $\subseteq$-relation. It is this feature that is responsible for the correct handling of sentences with multiple TPPs. As we have seen, the TPPs must form a cascade, with the quantification in each TPP restricted to the intervals set up by the previous TPP. In this respect, we claim, our account is an improvement on that of Dowty [7], pp. 328 ff. Although Dowty only sketches an account of how his proposed semantics might be extended to deal with multiple TPPs, it is clear that he requires the time within which the reported event is constrained to occur to satisfy a *conjunction* of conditions—one imposed by each TPP. But this is not the way TPPs combine. It is instructive in this regard to consider the only example Dowty gives:

(95) I first met John Smith at two o' clock in the afternoon on a Thursday in the first week of June in 1942.

In *this* example, the time of meeting is indeed one which is (i) at a 2 o'clock in the afternoon, (ii) on a Thursday, (iii) in the first week of June and (iv) in 1942. But if we consider instead the universally quantified example (91), then it no longer makes sense to regard the two TPPs as conjuncts: the quantification in the first TPP is limited to the interval set up by the second.

One final remark concerning the strategy adopted here. Intuitively, the TP during seems to denote some notion of containment within the intervals picked out by its complement (cf. before and after). So it is counterintuitive that, in our proposed meaning

(96) $[\![_{\mathrm{TPP}}\text{during every meeting}]\!] = \lambda P\lambda I[\mathbf{every}(\lambda J[\textsc{meeting}(J)\wedge J \subseteq I], P)]$,

no such relation of containment is present. (True, there is an occurrence of the $\subseteq$-relation; but it indicates the containment of the meeting in some larger temporal context, and anyway is contributed by the TNP every meeting, not by the TP during.) How, then did we manage to get the correct truth-conditions for sentences involving TPPs, such as (75)–(77)?

The answer is that the relevant relation of containment is provided by the sentence (modified or unmodified) to which the relevant TPP is applied, which already constrains the occurrence times of the events they pick out to be sub-intervals of some temporal context, represented by the variable I. Any TPPs which modify this sentence need only bind the temporal context variable I in a suitable quantifying function; this is precisely what meanings such as (96) do. The considerable advantages of taking the underlying sentence meaning to be relational will not emerge until we consider TPPs with modified sentential complements in section 4.7. Having made that decision, however, there is no need for the prepositions considered above to contribute any further notion of containment.

4.2 Deriving the meanings of TPPs

The TPPs considered so far consist of a temporal preposition and a TNP, where the preposition or the determiner of the TNP may fail to be syntactically realized. We propose that the meaning of a TPP be obtained by applying (using ordinary function-application) the meaning of the preposition to the meaning of its complement. This proposal leads to the following meaning for during:

(97) $[\![_{\mathrm{TP}}\text{during}]\!] = \lambda\mathcal{P}[\mathcal{P}]$.

In other words, the semantic contribution of during is, on this proposal, nothing at all: during denotes the identity function! Although counterintuitive, however, our proposed meaning gives correct truth-conditions for sentences involving during-phrases. To see this, note that the meaning we proposed for $[_{\mathrm{TPP}}\text{during the meeting}]$ in (82) is identical to the meaning we proposed for $[_{\mathrm{TNP}}\text{the meeting}]$ in (31). The derivation of (82) proceeds as follows:

(98) $[\![_{\mathrm{TPP}}\text{during the meeting}]\!] = [\![_{\mathrm{TP}}\text{during}]\!]([\![_{\mathrm{NP}}\text{the meeting}]\!]) =$
$[\![_{\mathrm{NP}}\text{the meeting}]\!] = \lambda P\lambda I[\mathbf{the}(\lambda J[\textsc{meeting}(J) \wedge J \subseteq I], P)]$.

The reader can check that during a meeting, during every meeting etc. all receive the correct truth-conditions on this account. In particular, during does not need to contribute any relation of containment. As we pointed out above, that relation is, for reasons to be given in section 4.7, already implicit in the meaning assigned to the unmodified sentence.

It might be objected that our account incorrectly implies that during can be omitted:

(99) * Mary kissed John the meeting.

Remember however that, in taking the meaning of meeting to be a relation between two *time-intervals*, we are already assuming (as a simplifying measure) a type-coercion from (25) to (27). And it seems reasonable to suppose that the main force of during is to provide this coercion. So, on a more realistic semantics, during would turn out to be something like the function:

(100) $[\![_{\mathrm{P}}\text{during}]\!] = \lambda\mathcal{P}\lambda P\lambda I[\mathcal{P}(\lambda x[P(\mathrm{time}(x))])(I)]$,

and hence not contentless.[10]

The preposition on (as in TPPs such as on Tuesday) can also be assigned the identity function as meaning, provided we assume Tuesday to have a missing determiner which contributes a the. Thus,

(101) $[\![_{\mathrm{TPP}}\textsf{on Tuesday}]\!] = [\![_{\mathrm{TP}}\textsf{on}]\!]([\![_{\mathrm{TNP}}\textsf{Tuesday}]\!]) = [\![_{\mathrm{TNP}}\textsf{Tuesday}]\!] =$
$\lambda P \lambda I[\mathbf{the}(\lambda J[\textsc{Tuesday}(J) \wedge J \subseteq I], P)]$,

as required. Similarly for the preposition in (as in TPPs such as in June). Finally, the missing preposition assumed in TPPs such as every Monday, one day etc. should also be assigned the identity function. The details are routine and are left to the reader to verify.

Like many other languages, English imposes some rather asystematic conditions on which temporal propositions may combine with various complements. For instance, we say in June, at the weekend, on Monday and so on, though all these TPPs serve to locate events within the time-intervals picked out by their respective complements. Such selection restrictions occupy a central place within the cognitive liguistics tradition, because they are sometimes claimed as evidence for the utilization of various cross-modality conceptual mechanisms or cognitive metaphors.[11] Whatever the truth or importance of these claims, however, we regard them as being outside the scope of this paper, which is concerned exclusively with the derivation of truth-conditional meaning. Obviously, just because two temporal prepositions have the same (truth-conditional) meaning, that does not mean that they are interchangeable.

4.3 Warp functions

So far, we have concentrated on temporal prepositions such as during, on, in and the missing preposition, which, as we have seen, are taken on our compositional approach to make no actual contribution to truth-conditions at all. However, it is clear that other temporal prepositions—most obviously before and after—have a semantic content indicating temporal order, and it is to these that we now turn.

Whereas the TPP during the meeting serves to locate events in the sub-interval of the interval of evaluation *occupied by* the meeting, so the TPP before the meeting serves to locate them in the sub-interval of the interval of evaluation *leading up* to the interval occupied by the meeting (symmetrically for the TPP after the meeting). To formalize this idea, we define the partial functions time-to and time-from:

(102) $\text{time-to}([a,b],[c,d]) =_{\mathrm{Def}} [a,c] \text{ if } [c,d] \subseteq [a,b]$
$\text{time-from}([a,b],[c,d]) =_{\mathrm{Def}} [d,b] \text{ if } [c,d] \subseteq [a,b]$.

Intuitively, the role of these functions is to move the interval of subsequent evaluation either forwards or backwards. Accordingly, we call them *temporal warp functions.* Let I_0 be an interval over which a meeting takes place in some temporal context I_1. Then the intervals time-to(I_1, I_0) and time-from(I_1, I_0) are depicted in fig. 1. Assuming, then, that there is only one meeting within the interval I_1, we know from section 4.1 that events in I_1 can be located during that meeting by means of the TGQ

(103) $\lambda P \lambda I[\mathbf{the}(\lambda J[\textsc{meeting}(J) \wedge J \subseteq I], P)]$.

Likewise, events in I_1 can be located before and after the meeting by means of the TGQs

(104) $\lambda P \lambda I[\mathbf{the}(\lambda J[\textsc{meeting}(J) \wedge J \subseteq I], \lambda I'[P(\text{time-to}(I, I'))])]$

[10] It is interesting to note that, when temporal prepositions are omitted, it is usually with TNPs that clearly denote intervals, as in, e.g. Mary telephoned John one Monday. However, the precise rules governing the use of covert TPPs are complex and dialect-dependent (varying, for instance, between US and British English), and probably cannot be entirely semantically motivated.

[11] See Herskovits [11]. See also Lakoff [19] pp. 416–461 for an extended discussion of the preposition over.

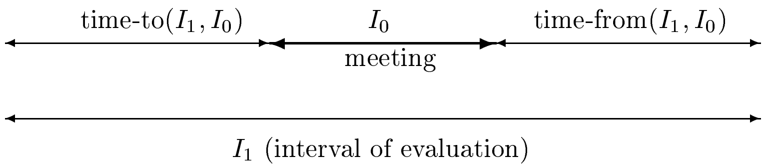

Figure 1: Simple representation of before, during and after.

(105) $\lambda P \lambda I[\mathbf{the}(\lambda J[\textsc{meeting}(J) \wedge J \subseteq I], \lambda I'[P(\text{time-from}(I, I'))])]$,

respectively.

The upshot of the above analysis is that the temporal prepositions before and after can be assigned meanings in the same style as during, thus:

(106) $[\![_{\mathrm{P}}\mathsf{before}]\!] = \lambda\mathcal{P}\lambda P\lambda I[\mathcal{P}(\lambda I'[P(\text{time-to}(I, I'))])(I)]$

(107) $[\![_{\mathrm{P}}\mathsf{after}]\!] = \lambda\mathcal{P}\lambda P\lambda I[\mathcal{P}(\lambda I'[P(\text{time-from}(I, I'))])(I)]$.

To see how this works, we simply compute:

(108) $[\![_{\mathrm{TPP}}$ before the meeting $]\!] = [\![_{\mathrm{P}}$ before$]\!]([\![_{\mathrm{NP}}$ the meeting $]\!]) =$
$\lambda P \lambda I[\mathbf{the}(\lambda J[\textsc{meeting}(J) \wedge J \subseteq I],$
$\lambda I'[P(\text{time-to}(I, I'))])]$

(109) $[\![_{\mathrm{TPP}}$ after the meeting $]\!] = [\![_{\mathrm{P}}$ after$]\!]([\![_{\mathrm{NP}}$ the meeting $]\!]) =$
$\lambda P \lambda I[\mathbf{the}(\lambda J[\textsc{meeting}(J) \wedge J \subseteq I],$
$\lambda I'[P(\text{time-from}(I, I'))])]$.

Hence, using the by now familiar patterns of derivation:

(110) $[\![_{\hat{\mathrm{S}}}$ Mary kissed John before the meeting $]\!] =$
$\mathcal{R}_{\mathbf{a}}(_1[\![_{\mathrm{TPP}}$ before the meeting $]\!](_2[\![_{\mathrm{S}}$ Mary kissed John $]\!])_2)_1 =$
$\lambda P \lambda I_1[\mathbf{a}(\lambda J_0[\mathbf{the}(\lambda J_1[\textsc{meeting}(J_1) \wedge J_1 \subseteq I_1],$
$\lambda I_0[\textsc{kiss}(\textsc{mary}, \textsc{john})(J_0) \wedge J_0 \subseteq \text{time-to}(I_1, I_0)])],$
$P)]$

(111) $[\![_{\hat{\mathrm{S}}}$ Mary kissed John after the meeting $]\!] =$
$\mathcal{R}_{\mathbf{a}}(_1[\![_{\mathrm{TPP}}$ after the meeting $]\!](_2[\![_{\mathrm{S}}$ Mary kissed John $]\!])_2)_1 =$
$\lambda P \lambda I_1[\mathbf{a}(\lambda J_0[\mathbf{the}(\lambda J_1[\textsc{meeting}(J_1) \wedge J_1 \subseteq I_1],$
$\lambda I_0[\textsc{kiss}(\textsc{mary}, \textsc{john})(J_0) \wedge$
$J_0 \subseteq \text{time-from}(I_1, I_0)])],$
$P)]$.

As the reader can verify, these truth-conditions locate the event of Mary's kissing John somewhere in the intervals time-to(I_1, I_0) and time-from(I_1, I_0), respectively, in figure 1.

Plausible as the above truth-conditions are, there is much more to be said about the meanings of before and after. For example, before the meeting can also mean *just* or *a short time before the meeting*. That is, it can serve to locate events within (what the context determines to be) a short interval immediately preceeding the meeting. And *before* is often used with a durative modifier as in five minutes before which serves to locate events within (what the context determines to be) a short interval 5 minutes before the (start of) the meeting. The first of these meanings might be given as:

(112) $[\![_{\hat{\mathrm{S}}}$ John kissed Mary (just) before the meeting $]\!] =$
$\lambda P \lambda I_1[\mathbf{a}(\lambda J_0[\mathbf{the}(\lambda J_1[\textsc{meeting}(J_1) \wedge J_1 \subseteq I_1],$

$$
\begin{aligned}
&\qquad\qquad \lambda I_0[\textsc{kiss}(\textsc{John}, \textsc{Mary})(J_0)\wedge \\
&\qquad\qquad\quad J_0 \subseteq \text{just-before}(I_1, I_0)])], \\
&P)],
\end{aligned}
$$

where just-before is another warp-function defined by

(113) $\text{just-before}([a,b],[c,d]) = [c-\varepsilon, c]$ if $[c-\varepsilon, d] \subseteq [a,b]$

and ε is a contextually determined parameter. Similarly,

(114) $[\![_{\hat{S}}$ John kissed Mary 5 minutes before the meeting $]\!] =$

$$
\begin{aligned}
&\lambda P \lambda I_1[\mathbf{a}(\lambda J_0[\mathbf{the}(\lambda J_1[\textsc{meeting}(J_1)\wedge J_1 \subseteq I_1], \\
&\qquad\qquad \lambda I_0[\textsc{kiss}(\textsc{John}, \textsc{Mary})(J_0)\wedge \\
&\qquad\qquad\quad J_0 \subseteq \text{5-mins-before}(I_1, I_0)])], \\
&\quad P)],
\end{aligned}
$$

with a suitable definition of 5-mins-before. Corresponding remarks apply to after, of course.[12]

Even these observations only scratch the surface of the behaviour of before and after. We cannot investigate this behaviour in depth here. Instead we content ourselves with the claim that the warp-functions introduced above allow the meanings of the main senses of before and after to be given as TGQs. Finally, we mention a technical detail for the sake of uniformity. If we define the function

(115) $\text{time-while}(I, I') =_{\text{def}} I'$,

then we can give the meanings of during, before and after in the following common form:

(116) $[\![_P \mathsf{P}]\!] = \lambda \mathcal{P} \lambda P \lambda I[\mathcal{P}(\lambda I'[P(w(I, I'))], I)]$.

Thus, the meaning of during is given by setting $w =$ time-while, the two meanings of before considered above are given by setting $w =$ time-to and $w =$ just-before, and so on. As we shall see, this schema allows us to give the meanings of all the temporal prepositions considered in this paper.

4.4 Temporal prepositions and quantification

Temporal prepositions serve not only to convey information about the ordering of events, but also to quantify over them. This section establishes a framework for recording the quantificational force of temporal prepositions.

4.4.1 Quantification restrictions on the modificand

We begin with the temporal prepositions for, until and throughout. These words are distinguished by the fact that they can modify verb phrases involving *universal*, but not *existential* temporal quantification, as the following examples show (we assume that meetings are of such a length that many fit into a period lasting several months):

(117) John telephoned Mary during every meeting {for six months/until Christmas/throughout the summer}

(118) John telephoned Mary during a meeting *{for six months/until Christmas/throughout the summer}.

[12] A full account of the semantics of temporal prepositions would have to show how pre-posed arguments as in 5 minutes before contributed to these warp-functions, of course. However, we leave the semantics of such arguments for another occasion.

By contrast, both universal and existential temporal quantification are acceptable in the modificands of some other TPPs:

(119) John telephoned Mary during every meeting {in July/before Christmas/after the conference}

(120) John telephoned Mary during a meeting {in July/before Christmas/after the conference}.

Moreover, for, throughout and until can also be used in state-reporting sentences without any explicit temporal quantification, thus:

(121) John slept for six hours/until 5 o'clock/throughout the lecture.

A related phenomenon is that these prepositions coerce normally eventive-sentences to have a repeated or habitual reading (and hence, on our approach to temporal ontology, into stative sentences):

(122) John telephoned Mary {for six months/until Christmas/throughout the summer}. (*i.e. repeatedly*)

We return to these stative examples in section 5. For the moment, we confine ourselves to event-reporting sentences.

According to the analysis of previous sections, we have the following possible meaning-assignments:

(123) $[\![_{\hat{\mathrm{S}}}$ John telephoned Mary during every meeting $]\!] =$
$$\lambda P\lambda I_1[\mathbf{every}(\lambda J_1[\textsc{meeting}(J_1) \wedge J_1 \subseteq I_1], \lambda I_0[\mathbf{a}(\lambda J_0[\textsc{telephone}(\textsc{john}, \textsc{mary})(J_0) \wedge J_0 \subseteq I_0], P)])]$$

(124) $[\![_{\hat{\mathrm{S}}}$ John telephoned Mary during a meeting $]\!] =$
$$\lambda P\lambda I_1[\mathbf{a}(\lambda J_1[\textsc{meeting}(J_1) \wedge J_1 \subseteq I_1], \lambda I_0[\mathbf{a}(\lambda J_0[\textsc{telephone}(\textsc{john}, \textsc{mary})(J_0) \wedge J_0 \subseteq I_0], P)])].$$

We propose that the prepositions for, until, and throughout require their modificands to be of the form $\lambda P\lambda I[\mathbf{every}(\_, \_)]$, whereas, for example, during, on, before, and after allow their modificands to have any quantificational pattern. Thus, we take the universal temporal quantification associated with for, until and throughout to be a restriction on the usage of the temporal prepositions in question, and not a part of their contribution to the truth-conditions of the sentence. Then we can write:

(125) $[\![_{\mathrm{P}}$ throughout $]\!] = \lambda\mathcal{P}[\mathcal{P}]$.

In other words, throughout has the same meaning as during. For we can then derive, via the methods of previous sections:

(126) $[\![_{\hat{\mathrm{S}}}$ John telephoned Mary during every meeting throughout January $]\!] =$
$$\lambda P\lambda I_2[\mathbf{the}(\lambda J_2[\textsc{january}(J_2) \wedge J_2 \subseteq I_2], \lambda I_1[\mathbf{every}(\lambda J_1[\textsc{meeting}(J_1) \wedge J_1 \subseteq I_1], \lambda I_0[\mathbf{a}(\lambda J_0[\textsc{telephone}(\textsc{john}, \textsc{mary})(J_0) \wedge J_0 \subseteq I_0], P)])])].$$

as required.[13] Remember, however, that throughout is allowed only to modify items with universal temporal quantification, whereas during is subject to no such restriction. It is this restriction which

[13]Though acceptable, sentence (126) sounds somewhat awkward. The awkwardness might be due to fact that it is semantically overdetermined: the alternative John telephoned Mary during every meeting in January would have the same, unambiguously universally quantified meaning, without the aid of the constraint imposed by throughout. However, we will encounter examples below, particularly with state-reporting sentences, where this constraint does useful work. We remark that if January is replaced by a vaguer temporal NP, such as the summer, the force of throughout seems to be to stretch the interval picked out by that noun phrase to the maximum extent. Compare, for example, John telephoned Mary during every meeting in/throughout the summer. This example illustrates just one of the many subtleties in the meanings of TPPs not considered in this paper.

blocks the use of throughout in (118); throughout itself (somewhat counterintuitively) contributes no universal quantification.

Furthermore, we claim that it is the restriction of throughout to universally quantified modificands which forces the repeated or habitual reading of (122). For, on the ordinary (eventive) interpretation of telephoned, and supposing throughout to impose *universal* sentence-determination ($\mathbf{Q} = \mathbf{every}$), we would have:

(127) *$[\![_{\text{S}}$John telephoned Mary throughout the summer$]\!] =$

$$\lambda P \lambda I_1[\mathbf{the}(\lambda J_1[\textsc{summer}(J_1) \wedge J_1 \subseteq I_1], \lambda I_0[\mathbf{every}(\lambda J_0[\textsc{telephone}(\textsc{john}, \textsc{mary})(J_0) \wedge J_0 \subseteq I_0], P)])].$$

But this truth-condition is trivially false on the assumption that events of John's telephoning Mary cannot overlap. And since the eventive verb telephone cannot receive its normal interpretation, we hear only the repeated or habitual interpretation, which can be treated similarly to the stative example (121), explained in section 5. For now, we merely note that the impossibility of combining throughout with simple event-reporting sentences arises, on our account, from its restriction to universally quantified modificands.

Even more surprisingly, perhaps, the preposition for can also be assigned the identity function as its meaning. Like throughout, it requires its modificand to be universally quantified. Unlike throughout, however, it requires its complement to denote some sort of *duration*.[14] The way for treats its complements is complicated by the fact that the period it denotes is often related to the time of reference in a way that depends on tense and aspect, thus:

(128) John will telephone Mary every day for three weeks (*i.e. the next three weeks*)

(129) John has telephoned Mary every day for three weeks (*i.e. the last three weeks*).

However, for can be used in a *floating* sense, denoting some duration or other

(130) (Last year,) John telephoned Mary every day for three weeks (*i.e. some three-week period or other*).

and this is the usage we shall concentrate on. An analysis of numerically quantified, duration-denoting phrases such as three weeks lies outside the scope of this paper. However, we may reasonably assume the following meaning in the contexts we are considering:

(131) $[\![_{\text{TNP}}$ three weeks $]\!] = \lambda P \lambda I[\mathbf{a}(\lambda J[\textsc{3-week}(J) \wedge J \subseteq I], P)]$

where $\textsc{3-week}(J)$ is a predicate true of all and only those intervals of time lasting three weeks. Assuming $[\![_{\text{TP}}$ for $]\!]$ to be the identity function, so that $[\![_{\text{TPP}}$ for three weeks $]\!] = [\![_{\text{NP}}$ three weeks $]\!]$, we derive, in the familiar way:

(132) $[\![_{\hat{\text{S}}}$ John telephoned Mary during every meeting for 3 weeks $]\!] =$

$$\lambda P \lambda I_2[\mathbf{a}(\lambda J_2[\textsc{3-week}(J_2) \wedge J_2 \subseteq I_2], \lambda I_1[\mathbf{every}(\lambda J_1[\textsc{meeting}(J_1) \wedge J_1 \subseteq I_1], \lambda I_0[\mathbf{a}(\lambda J_0[\textsc{telephone}(\textsc{john}, \textsc{mary})(J_0) \wedge J_0 \subseteq I_0], P)])])].$$

Again, we assume that meetings are of such a length that many fit into a 3-week-long period. As for throughout so for for: the restriction to universally quantified modificands is what blocks its use in (118) and forces the habitual/repeated reading in (122); but for contributes no universal quantification itself.

While on the subject of for, it seems appropriate to mention in with durative complements. Again, we confine our remarks here to uses unrelated to the time of reference, e.g.

[14] We ignore uses such as I'll do it for 5 o'clock, where for is synonymous with by.

(133) (Yesterday,) John wrote the letter in 5 minutes.

This states that the writing of the letter occupied a period of no longer than 5 minutes' duration. We propose that in, with a durative complement, be given exactly the same (null) meaning as for, except that it be restricted to *existentially* quantified $\hat{\mathrm{S}}$-modificands of the form $\lambda P \lambda I[\mathbf{a}(\_,\_)]$. The reader can verify that (133) receives the correct truth-conditions on this account. By constrast,

(134) * John telephoned Mary every day in five weeks

is blocked by our proposed modificand restrictions on in. (Analogous restrictions on combining in-adverbials with state-reporting verbs are slightly more complex, and are explained in section 5.) We note in passing that, unlike Dowty's account in [7], pp. 332 ff., where for- and in-adverbials are taken to be of a different type to locative adverbials, our account gives a uniform treatment.

Finally, we come to until. Unlike for and throughout, the meaning of this preposition cannot be taken to be the identity function, since it contributes ordering information. Thus, referring back to fig. 1, we see that, in an interval of evaluation in which there is an unique meeting, until the meeting locates events in the interval marked "time-to(I_1, I_0)". Therefore, we propose that until be assigned the same meaning as before:

(135) $[\![_{\mathrm{TP}}\ \text{until}\ ]\!] = \lambda \mathcal{P} \lambda P \lambda I[\mathcal{P}(\lambda I'[P(\text{time-to}(I, I'))])(I)]$.

Unlike before, however, until requires its modificand to be universally temporally quantified. Thus, we derive, again, in the familiar way:

(136) $[\![_{\hat{\mathrm{S}}}$ John telephoned Mary during every meeting until Christmas $]\!] =$

$$\begin{aligned}
&\lambda P \lambda I_2[\mathbf{the}(\lambda J_2[\textsc{Christmas}(J_2) \wedge J_2 \subseteq I_2],\\
&\qquad \lambda I_1[\mathbf{every}(\lambda J_1[\textsc{meeting}(J_1) \wedge J_1 \subseteq \text{time-to}(I_2, I_1)],\\
&\qquad\qquad \lambda I_0[\mathbf{a}(\lambda J_0[\textsc{telephone}(\textsc{john}, \textsc{mary})(J_0) \wedge\\
&\qquad\qquad\qquad J_0 \subseteq I_0],\\
&\qquad\qquad\quad P)])])],
\end{aligned}$$

which is the correct truth-condition. (We assume a missing determiner contributing a **the** to $[\![_{\mathrm{NP}}$ Christmas$]\!]$.)

While on the subject of until, it seems appropriate to mention since and by. *Very roughly*, since is the a mirror image of until, except that it does not require a universally temporally quantified modificand:

(137) John has telephoned Mary every day since Christmas

(138) John has telephoned Mary since Christmas (*i.e. has made at least one call*).

Thus, we assign since the same meaning as after. This allows us to generate, for example:

(139) $[\![_{\hat{\mathrm{S}}}$ John has telephoned Mary during every meeting since Christmas $]\!] =$

$$\begin{aligned}
&\lambda P \lambda I_2[\mathbf{the}(\lambda J_2[\textsc{Christmas}(J_2) \wedge J_2 \subseteq I_2],\\
&\qquad \lambda I_1[\mathbf{every}(\lambda J_1[\textsc{meeting}(J_1) \wedge J_1 \subseteq \text{time-from}(I_2, I_1)],\\
&\qquad\qquad \lambda I_0[\mathbf{a}(\lambda J_0[\textsc{telephone}(\textsc{john}, \textsc{mary})(J_0) \wedge\\
&\qquad\qquad\qquad J_0 \subseteq I_0],\\
&\qquad\qquad\quad P)])])],
\end{aligned}$$

(140) $[\![_{\hat{\mathrm{S}}}$ John has telephoned Mary since Christmas $]\!] =$

$$\begin{aligned}
&\lambda P \lambda I_1[\mathbf{the}(\lambda J_1[\textsc{Christmas}(J_1) \wedge J_1 \subseteq I_1],\\
&\qquad \lambda I_0[\mathbf{a}(\lambda J_0[\textsc{telephone}(\textsc{john}, \textsc{mary})(J_0) \wedge\\
&\qquad\qquad J_0 \subseteq \text{time-from}(I_1, I_0)],\\
&\qquad\quad P)])].
\end{aligned}$$

The main difference between (temporal) since and after is that the perfect aspect is mandatory in a main clause modified by temporal since.[15] Semantically, since is inappropriate when the interval does not end with the time of reference, while after is unusual (though acceptable) when it does. Thus, after would sound strained in (137) and (138), and since (together with the perfect aspect) could not be used instead of after in:

(141) John arrived after 5 o clock every day.

Like since, by exhibits idiosyncracies we cannot enter into here, especially concerning its interaction with verb-aspect. For example, compare:

(142) John posted the letter by 8 o' clock.

(143) John was working in his office by 8 o' clock,

where the latter states (or at least implicates) that John was still working in his office at 8 o' clock. Again, we cannot dwell on this issue. *Very roughly*, and concentrating on its use without progressive aspect in event-reporting sentences such as (142), we we can take by to mean the same as until and before, except that it is restricted to modificands involving *existential* temporal quantification. Hence:

(144) John will telephone Mary by Wednesday

(145) John will fall asleep during a lecture by Christmas

(146) (?) John will telephone Mary {every day/during every meeting} by Wednesday.

The reader can verify that, on these proposals, sentences (144) and (145) are assigned plausible truth-conditions.

In this subsection, we have shown that temporal prepositions may impose restrictions on the temporal quantification in their *modificands*. A slightly counterintuitive characteristic of our semantics is that prepositions such as for, throughout and until do not themselves contribute universal quantifiers to truth-conditions: their universal quantificational force is carried by a restriction that they may only apply to universally quantified modificands. This characteristic allows us to give a uniform treatment of sentences in which this universal quantification is already provided elsewhere, for example, by a TPP such as during every meeting or every day.

4.4.2 Quantification restrictions on the complement

As an example of how some temporal prepositions impose restrictions on the temporal quantification appearing in their complements, consider

(147) John telephoned Mary every day until {the meeting/*every meeting/* a meeting}

(148) John telephoned Mary by {Tuesday/*a Tuesday/*every Tuesday}.

Hence, it appears that until and by require their complements to be definitely quantified. It is not difficult to find a semantic motivation for this requirement. Given the meaning (135), we can compute, for example:

(149) * $[\![_{\hat{S}}$ John telephoned Mary during every meeting until every Tuesday $]\!] =$

$$\begin{aligned}
&\lambda P \lambda I_2[\mathbf{every}(\lambda J_2[\textsc{tuesday}(J_2) \wedge J_2 \subseteq I_2],\\
&\qquad \lambda I_1[\mathbf{every}(\lambda J_1[\textsc{meeting}(J_1) \wedge J_1 \subseteq \text{time-to}(I_2, I_1)],\\
&\qquad\qquad \lambda I_0[\mathbf{a}(\lambda J_0[\textsc{telephone}(\textsc{john}, \textsc{mary})(J_0) \wedge\\
&\qquad\qquad\qquad J_0 \subseteq I_0],\\
&\qquad\qquad\quad P)])])].
\end{aligned}$$

[15] Compare Mary came, since John telephoned (causal since) with Mary has come since John telephoned (either temporal or causal since).

(Again, we assume that meetings are of, say, several hours'—not several weeks'—duration). This truth-condition is equivalent to stating that John telephoned Mary during every meeting until *the last* Tuesday in the interval of interest. But there are more direct ways of expressing this truth condition, for example using the TPP until (the) last Tuesday. Similar remarks apply to until a Tuesday.[16] It seems therefore that the oddness of combining until with every or a stems from its semantic redundancy.

The need for definite quantitification extends to all temporal prepositions involving the temporal warp-functions time-to(I, I') and time-from(I, I'). A subtle manifestation of this fact is the shift in meaning that occurs with the prepositions before and after. We remarked above that the sentence John kissed Mary before the meeting can be read in either of the two senses *any time before* and *just before*. In the former case, the temporal warp function is time-to(I, I'); in the latter, it is just-before(I, I'). Now in this latter case, there is nothing semantically redundant about having an **a**- or **every**-quantifier in the complement:

(150) $[\![_{\hat{\mathrm{S}}}$ John kissed Mary (just) before every meeting $]\!] =$
$$\lambda P \lambda I_1[\mathbf{every}(\lambda J_1[\text{MEETING}(J_1) \wedge J_1 \subseteq I_1], \lambda I_0[\mathbf{a}(\lambda J_0[\text{KISS}(\text{JOHN}, \text{MARY})(J_0) \wedge J_0 \subseteq \text{just-before}(I_1, I_0)], P)])].$$

One would therefore expect that non-definite quantification in the complement can force the latter reading. And this does seem to be the case. For example, consider:

(151) John telephoned Mary before every meeting

(152) John telephoned Mary before a meeting.

In sentences (151) and (152), before means *just before* or *shortly before*, and certainly not *any time before*. To see this, note that, on the *any-time-before*-reading, (151) would mean that John telephoned Mary before the *first* meeting, and (152) would mean that John telephoned Mary before the *last* meeting. But these do not seem to be available meanings. Again, if one means *before the first/last meeting*, one ought to say so.

4.5 Interaction of temporal prepositional modification with subcategorized quantified arguments

So far, we have considered TPPs only in sentences where the subject and verb-complements are the proper nouns John and Mary. We now turn our attention to sentences with quantifiers both in the verb's subcategorized arguments and in the TPPs. Here, the familiar phenomenon of scope ambiguities arises again. For example, the sentence

(153) Mary interviewed every student on a Monday

admits of three readings: (i) that there was a certain Monday (within the toi) on which Mary interviewed every one of the students separately, with a possibly different occurrence time, (ii) that there was a certain Monday (within the toi) on which Mary interviewed every one of the students collectively, with one occurrence time, and (iii) that, for every student, there was (within the toi) a Monday on which Mary interviewed him (or her), where the Monday (and, *a fortiori*, the occurrence time) may depend on the student.

We must show that all three readings, and no others, are derivable given the resources introduced so far. For example, one possible derivation starts by incorporating the verb-complement without gapping

[16] The expression until one Tuesday, is, however, acceptable, particularly when additional information follows about the Tuesday in question, e.g. John telephoned Mary during every meeting until one Tuesday in April, when she made a complaint. Even here, though, the speaker must have one particular day in mind. Certainly, until one Tuesday cannot, in ordinary speech, be used to mean *until the first Tuesday in the toi*.

to obtain $\llbracket_{\mathrm{S}}\textsf{Mary interviewed every student}\rrbracket$ as in (57), and then pseudo-applying $\llbracket_{\mathrm{TPP}}\textsf{on a Monday}\rrbracket$ as follows:

(154)
$$
\begin{aligned}
&\llbracket_{\mathrm{S}}\textsf{Mary interviewed every student on a Monday}\rrbracket = \\
&\llbracket_{\mathrm{TPP}}\textsf{on a Monday}\rrbracket({}_2\llbracket_{\mathrm{S}}\textsf{Mary interviewed every student}\rrbracket)_2 \\
&= \lambda P \lambda I_1[\mathbf{a}(\lambda J_1[\textsc{Monday}(J_1) \wedge J_1 \subseteq I_1], P)] \\
&\qquad ({}_2\lambda J_0 \lambda I_0[\mathbf{every}(\lambda y_1[\textsc{student}(y_1)], \\
&\qquad\qquad\qquad\qquad \lambda y_2[\textsc{interview}(\textsc{mary}, y_2)(J_0) \wedge J_0 \subseteq I_0])])_2 \\
&= \lambda J_0 \lambda I_1[\mathbf{a}(\lambda J_1[\textsc{Monday}(J_1) \wedge J_1 \subseteq I_1], \\
&\qquad\qquad \lambda I_0[\mathbf{every}(\ \lambda y_1[\textsc{student}(y_1)], \\
&\qquad\qquad\qquad\qquad \lambda y_2[\textsc{interview}(\textsc{mary}, y_2)(J_0) \wedge J_0 \subseteq I_0])])].
\end{aligned}
$$

Determination yields the $\hat{\mathrm{S}}$-meaning:

(155)
$$
\begin{aligned}
&\llbracket_{\hat{\mathrm{S}}}\textsf{Mary interviewed every student on a Monday}\rrbracket = \\
&\lambda P \lambda I_1[\mathbf{a}(\lambda J_0[\mathbf{a}(\lambda J_1[\textsc{Monday}(J_1) \wedge J_1 \subseteq I_1], \\
&\qquad\qquad \lambda I_0[\mathbf{every}(\ \lambda y_1[\textsc{student}(y_1)], \\
&\qquad\qquad\qquad \lambda y_2[\textsc{interview}(\textsc{mary}, y_2)(J_0) \wedge \\
&\qquad\qquad\qquad\quad J_0 \subseteq I_0])])], \\
&\qquad P)],
\end{aligned}
$$

which is reading (ii) above.

Generalizing from this derivation, we can summarize all possible derivations of meaning of (153) as follows. There are three freely-applicable operations: **O**bject pseudo-application (perhaps on gappy S- or $\hat{\mathrm{S}}$-meanings), **T**PP pseudo-application and **D**etermination. (Since the subject is a proper name, the choice of when to incorporate it is immaterial.) Thus, we get six derivations corresponding to possible orderings of the freely-applicable operations.

(156) **TOD** yields reading (i):

$$
\begin{aligned}
&\llbracket_{\hat{\mathrm{S}}}\textsf{Mary interviewed every student on a Monday}\rrbracket_1 = \\
&\llbracket_{\mathrm{TPP}}\textsf{on a Monday}\rrbracket({}_2\llbracket_{\mathrm{NP}}\textsf{every student}\rrbracket({}_2 \\
&\qquad \mathcal{R}_{\mathbf{a}}({}_1\llbracket_{\text{S-gap}}\textsf{Mary interviewed it}\rrbracket)_1)_2)_2 = \\
&\lambda P \lambda I_1[\mathbf{a}(\ \lambda J_1[\textsc{Monday}(J_1) \wedge J_1 \subseteq I_1], \\
&\qquad \lambda I_0[\mathbf{every}(\ \lambda y_1[\textsc{student}(y_1)], \\
&\qquad\qquad \lambda y_2[\mathbf{a}(\lambda J_0[\textsc{interview}(\textsc{mary}, y_2)(J_0) \wedge \\
&\qquad\qquad\qquad J_0 \subseteq I_0], \\
&\qquad\qquad\quad P)])])]
\end{aligned}
$$

(157) **TDO** yields reading (ii):

$$
\begin{aligned}
&\llbracket_{\hat{\mathrm{S}}}\textsf{Mary interviewed every student on a Monday}\rrbracket_2 = \\
&\llbracket_{\mathrm{TPP}}\textsf{on a Monday}\rrbracket({}_2\mathcal{R}_{\mathbf{a}}({}_1\llbracket_{\mathrm{S}}\textsf{Mary interviewed every student}\rrbracket)_1)_2 = \\
&\lambda P \lambda I_1[\mathbf{a}(\lambda J_1[\textsc{Monday}(J_1) \wedge J_1 \subseteq I_1], \\
&\qquad \lambda I_0[\mathbf{a}(\lambda J_0[\mathbf{every}(\ \lambda y_1[\textsc{student}(y_1)], \\
&\qquad\qquad\qquad \lambda y_2[\textsc{interview}(\textsc{mary}, y_2)(J_0) \wedge \\
&\qquad\qquad\qquad\quad J_0 \subseteq I_0])], \\
&\qquad\quad P)])]
\end{aligned}
$$

(158) **DTO** also yields reading (ii), as existential quantifiers commute:

$$
\begin{aligned}
&\llbracket_{\hat{\mathrm{S}}}\textsf{Mary interviewed every student on a Monday}\rrbracket_3 = \\
&\mathcal{R}_{\mathbf{a}}({}_1\llbracket_{\mathrm{TPP}}\textsf{on a Monday}\rrbracket({}_2\llbracket_{\mathrm{S}}\textsf{Mary interviewed every student}\rrbracket)_2)_1 = \\
&\lambda P \lambda I_1[\mathbf{a}(\lambda J_0[\mathbf{a}(\lambda J_1[\textsc{Monday}(J_1) \wedge J_1 \subseteq I_1], \\
&\qquad\qquad \lambda I_0[\mathbf{every}(\ \lambda y_1[\textsc{student}(y_1)], \\
&\qquad\qquad\qquad \lambda y_2[\textsc{interview}(\textsc{mary}, y_2)(J_0) \wedge
\end{aligned}
$$

$$
\begin{aligned}
&\qquad\qquad\qquad J_0 \subseteq I_0])])],\\
&\quad P)]
\end{aligned}
$$

(159) **DOT** also yields reading (ii), as any single interval over which all the students are interviewed cannot fall on more than one Monday:

$$
\begin{aligned}
&[\![_{\hat{\mathrm{S}}}\textsf{Mary interviewed every student on a Monday}]\!]_4 =\\
&\mathcal{R}_{\mathbf{a}}(_1[\![_{\mathrm{NP}}\textsf{every student}]\!](_2[\![_{\mathrm{TPP}}\textsf{on a Monday}]\!](_2\\
&\qquad [\![_{\text{S-gap}}\textsf{Mary interviewed it}]\!])_2)_2)_1 =\\
&\lambda P \lambda I_1[\mathbf{a}(\ \lambda J_0[\mathbf{every}(\ \lambda y_1[\mathrm{STUDENT}(y_1)],\\
&\qquad\qquad \lambda y_2[\mathbf{a}(\lambda J_1[\mathrm{MONDAY}(J_1) \wedge J_1 \subseteq I_1],\\
&\qquad\qquad\qquad \lambda I_0[\mathrm{INTERVIEW}(\mathrm{MARY}, y_2)(J_0) \wedge\\
&\qquad\qquad\qquad\quad J_0 \subseteq I_0])])],\\
&\quad P)]
\end{aligned}
$$

(160) **ODT** yields reading (iii):

$$
\begin{aligned}
&[\![_{\hat{\mathrm{S}}}\textsf{Mary interviewed every student on a Monday}]\!]_5 =\\
&[\![_{\mathrm{NP}}\textsf{every student}]\!](_2\mathcal{R}_{\mathbf{a}}(_1[\![_{\mathrm{TPP}}\textsf{on a Monday}]\!](_2\\
&\qquad [\![_{\text{S-gap}}\textsf{Mary interviewed it}]\!])_2)_1)_2 =\\
&\lambda P \lambda I_1[\mathbf{every}(\ \lambda y_1[\mathrm{STUDENT}(y_1)],\\
&\qquad \lambda y_2[\mathbf{a}(\lambda J_0[\mathbf{a}(\lambda J_1[\mathrm{MONDAY}(J_1) \wedge J_1 \subseteq I_1],\\
&\qquad\qquad\qquad \lambda I_0[\mathrm{INTERVIEW}(\mathrm{MARY}, y_2)(J_0) \wedge\\
&\qquad\qquad\qquad\quad J_0 \subseteq I_0])],\\
&\qquad\qquad P)])]
\end{aligned}
$$

(161) **OTD** also yields reading (iii), as existential quantifiers commute:

$$
\begin{aligned}
&[\![_{\hat{\mathrm{S}}}\textsf{Mary interviewed every student on a Monday}]\!]_6 =\\
&[\![_{\mathrm{NP}}\textsf{every student}]\!](_2[\![_{\mathrm{TPP}}\textsf{on a Monday}]\!](_2\mathcal{R}_{\mathbf{a}}(_1\\
&\qquad [\![_{\text{S-gap}}\textsf{Mary interviewed it}]\!])_1)_2)_2) =\\
&\lambda P \lambda I_1[\mathbf{every}(\ \lambda y_1[\mathrm{STUDENT}(y_1)],\\
&\qquad \lambda y_2[\mathbf{a}(\lambda J_1[\mathrm{MONDAY}(J_1) \wedge J_1 \subseteq I_1],\\
&\qquad\qquad \lambda I_0[\mathbf{a}(\lambda J_0[\mathrm{INTERVIEW}(\mathrm{MARY}, y_2)(J_0) \wedge\\
&\qquad\qquad\qquad J_0 \subseteq I_0],\\
&\qquad\qquad\quad P)])])].
\end{aligned}
$$

4.6 Sentential and preposition-phrase complements in temporal preposition phrases

Some temporal prepositions described above can take both sentential and noun phrase complements:

(162) John attended every meeting {until/before/after} {Christmas/Mary arrived}.

Other temporal prepositions, however, are restricted to complements of a particular category:

(163) John telephoned Mary {during/*not:* while} the meeting.[17]

(164) John telephoned Mary {while/*not:* during} Jane went to the station.

Sentence (164) locates the event of John's telephoning Jane during the (presumed unique) interval over which Mary went to the station. Thus, we have definite quantification over the type of event picked out by the complement-sentence. The temporal preposition when also takes sentential complements:

(165) John telephoned Mary when Jane went to the station.

[17]In some dialects, while is used in the sense of until; we ignore such usage here.

Sentence (165) locates the event of John's telephoning Jane either during or (more often) shortly after the interval over which Mary went to the station. In the former case, when has the same meaning as while; in the latter, is has the same meaning as (shortly) after. Which of these meanings of when is available is known to depend on the complement sentence in puzzling ways. For instance, in

(166) When John arrived at the airport, he went to the check-in desk

(167) ? When John drank his beer, he left the pub,

the odd nature of (167) stems from the fact that the just-after reading is, for some reason, unavailable (see [10] for a discussion). However, these issues are orthogonal to the framework developed here. The temporal preposition whenever can also function like when, except that there is universal (rather than definite) quantification over events picked out by the complement sentence:

(168) John telephoned Mary whenever Jane went to the station.

The usual remarks concerning the possibilities of other warp-functions (e.g. giving a just-after reading) apply to whenever. Generally speaking, whenever allows a very loose temporal connection between the main and subordinate clauses.

Let us now turn to the derivation of meanings for TPPs with sentential complements. Since both TNPs and Ŝs are taken to denote TGQs, we are in a position to give a uniform account of TPP complements. As an example, consider

(169) Mary kissed John when she arrived.

We suppress here the details of the resolution of the anaphoric reference. By our previous analysis, the meaning generated for the embedded sentence Mary arrived is (170) below.

(170) $[\![_{\hat{S}}\text{Mary arrived}]\!] = \lambda P \lambda I[\mathbf{Q}(\lambda J[\textsc{arrive}(\textsc{mary})(J) \wedge J \subseteq I], P)]$.

For the moment, let us take it that $[\![_{\mathrm{TP}}\text{when}]\!] = \lambda \mathcal{P}[\mathcal{P}]$ (that is, the temporal warp function for when is time-while). We propose that it is a lexical semantic property of when to require a definite time for its complement in a TPP. Thus, by chosing $\mathbf{Q} = \mathbf{the}$, we have

(171) $[\![_{\mathrm{TPP}}\text{when Mary arrived}]\!] = [\![_{\mathrm{TP}}\text{when}]\!]([\![_{\hat{S}}\text{Mary arrived}]\!]) =$
$[\![_{\hat{S}}\text{Mary arrived}]\!] = \lambda P \lambda I[\mathbf{the}(\lambda J[\textsc{arrive}(\textsc{mary})(J) \wedge J \subseteq I], P)]$.

From this point on, it makes no difference to the modification of the main clause whether the TPP has a TNP- or an Ŝ-complement. We thus get

(172) $[\![_{\hat{S}}\text{Mary kissed John when she arrived}]\!] =$
$$\begin{aligned}\lambda P \lambda I_1[\mathbf{a}(\lambda J_0[\mathbf{the}(&\lambda J_1[\textsc{arrive}(\textsc{mary})(J_1) \wedge J_1 \subseteq I_1],\\ &\lambda I_0[\textsc{kiss}(\textsc{mary}, \textsc{john})(J_0) \wedge J_0 \subseteq I_0])],\\ P)].&\end{aligned}$$

It might be objected that (172) gives the wrong truth-condition: presumably, Mary kissed John just after, not during, the interval picked out by her arrival. But this detail presents no difficulty for our account, since the choice of time-while as the temporal warp function for when can always be replaced by something more appropriate, most obviously, just-after. Since the derivation proceeds exactly as before, we give only the outcome:

(173) $[\![_{\hat{S}}\text{Mary kissed John when she arrived}]\!] =$
$$\begin{aligned}\lambda P \lambda I_1[\mathbf{a}(\lambda J_0[\mathbf{the}(&\lambda J_1[\textsc{arrive}(\textsc{mary})(J_1) \wedge J_1 \subseteq I_1],\\ &\lambda I_0[\textsc{kiss}(\textsc{mary}, \textsc{john})(J_0) \wedge\\ &\quad J_0 \subseteq \text{just-after}(I_1, I_0)])],\\ P)].&\end{aligned}$$

Similar accounts work for before and after; again, because TNP- and Ŝ-meanings are both TGQs, the meanings (106) and (107) work just as well for both categories of complement, provided, of course that we take the determining quantifier in the embedded sentence to be $\mathbf{Q} = \mathbf{the}$. Thus, we have:

(174) $[\![_{\hat{S}}\text{Mary kissed John before she arrived}]\!] =$
$$\lambda P \lambda I_1[\mathbf{a}(\lambda J_0[\mathbf{the}(\lambda J_1[\text{ARRIVE}(\text{MARY})(J_1) \wedge J_1 \subseteq I_1], \lambda I_0[\text{KISS}(\text{MARY}, \text{JOHN})(J_0) \wedge J_0 \subseteq \text{time-to}(I_1, I_0)])], P)].$$

(175) $[\![_{\hat{S}}\text{Mary kissed John after she arrived}]\!] =$
$$\lambda P \lambda I_1[\mathbf{a}(\lambda J_0[\mathbf{the}(\lambda J_1[\text{ARRIVE}(\text{MARY})(J_1) \wedge J_1 \subseteq I_1], \lambda I_0[\text{KISS}(\text{MARY}, \text{JOHN})(J_0) \wedge J_0 \subseteq \text{time-from}(I_1, I_0)])], P)].$$

Let us now consider a more interesting case:

(176) Mary kissed John whenever she arrived.

As we have observed, whenever indicates universal quantification over the type of event picked out by the complement sentence. We propose to secure this effect by restricting whenever to universally-quantified complements. This restriction means that, when generating the meaning of the embeded sentence Mary arrived, we must choose $\mathbf{Q} = \mathbf{every}$. It is then possible to derive, assuming—say—the just-after interpretation for **whenever**,

(177) $[\![_{\text{TPP}}\text{whenever Mary arrived}]\!] =$
$$\lambda P \lambda I[\mathbf{every}(\lambda J[\text{ARRIVE}(\text{MARY})(J) \wedge J \subseteq I], \lambda I'[P(\text{just-after}(I, I'))])],$$

whence

(178) $[\![_{\hat{S}}\text{Mary kissed John whenever she arrived}]\!] =$
$$\lambda P \lambda I_1[\mathbf{every}(\lambda J_1[\text{ARRIVE}(\text{MARY})(J_1) \wedge J_1 \subseteq I_1], \lambda I_0[\mathbf{a}(\lambda J_0[\text{KISS}(\text{MARY}, \text{JOHN})(J_0) \wedge J_0 \subseteq \text{just-after}(I_1, I_0)], P)])].$$

We see that the free choice of the schematic $\mathbf{Q}$ in determination is crucial for generating correct truth-conditions. Notice also that, in (178), sentence determination in the main clause has to take place *before* application of the TPP; the reason for this is the same as for other TPPs with universally-quantified complements, such as every day, as explained in connection with sentence (87).

Finally, we turn briefly to TPPs with TPP-complements. Examples include

(179) John telephoned Mary every day until after the conference

(180) John has telephoned Mary every day since before she arrived.

Again, we cannot enter into an exhaustive analysis here. We examine sentence (179) as an illustration. We take it that the force of the after in (179) is to make the universal quantification extend throughout the period before and during the conference. Thus, John must telephone Mary every day until the end of the conference, but not necessarily afterwards.

Now, on the account proposed here, $[\![_{\text{TPP}}\text{after the conference}]\!]$ is a TGQ, and so can certainly figure as a complement to a temporal preposition. In fact, we have, by routine calculation:

(181) $[\![_{\text{TPP}}\text{after the conference}]\!] = [\![_{\text{TP}}\text{after}]\!]({}_1[\![_{\text{TNP}}\text{the conference}]\!])_1 =$
$$\lambda P \lambda I[\mathbf{the}(\lambda J[\text{CONFERENCE}(J) \wedge J \subseteq I], \lambda I'[P(\text{time-from}(I, I'))])]$$

(182) $[\![_{\text{TPP}}\text{until after the conference}]\!] =$
$[\![_{\text{TP}}\text{until}]\!]([\![_{\text{TPP}}\text{after the conference}]\!]) =$

$$\lambda P \lambda I[\mathbf{the}(\lambda J[\textsc{conference}(J) \wedge J \subseteq I], \\ \lambda I'[P(\text{time-to}(I, \text{time-from}(I, I')))])].$$

The result is a perfectly ordinary TGQ: notice how the functions time-to and time-from have been inserted. We can then derive, in the by now familiar way:

(183) $[\![_{\hat{S}}$ John telephoned Mary every day until after the conference $]\!] =$
$[\![_{TPP}$ until after the conference $]\!](_2$
$[\![_{\hat{S}}$ John telephoned Mary every day$]\!])_2 =$

$$\lambda P \lambda I_2[\mathbf{the}(\lambda J_2[\textsc{conference}(J_2) \wedge J_2 \subseteq I_2], \\ \lambda I_1[\mathbf{every}(\lambda J_1[\textsc{day}(J_1) \wedge \\ J_1 \subseteq \text{time-to}(I_2, \text{time-from}(I_2, I_1))], \\ \lambda I_0[\mathbf{a}(\lambda J_0[\textsc{telephone}(\textsc{john}, \textsc{mary})(J_0) \wedge \\ J_0 \subseteq I_0], \\ P)])])],$$

The reader can check that these truth-conditions are as we claimed they should be.

There is much more to be said about TPPs with TPP-complements than we can go into here. The main challenge for the present account is to block generation of unwanted examples, for example:

(184) * John telephoned Mary every day until during the conference

(185) * John telephoned Mary after before the meeting.

Some of these non-sentences can be rejected on purely semantic grounds. Thus, for example, the during in sentence (184) is redundant. Sentence (185), however, is unlikely to yield to such treatment. We have no account of why since (just) before is acceptable but after (just) before is not.

4.7 Structural ambiguities

We mentioned in passing in section 1 that sentences containing several TPPs can exhibit structural ambiguities. For example, the sentence

(186) John will telephone Mary before the meeting on Wednesday

has two phrase-structures, namely:

(187) John will telephone Mary
[$_{\text{TPP}}$ before [$_{\text{TNP}}$ the meeting]] [$_{\text{TPP}}$ on [$_{\text{TNP}}$ Wednesday]]

(188) John will telephone Mary
[$_{\text{TPP}}$ before [$_{\text{TNP}}$ the [$_{\text{TN}}$ meeting [$_{\text{TPP}}$ on [$_{\text{TNP}}$ Wednesday]]]]].

In (187), two parallel TPPs modify the VP; in (188), by contrast, the second TPP modifies the TN which heads the complement of the first TPP. The task of this section is to explain how meanings can be derived in both cases. As we shall see, the proposals made in previous sections have already put at our disposal everything we need to complete this task.

Before we actually derive any meanings for (186), let us establish what the result ought to be. For the sake of simplicity, let before be understood in the sense of "any time before", and suppose that the toi stretches forward from the time of utterance—say, on Monday at 9:00. At what times can John telephone Mary for this sentence to be true? There seem to be two possible answers: (i) any time from the start of Wednesday until the meeting that day, and (ii) any time from 9:00 on Monday until the meeting on Wednesday. Let us call these two readings of (186) the 'short' and 'long' readings, respectively.

Since we have two phrase-structures for sentence (186) and also two meanings, let us investigate this hypothesis that each meaning corresponds to one of the phrase-structures. Consider the following, slightly awkward, variant of sentence (186):

(189) John will telephone Mary before the meeting using his mobile 'phone on Wednesday.

Notice that, in sentence (189), only the short reading is possible: on Wednesday, John will telephone Mary using his mobile phone—and, what is more, he will do so before the meeting on that day. But the interposed verb-phrase adjunct using his mobile 'phone prevents generation of the type of phrase-structure exhibited in (188). Hence, this observation provides evidence that only the short truth-condition is associated with phrase-structure in (187).

For evidence supporting the converse claim, consider the temporal preposition of, which is a familiar component of standard (spoken) calendrical idioms such as the 31st of March as well as non-canonical calendar systems found in, for example, schools and universities, thus:

(190) John will telephone Mary before Wednesday of week 3.

Notice that, in sentence (190), only the long reading is possible: John must telephone Mary any time between the time of utterance and Wednesday of week 3—i.e. including any day in, say, week 2. But this form of of cannot modify verb phrases, so sentence (190) must have the type of phrase-structure exhibited in (188). Hence, this observation provides evidence that only the long truth-condition is associated with phrase-structure in (188). Thus, we have argued that the two possible phrase-structures for sentence (186) should be given different truth-conditions: the short truth-condition for phrase-structure (187) and the long truth-condition for phrase-structure (188).

We now show that our proposed semantics of temporal prepositions generates these truth-conditions unproblematically. First, we consider (187): the derivation in this case follows exactly the path laid out in section 3. The meaning of the TPP before the meeting is:

(191) $[\![_{\mathrm{TPP}}\text{before the meeting}]\!] =$
$$\lambda P \lambda I[\mathbf{the}(\lambda J[\textsc{meeting}(J) \wedge J \subseteq I], \lambda I'[P(\text{time-to}(I, I'))])].$$

The meaning of the TPP on Wednesday is:

(192) $[\![_{\mathrm{TPP}}\text{on Wednesday}]\!] =$
$$\lambda P \lambda I[\mathbf{the}(\lambda J[\textsc{wednesday}(J) \wedge J \subseteq I], P)].$$

The undetermined S-meaning is:

(193) $[\![_{\mathrm{S}}\text{John will telephone Mary}]\!] =$
$$\lambda J_0 \lambda I_0[\textsc{telephone}(\textsc{john}, \textsc{mary})(J_0) \wedge J_0 \subseteq I_0].$$

Pseudo-applying the TGQs (191) and (192) in the only sensible order yields:

(194) $[\![_{\mathrm{S}}\text{John will telephone Mary before the meeting on Wednesday}]\!]_1 =$
$$\lambda J_0 \lambda I_2[\mathbf{the}(\lambda J_2[\textsc{wednesday}(J_2) \wedge J_2 \subseteq I_2], \lambda I_1[\mathbf{the}(\lambda J_1[\textsc{meeting}(J_1) \wedge J_1 \subseteq I_1], \lambda I_0[\textsc{telephone}(\textsc{john}, \textsc{mary})(J_0) \wedge J_0 \subseteq \text{time-to}(I_1, I_0)])])].$$

Determination yields the final meaning for (187), namely

(195) $[\![_{\hat{\mathrm{S}}}\text{John will telephone Mary before the meeting on Wednesday}]\!]_1 =$
$$\lambda P \lambda I_2[\mathbf{a}(\lambda J_0[\mathbf{the}(\lambda J_2[\textsc{wednesday}(J_2) \wedge J_2 \subseteq I_2], \lambda I_1[\mathbf{the}(\lambda J_1[\textsc{meeting}(J_1) \wedge J_1 \subseteq I_1], \lambda I_0[\textsc{telephone}(\textsc{john}, \textsc{mary})(J_0) \wedge J_0 \subseteq \text{time-to}(I_1, I_0)])])],$$

$P)]$,

which is the short truth-condition, as required.

Next we come to the phrase-structure (188). To derive the corresponding truth-condition, we must determine the meaning of the TPP before the meeting on Wednesday; and, in order to do that, we must first determine the meaning of the TNP the meeting on Wednesday. Now, so far in this paper, we have applied TPP-modification only to Ss and Ŝs. But, of course, given the identity of form between sentence meanings and noun phrase meanings, the latter ought to present no difficulty. Let us see whether this is in fact so.

Proceeding by analogy with our earlier treatment of sentences, we combine the TPP on Wednesday to the *undetermined* TN Wednesday. Using the notation TN′ to indicate an undetermined temporal noun phrase, we have:

(196) $[\![_{\mathrm{TN}'}\text{meeting on Wednesday}]\!] = [\![_{\mathrm{TPP}}\text{on Wednesday}]\!]({}_2[\![_{\mathrm{TN}}\text{meeting}]\!])_2 =$
$\lambda P \lambda I_2[\mathbf{the}(\lambda J_2[\textsc{Wednesday}(J_2) \wedge J_2 \subseteq I_2], P)]({}_2$
$\lambda J_1 \lambda I_1[\textsc{meeting}(J_1) \wedge J_1 \subseteq I_1])_2 =$
$\lambda J_1 \lambda I_2[\mathbf{the}(\lambda J_2[\textsc{Wednesday}(J_2) \wedge J_2 \subseteq I_2],$
$\lambda I_1[\textsc{meeting}(J_1) \wedge J_1 \subseteq I_1])]$.

Note that the temporal variables have been indexed from 1 rather than 0; this is for compatibility with later material.

It is important to observe the "pull-out" of the variable J_1 corresponding to the interval occupied by the meeting. This feature plays an important role in the rest of the derivation. Now (196) has the same form as the meaning of a TN. Hence, pesudo-applying the meaning of the determiner the in the usual way gives us

(197) $[\![_{\mathrm{TNP}}\text{the meeting on Wednesday}]\!] =$
$\lambda P \lambda I_2[\mathbf{the}(\lambda J_1[\mathbf{the}(\lambda J_2[\textsc{Wednesday}(J_2) \wedge J_2 \subseteq I_2],$
$\lambda I_1[\textsc{meeting}(J_1) \wedge J_1 \subseteq I_1])],$
$P)]$.

Since the meaning in (197) is a TGQ, it can form the complement of a temporal preposition, again in the normal way, thus:

(198) $[\![_{\mathrm{TPP}}\text{before the meeting on Wednesday}]\!] =$
$[\![_{\mathrm{TP}}\text{before}]\!]([\![_{\mathrm{TNP}}\text{the meeting on Wednesday}]\!]) =$
$\lambda P \lambda I_2[\mathbf{the}(\lambda J_1[\mathbf{the}(\lambda J_2[\textsc{Wednesday}(J_2) \wedge J_2 \subseteq I_2],$
$\lambda I_1[\textsc{meeting}(J_1) \wedge J_1 \subseteq I_1])],$
$\lambda I'[P(\text{time-to}(I_2, I'))])]$.

Again, as (198) has the usual form of a TPP-meaning, it can now modify the undetermined S-meaning of John will telephone Mary to derive the S-meaning for (188) in the usual way, thus:

(199) $[\![_{\mathrm{S}}\text{John will telephone Mary before the meeting on Wednesday}]\!]_2 =$
$\lambda J_0 \lambda I_2[\mathbf{the}(\lambda J_1[\mathbf{the}(\lambda J_2[\textsc{wednesday}(J_2) \wedge J_2 \subseteq I_2],$
$\lambda I_1[\textsc{meeting}(J_1) \wedge J_1 \subseteq I_1])],$
$\lambda I_0[\textsc{telephone}(\textsc{john}, \textsc{mary})(J_0) \wedge$
$J_0 \subseteq \text{time-to}(I_2, I_0)])]$.

Determination then yields

(200) $[\![_{\hat{\mathrm{S}}}\text{John will telephone Mary before the meeting on Wednesday}]\!]_2 =$
$\lambda P \lambda I_2[\mathbf{a}(\lambda J_0[\mathbf{the}(\lambda J_1[\mathbf{the}(\lambda J_2[\textsc{wednesday}(J_2) \wedge J_2 \subseteq I_2],$
$\lambda I_1[\textsc{meeting}(J_1) \wedge J_1 \subseteq I_1])],$

$$\lambda I_0[\text{TELEPHONE}(\text{JOHN}, \text{MARY})(J_0) \wedge J_0 \subseteq \text{time-to}(I_2, I_0)])],$$
$$P)],$$

which is the long truth-condition, as expected. Notice how, in this truth-condition, the outer temporal preposition—in this case before—latches on to the "inner" event—that of the meeting—rather than the Wednesday within that inner event is located. The mechanism responsible for this behaviour is the "pull-out" of the interval J_1 in the derivation of the TPP-complement. We remark that this mechanism can only operate because of the double-indexing and inclusion of the $\subseteq$ relation in temporal noun-meanings.

Of course, exactly the same mechanisms operate when the the prepositionally modified TPP complement is a sentence rather than a noun phrase. Consider the sentence:

(201) John telephoned Mary before she arrived on Wednesday.

This sentence, like (186), has two phrase-structures, and two corresponding truth-conditions. As a demonstration of how easily our approach copes with both noun-phrase and sentential complements, we derive the long truth conditions for (201). From the results of previous sections, we have:

(202) $[\![_{\hat{S}}\text{Mary arrived on Wednesday}]\!] =$
$$\lambda P \lambda I_2[\mathbf{Q}(\lambda J_1[\mathbf{the}(\lambda J_2[\text{WEDNESDAY}(J_2) \wedge J_2 \subseteq I_2], \lambda I_1[\text{ARRIVE}(\text{MARY})(J_1) \wedge J_1 \subseteq I_1])], P)].$$

Then we can again exploit the similarity of form between (197) and (202) to obtain:

(203) $[\![_{\hat{S}}\text{before Mary arrived on Wednesday}]\!] =$
$$\lambda P \lambda I_2[\mathbf{the}(\lambda J_1[\mathbf{the}(\lambda J_2[\text{WEDNESDAY}(J_2) \wedge J_2 \subseteq I_2], \lambda I_1[\text{ARRIVE}(\text{MARY})(J_1) \wedge J_1 \subseteq I_1])], \lambda I_0[P(\text{time-to}(I_2, I_0))])].$$

Again, we have set $\mathbf{Q} = \mathbf{the}$, as is normal for sentential TPP complements. It is then straightforward to derive the long truth-conditions:

(204) $[\![_{\hat{S}}\text{John telephoned Mary before}[_S\text{she arrived on Wednesday}]]\!]_2 =$
$$\lambda P \lambda I_2[\mathbf{a}(\lambda J_0[\mathbf{the}(\lambda J_1[\mathbf{the}(\lambda J_2[\text{WEDNESDAY}(J_2) \wedge J_2 \subseteq I_2], \lambda I_1[\text{ARRIVED}(\text{MARY})(J_1) \wedge J_1 \subseteq I_1])], \lambda I_0[\text{TELEPHONE}(\text{JOHN}, \text{MARY})(J_0) \wedge J_0 \subseteq \text{time-to}(I_2, I_0)])], P)].$$

Again, notice how the "pull-out" of the variable J_1 in the derivation of the TPP-complement causes the preposition before to latch on to the "inner" event—that of Mary's arriving—rather than the Wednesday within that inner event is located. And again, this mechanism can only operate because of the double-indexing and inclusion of the $\subseteq$ relation in sentence-meanings. Recall that it is precisely this feature of sentence-meanings that allowed us to assign such "minimal" meanings to temporal prepositions such as, for example, during.

We conclude with two related points of a technical nature. The first is a promised explanation of why TPPs must be allowed to pseudo-apply *before* sentence determination. (Recall that, in the examples of section 4.1, it turned out to be possible to leave TPP-modification until after determination.) Consider:

(205) John telephoned Mary whenever [$_S$ she arrived on a Monday],

Here, the TP whenever requires universal quantification over arrivals on some Monday or other. This requirement can only be fulfilled if the determination-quantifier $\mathbf{Q} = \mathbf{every}$ in the subordinate clause is permitted to scope over the TGQ corresponding to on a Monday. The truth-conditions can then be generated as described above:

(206) $[\![_{\hat{S}}$John telephoned Mary whenever$[_{S}$she arrived on a Monday$]]\!]_2 =$
$$\lambda P \lambda I_2[\mathbf{every}(\lambda J_1[\mathbf{a}(\lambda J_2[\text{MONDAY}(J_2) \wedge J_2 \subseteq I_2],$$
$$\lambda I_1[\text{ARRIVED}(\text{MARY})(J_1) \wedge J_1 \subseteq I_1])],$$
$$\lambda I_0[\mathbf{a}(\lambda J_0[\text{TELEPHONE}(\text{JOHN}, \text{MARY})(J_0) \wedge$$
$$J_0 \subseteq \text{just-after}(I_2, I_0)],$$
$$P)])].$$

The second point is related to the first. In all the examples considered in this sub-section, when the meaning of of the TPP complement was derived, the last operation was determination; yet we have seen that, in some temporally modified sentences, TPPs were pseudo-applied to determined sentence-meanings. Likewise, when considering TPPs in temporal noun phrases in this sub-section, we always pseudo-applied the TPP before the determiner; yet, technically, there is no reason why a TPP should not modify a TNP. This leads us to ask: if we have a TP-complement of category $\hat{\text{S}}$ or TNP which is itself modified by TNPs, must the determination quantifier always have widest scope?

In many cases (including those considered above) it makes no difference when determination in the subordinate clause occurs. Where it does make a difference, however, it appears that determination must occur last. Consider, for example, the sentence:

(207) (?) Peter was outraged whenever $[_{\hat{S}}$ Mary Kissed John every day].

This sentence is difficult to interpret unless we treat it as elliptical for

(208) Peter was outraged whenever Mary kissed John every day during some period

(in which case the above account applies unproblematically). Yet, we agreed above that the meaning of the embedded sentence was

(209) $[\![_{\hat{S}}$Mary kissed John every day$]\!] =$
$[\![_{\text{TPP}}$every day$]\!](_2[\![_{\hat{S}}$Mary kissed John$]\!])_2 =$
$$\lambda P \lambda I_2[\mathbf{every}(\lambda J_2[\text{DAY}(J_2) \wedge J_2 \subseteq I_2],$$
$$\lambda I_1[\mathbf{a}(\lambda J_1[\text{KISS}(\text{MARY}, \text{JOHN})(J_1) \wedge J_1 \subseteq I_1],$$
$$P)])].$$

Taking the temporal warp function in whenever to be time-while, we could derive:

(210) $[\![_{\hat{S}}$Peter was outraged whenever Mary kissed John every day$]\!] =$
$[\![_{\text{TPP}}$whenever Mary kissed John every day$]\!](_2[\![_{\hat{S}}$Peter was outraged$]\!])_2 =$
$$\lambda P \lambda I_2[\mathbf{every}(\lambda J_2[\text{DAY}(J_2) \wedge J_2 \subseteq I_2],$$
$$\lambda I_1[\mathbf{a}(\lambda J_1[\text{KISS}(\text{MARY}, \text{JOHN})(J_1) \wedge J_1 \subseteq I_1],$$
$$\lambda I_0[\mathbf{a}(\lambda J_0[\text{OUTRAGED}(\text{JOHN})(J_0) \wedge J_0 \subseteq I_0],$$
$$P)])])].$$

But this is just wrong: it says that, on every day in the toi, there is a time when John kisses Mary, and that Peter was outraged during (or, given a different warp function, at about) that time. We conclude that in TP-complements of category $\hat{\text{S}}$ or TNP, the determination-quantifier is required to have widest scope.

4.8 Summary

4.8.1 A table of temporal prepositions

As we have stressed above, the material presented here is incomplete in many respects. First, we have ignored certain general aspects of the semantics of temporal prepositions, most notably, the involvement of the time-of-reference and time-of-utterance as in in 5 minutes (from now/then) or 5 minutes ago. Second, we have treated only fleetingly pre-posed preposition-complements, as in shortly/sometime/five minutes before. Third, we have ignored many details of the way the various English temporal prepositions function, most obviously, the characteristically idiosyncratic complement restrictions (e.g. *on* Tuesday, *at* the weekend, *in* July) and the subtle interactions with verb-tense and aspect. Fourth, we have ignored a clutch of difficulties concerning the interaction of TPPs with the 'internal' semantics of various verbs; a classic example[18] is

(211) The sheriff of Nottingham imprisonned Robin Hood for four years.

Fifth, we have considered TPPs only as modifiers and not as verb-complements or in predicative use.[19] Sixth, we have studied temporal prepositions in isolation from spatial prepositions. Nevertheless, we have accounted for the most salient semantic characteristics of many of the commonly used English temporal prepositions. Our account is 'minimal', in the sense that we locate surprisingly little actual content in the temporal prepositions themselves.[20] According to our account, these semantic characteristics have three dimensions: (i) the actual contribution to the compositional derivation of truth-conditions (this is determined by the temporal warp function), (ii) the restrictions on the temporal quantification in the modified phrase, and (iii) the restrictions on the temporal quantification in the preposition's complement. We summarize these characteristics in table 1.

5 Temporal TPP-modification of stative sentences

In this section, we turn our attention to meanings assigned to temporally modified sentences involving stative verbs. Recall that we content ourselves in this paper with a coarse distinction between *states* and *events*. The reader is referred to section 3.2 for a discussion of our use of these terms.

[18] Apparently, due originally to Robert Binnick.

[19] The importance of accounting for these uses of spatial PPs is stressed by Wunderlich [29].

[20] It has to be admitted that, in this respect, our account sits very uncomfortably with existing accounts of spatial prepositions. See, e.g. Crangle and Suppes [4] and Zwarts and Winter [30]. However, our account works so smoothly for many examples that we do not consider this objection decisive.

[21] The complement must be a day or a day part. Usually, the definite quantifier is omitted.

[22] This is the sense of in as it occurs in, e.g. in July or in 1987. The complement must be (in general) a large calendrical interval such as a day-part, week, month or year. The definite quantifier in the complement is often omitted.

[23] The complement is normally a clock-time, or any short, vaguely calendrical item, e.g. at 5 o'clock, at sunset. Taking the warp-function to be time-while is only possible if these noun phrases to denote short, but *non-point*, intervals of time.

[24] We have only looked at existential durational complements here. Definitelty quantified durational complements are possible, as in for the last three months. Similar remarks apply to in (below).

[25] This is the sense of in as it occurs in, e.g. (Yesterday,) Mary examined a student in three minutes. The complement must be a duration, as with for.

[26] There are complex interactions with aspect, e.g. in John will be working on the paper by 5 o clock.

[27] Before and after are frequently used with a pre-posed complement as in five minutes before. This changes the warp function as indicated in the text.

[28] Requires the perfect aspect in the main clause.

Preposition	Warp-function	Modificand quantification restrictions	Complement quantification restrictions
during	time-while	–	–
on	time-while	–	–[21]
in[22]	time-while	–	definite
at	time-while	–	–[23]
throughout	time-while	universal	–
for	time-while	universal	existential[24]
in[25]	time-while	existential	existential
until	time-to	universal	definite
by[26]	time-to	existential	definite
before	time-to	–	definite
before	just-before[27]	–	–
after	time-from	–	definite
after	just-after	–	–
since[28]	time-from	–	definite
while	time-while	–	definite
when	time-while	–	definite
when	just-after	–	definite
whenever	time-while	–	universal
whenever	just-after	–	universal

Table 1: Summary of some temporal prepositions

5.1 Stative main clauses

Consider the sentences

(212) Mary slept until 5 o clock

(213) Mary slept for five hours

(214) Mary slept throughout the meeting.

Sentence (212) asserts that the state of Mary's sleeping holds at every time point in that sub-interval of the toi leading up to the unique five o' clock in the toi; (one reading of) sentence (213) asserts the holding of that state at every time point in some 5-hour-long sub-interval of the toi; and Sentence (214) asserts the holding of that state at every time point in the unique sub-interval of the toi occupied by a meeting. Accordingly, we propose the following truth-conditions:

(215) $[\![_{\hat{S}}\text{Mary slept until five oclock}]\!] =$
$$\lambda P \lambda I_1[\mathbf{the}(\lambda J_1[5{:}00(J_1) \wedge J_1 \subseteq I_1], \lambda I_0[\mathbf{every}(\lambda t_1[t_1 \in \text{time-to}(I_1, I_0)], \lambda t_2[\textsc{sleep}(\textsc{mary})(t_2)])])]$$

(216) $[\![_{\hat{S}}\text{Mary slept for five hours}]\!] =$
$$\lambda P \lambda I_1[\mathbf{a}(\ \lambda J_1[5\text{-}\textsc{hours}(J_1) \wedge J_1 \subseteq I_1], \lambda I_0[\mathbf{every}(\lambda t_1[t_1 \in I_0], \lambda t_2[\textsc{sleep}(\textsc{mary})(t_2)])])]$$

(217) $[\![_{\hat{S}}\text{Mary slept throughout the meeting}]\!] =$
$$\lambda P \lambda I_1[\mathbf{the}(\ \lambda J_1[\textsc{meeting}(J_1) \wedge J_1 \subseteq I_1], \lambda I_0[\mathbf{every}(\lambda t_1[t_1 \in I_0], \lambda t_2[\textsc{sleep}(\textsc{mary})(t_2)])])].$$

In our formalization, we use t to range over time points, with the self-explanatory notation $t \in I$.

Our task now is to explain how these truth-conditions are computed. First, we make use of the following abbreviation for any predicate $\phi(x_1, \ldots, x_n)(t)$:

(218) $\overline{\phi}(x_1, \ldots, x_n)(I) =_{\text{Def}} \mathbf{every}(\lambda t_1[t_1 \in I], \lambda t_2[\phi(x_1, \ldots, x_n)(t_2)])$.

We then propose that stative verbs receive a pair of (systematically related) meanings. The first meaning-assignment to stative verbs has the following general form:

(219) $[\![_{\hat{\text{V}}}\mathsf{v}]\!]_1 = \lambda x_1 \ldots \lambda x_n \lambda P \lambda I[\overline{\text{V}}(x_1, \ldots, x_n)(I)] =$
$\lambda x_1 \ldots \lambda x_n \lambda P \lambda I[\mathbf{every}(\lambda t_1[t_1 \in I], \lambda t_2[\text{V}(x_1, \ldots, x_n)(t_2)])]$.

For the stative verb slept, we get

(220) $[\![_{\hat{\text{V}}}\mathsf{slept}]\!]_1 = \lambda x \lambda P \lambda I[\overline{\text{SLEEP}}(x)(I)] =$
$\lambda x \lambda P \lambda I[\mathbf{every}(\lambda t_1[t_1 \in I], \lambda t_2[\text{SLEEP}(x)(t_2)])]$.

Notice that we denote this meaning as $[\![_{\hat{\text{V}}} \ldots]\!]$, not $[\![_{\text{V}} \ldots]\!]$. This notation serves to remind us that the universal quantification over time points means that there is no occurrence-interval available for later quantification.

Sentence subjects and objects are combined using pseudo-application in the usual way, yielding:

(221) $[\![_{\hat{\text{S}}}\mathsf{Mary\ slept}]\!]_1 = [\![_{\text{NP}}\mathsf{Mary}]\!]({}_1[\![_{\hat{\text{VP}}}\mathsf{slept}]\!]_1)_1 =$
$\lambda P \lambda I[\mathbf{every}(\lambda t_1[t_1 \in I], \lambda t_2[\text{SLEEP}(\text{MARY})(t_2)])]$.

Thus, on the reading in (221), the sentence reports the holding, over all time points within the temporal context I, of the state of Mary's sleeping. (We will encounter another reading of this sentence below.) Again, only a determined meaning is available here, as there is no occurrence-interval available for later quantification. One oddity of the meaning in (221) is that the abstracted variable P does not occur in the body of the λ-expression. This variable is present merely for the sake of uniformity.

We now turn to TPP-modification of state-reporting sentences. This temporal modification causes a relativization of the universal quantification over points to subintervals of the current temporal context, a phenomenon with which we are familiar from our ealier treatment of eventive sentences. From table 1 at the end of section 4, we can compute:

(222) $[\![_{\text{TPP}}\ \mathsf{until\ 5\ o'\ clock}\ ]\!] =$
$\lambda P \lambda I[\mathbf{the}(\lambda J[5{:}00(J) \wedge J \subseteq I], \lambda I'[P(\text{time-to}(I, I'))])]$

(223) $[\![_{\text{TPP}}\ \mathsf{for\ 5\ hours}\ ]\!] = \lambda P \lambda I[\mathbf{a}(\lambda J[5\text{-HOUR}(J) \wedge J \subseteq I], P)]$

(224) $[\![_{\text{TPP}}\mathsf{throughout\ the\ meeting}]\!] =$
$\lambda P \lambda I[\mathbf{the}(\lambda J[\text{MEETING}(J) \wedge J \subseteq I], P)]$,

noting that these these TPPs are restricted to universally quantified modificands. To generate the meanings of sentences (212)–(214), we pseudo-apply the meanings of the respective TPPs to the universally quantified $\hat{\text{S}}$-meaning (221). The reader can check that doing so results in the meaning-assignments (215)–(217).

We remark at this point that taking state-reporting verbs such as sleep to be 'pre-quantified'—i.e. to be $\hat{\text{V}}$s rather than Vs—forces existential quantifiers to scope over the implicit universal quantification over time-points. Thus,

(225) $[\![_{\hat{\text{S}}}\mathsf{A\ student\ slept\ throughout\ the\ lecture}]\!] =$
$\lambda P \lambda I_1[\mathbf{the}(\ \lambda J_1[\text{LECTURE}(J_1) \wedge J_1 \subseteq I_1],$
$\lambda I_0[\mathbf{a}(\ \lambda x_1[\text{STUDENT}(x_1)],$
$\lambda x_2[\overline{\text{SLEEP}}(x_2)(I_0)])])]$

is derivable, according to which a single student slept at all times during the lecture. However, we cannot derive the truth-condition that, at all these times, *one student or another* was asleep. This seems intuitively correct. To get existential quantifiers to take narrow scope here requires a special construction (such as one ... or another) or perhaps semantic pressure, as in:

(226) A soldier has guarded the eternal flame for 50 years.

These cases are beyond the scope of the present treatment.

Let us now turn to our proposed second form of meaning-assignment to stative verbs. By way of motivation, consider the sentence

(227) Mary slept during the meeting.

Sentence (227) *can* mean the same as sentence (214), and this (universally quantified) meaning is clearly derivable on our account, since during and throughout make the same semantic contribution, namely the null contribution. However, sentence (227) can also mean that Mary slept over some period within the meeting (not necessarily the whole of it):

(228) $[\![_{\hat{S}}\text{Mary slept during the meeting}]\!] =$
$$\lambda P \lambda I_1[\mathbf{a}(\ \lambda J_0[\mathbf{the}(\lambda J_1[\textsc{meeting}(J_1) \wedge J_1 \subseteq I_1], \lambda I_0[\overline{\textsc{sleep}}(\textsc{mary})(J_0) \wedge J_0 \subseteq I_0])], P)].$$

In order to determine this truth-condition, we propose that meaning-assignments to stative verbs can be of the form:

(229) $[\![_{\hat{V}}\mathsf{v}]\!]_2 = \lambda x_1 \ldots \lambda x_n \lambda J \lambda I[\overline{\mathrm{v}}(x_1, \ldots, x_n)(J) \wedge J \subseteq I].$

For the stative verb slept, we get

(230) $[\![_{V_s}\text{slept}]\!]_2 = \lambda x \lambda J \lambda I[\overline{\textsc{sleep}}(x)(J) \wedge J \subseteq I].$

Notice that this lexical meaning is a V, not a $\hat{\mathrm{V}}$. The J-variable is thus available for quantification. Since this meaning is almost identical to the meanings of the event-reporting verbs considered above, it is easy to see that the derivation of meanings such as (228) proceeds exactly as for event-reporting verbs. Thus, we obtain, for example:

(231) $[\![_{S}\text{Mary slept}]\!]_2 = \lambda J_0 \lambda I_0[\overline{\textsc{sleep}}(\textsc{mary})(J_0) \wedge J_0 \subseteq I_0]$

(232) $[\![_{\hat{S}}\text{Mary slept}]\!]_2 = \lambda P \lambda I_0[\mathbf{a}(\lambda J_0[\overline{\textsc{sleep}}(\textsc{mary})(J_0) \wedge J_0 \subseteq I_0], P)]$

(233) $[\![_{S}\text{Mary slept during the meeting}]\!] =$
$$\lambda J_0 \lambda I_1[\mathbf{the}(\lambda J_1[\textsc{meeting}(J_1) \wedge J_1 \subseteq I_1], \lambda I_0[\overline{\textsc{sleep}}(\textsc{mary})(J_0) \wedge J_0 \subseteq I_0])].$$

(234) $[\![_{\hat{S}}\ \text{Mary slept during the meeting}\ ]\!] =$
$$\lambda P \lambda I_1[\mathbf{a}(\lambda J_0[\mathbf{the}(\lambda J_1[\textsc{meeting}(J_1) \wedge J_1 \subseteq I_1], \lambda I_0[\overline{\textsc{sleep}}(\textsc{mary})(J_0) \wedge J_0 \subseteq I_0])], P)],$$

as required.

We end this section with a brief return to our earlier discussion of in. In section 4.4.1, we accounted for certain restrictions on the use of TPPs headed by throughout, for and until, as illustrated by the examples (118) and (122), as well as a restriction on the use of TPPs headed by in, as illustrated by example (134). In all cases, our account appealed to a restriction on the kind of quantification allowed in the modificands of these TPPs. But there is a further restriction on the use of in for which we have yet to account. Consider

(235) * Mary slept in five hours (yesterday).

This sentence ought to be blocked. But it looks like we can use the meaning (232) to generate:

(236) $*[\![_{\hat{S}}$ Mary slept in 5 hours $]\!] =$
$$\lambda P \lambda I_1[\mathbf{a}(\lambda J_1[\text{5-HOUR}(J_1) \wedge J_1 \subseteq I_1], \lambda I_0[\mathbf{a}(\lambda J_0[\overline{\text{SLEEP}}(\text{MARY})(J_0) \wedge J_0 \subseteq I_0], P)])],$$

So, apparently our account fails to block the derivation of a meaning for sentence (235). But on reflection, the unacceptability of this sentence is in fact *explained* by our account. For, according to the meaning (236), this sentence is equivalent to the simpler Mary slept. And if that is all we mean, then that is all we ought to say. Thus, just as we may suppose grammatical intuition to filter out logically false TPP-combinations, so too we may suppose it to filter out logically redundant ones.[29]

5.2 Stative subordinate clauses

Matters are slightly more difficult when state-reporting sentences form the complements of temporal prepositions. Consider the sentence:

(237) John telephoned Jane while Mary slept.

To derive the meaning of this sentence, we employ the existential meaning:

(238) $[\![_{\hat{S}}$ Mary slept $]\!]_2 = \lambda P \lambda I[\mathbf{a}(\lambda J[\overline{\text{SLEEP}}(\text{MARY})(J) \wedge J \subseteq I], P)]$.

and take while to have its normal meaning, except that it modifies an *existentially* quantified modificand. Thus, since $[\![_{TP}$while$]\!]$ is the identity function, we have:

(239) $[\![_{TPP}$while Mary slept$]\!] = [\![_{TP}$while$]\!]([\![_{\hat{S}}$Mary slept$]\!]_2) =$
$$\lambda P \lambda I[\mathbf{a}(\lambda J[\overline{\text{SLEEP}}(\text{MARY})(J) \wedge J \subseteq I], P)].$$

Pseudopplying this GTQ as above yields:

(240) $[\![_S$John telephoned Jane while Mary slept$]\!] =$
$[\![_{TPP}$while Mary slept$]\!](_2[\![_V$telephoned Jane$]\!])_2 =$
$$\lambda P' \lambda I_1[\mathbf{a}(\ \lambda J_1[\overline{\text{SLEEP}}(\text{MARY})(J_1) \wedge J_1 \subseteq I_1], P')](_2\ \lambda J_0 \lambda I_0[\text{TELEPHONE}(\text{JOHN}, \text{JANE})(J_0) \wedge J_0 \subseteq I_0])_2 =$$
$$\lambda J_0 \lambda I_1[\mathbf{a}(\lambda J_1[\overline{\text{SLEEP}}(\text{MARY})(J_1) \wedge J_1 \subseteq I_1], \lambda I_0[\text{TELEPHONE}(\text{JOHN}, \text{JANE})(J_0) \wedge J_0 \subseteq I_0])].$$

Determination proceeds as before, yielding:

(241) $[\![_{\hat{S}}$ John telephoned Jane while Mary slept $]\!] =$
$$\lambda P \lambda I_1[\mathbf{a}(\lambda J_0[\mathbf{a}(\lambda J_1[\overline{\text{SLEEP}}(\text{MARY})(J_1) \wedge J_1 \subseteq I_1], \lambda I_0[\text{TELEPHONE}(\text{JOHN}, \text{JANE})(J_0) \wedge J_0 \subseteq I_0])], P)].$$

Notice the need for the **a**-quantifier immediately before λJ_1: given our analysis of states, there is certainly no *unique* interval throughout which Mary slept, but rather infinitely many.[30]

What happens when state-reporting sentences form the main clause as well as the subordinate clause? Well, given what has already been said, we have the meanings:

(242) $[\![_{\hat{S}}$John read while Mary slept$]\!]_1 =$
$[\![_{TPP}$while Mary slept$]\!](_2[\![_{\hat{S}}$John read$]\!]_1)_2 =$

[29] Thus, we take the modification to the semantics of in proposed by Dowty [7], p. 335, for dealing with this problem, to be unnecessary.

[30] An alternative account is possible, where a state is modelled by predicates taken to be true only at *maximal* intervals throughout which it holds, and the temporal quantification in the subordinate is taken to be **the**, not **a**. This alternative is touched on below.

$$\lambda P \lambda I_1[\mathbf{a}(\lambda J_1[\overline{\text{SLEEP}}(\text{MARY})(J_1) \wedge J_1 \subseteq I_1],$$
$$\lambda I_0[\overline{\text{READ}}(\text{JOHN})(I_0)])].$$

(243) $[\![_{\hat{\text{S}}}\text{John read while Mary slept}]\!]_2 =$
$$\mathcal{R}_{\mathbf{a}}({}_1[\![_{\text{TPP}}\text{while Mary slept}({}_2[\![_{\hat{\text{S}}}\text{John read}]\!]_2)_2)_1 =$$
$$\lambda P \lambda I_1[\mathbf{a}(\lambda J_0[\mathbf{a}(\lambda J_1[\overline{\text{SLEEP}}(\text{MARY})(J_1) \wedge J_1 \subseteq I_1],$$
$$\lambda I_0[\overline{\text{READ}}(\text{JOHN})(J_0) \wedge J_0 \subseteq I_0])],$$
$$P)],$$

which turn out to be equivalent: on this reading, there is at least some interval throughout which John is reading and Mary is sleeping. This is the weakest of the possible readings of while.

However, according to a stronger (and, arguably, quite natural) reading of this sentence, we require that Mary slept over some definite interval within the toi, and John read throughout *that* interval, possibly longer. This reading requires an extension to the proposals made above. Specifically, we must assume temporal determination in the subordinate clause involves **the_maximal** defined by:

(244) $\lambda P \lambda Q[\mathbf{the\_maximal}(P, Q)] =_{\text{Def}} \lambda P \lambda Q[\exists J[\forall K[(P(K) \wedge K \subseteq I) \leftrightarrow K \subseteq J] \wedge Q(J)]].$

The resulting truth-conditions are then plausible. Depending on whether we take the universal or existential reading of the stative verb read, we get:

(245) $[\![_{\hat{\text{S}}}\text{John read while Mary slept}]\!]_3 =$
$$\lambda P \lambda I_1[\mathbf{the\_maximal}(\lambda J_1[\overline{\text{SLEEP}}(\text{MARY})(J_1) \wedge J_1 \subseteq I_1],$$
$$\lambda I_0[\overline{\text{READ}}(\text{JOHN})(I_0)])].$$

(246) $[\![_{\hat{\text{S}}}\text{John read while Mary slept}]\!]_4 =$
$$\lambda P \lambda I_1[\mathbf{a}(\lambda J_0[\mathbf{the\_maximal}(\lambda J_1[\overline{\text{SLEEP}}(\text{MARY})(J_1) \wedge J_1 \subseteq I_1],$$
$$\lambda I_0[\overline{\text{READ}}(\text{JOHN})(J_0) \wedge J_0 \subseteq I_0])],$$
$$P)].$$

Truth-condition (245) requires that John read throughout the maximal interval over which Mary slept, while (246) requires merely that John read for some of that interval.

In this section, we have only scratched the surface of the behaviour of state-reporting sentences as temporal preposition complements. As usual, these sentences raise a host of detailed problems which a fully adequate semantics would have to resolve. However, we do claim to have established the applicability, in principle, of the framework proposed in earlier sections. State-reporting sentences, though they involve a host of difficulties of their own, fit smoothly into our account.

6 Conclusion

Our aim in constructing this account of the semantics of temporal prepositions was to be as systematic as possible. Thus, for example, we laid great emphasis on dealing with all temporal prepositions in a uniform way, regardless of whether they modify temporal noun phrases or verb phrases, and regardless of whether their complements are temporal noun phrases, sentences or temporal preposition phrases. We also showed how, in sentences with multiple temporal preposition phrases, one preposition phrase characteristically restricts the range of quantification in the others, leading to a cascade of embedded quantifiers. We claimed that, despite the considerable literature on the semantics of prepositions generally, and the somewhat smaller literature on the semantics of temporal prepositions in particular, these semantic effects are not properly accounted for elsewhere.

This focus has endowed the resulting account with some rather unusual features. The first such feature is the double-indexing and insertion of the subset-relation in temporal noun meanings; we argued that this was the most elegant way to make sense of cascaded quantification with multiple TPPs. The second unusual feature is the relatively bland semantic assignments to the temporal prepositions themselves; this blandness is a result partly of our relational treatment of temporal nouns, and partly of our observations about the possible sources of temporal quantification in sentences. The third unusual feature is the employment of temporal generalized quantifiers to serve as the meanings of temporal noun phrases, sentences and temporal preposition phrases; this feature requires a somewhat ungainly finalization process to recover ordinary sentence-meanings, but otherwise contributes greatly to the uniformity of our theory.

Much work, as ever, remains. In the drive for systematicity, we have paid little attention to the idiosyncrasies of the various English temporal prepositions. We have ignored the vital topics of tense and aspect, as well as the predicative use of temporal prepositions and their role as verb complements. We have disregarded the way temporal prepositions exploit the time of reference, as well as their role in temporal anaphora. We have not investigated how our account of temporal prepositions meshes with existing work on non-temporal prepositions, and we have not pursued the inviting generalizations of our motivating observations to non-temporal domains. But despite these unanswered questions, we have nevertheless achieved a considerable degree of systematicity and coverage in our chosen domain. At the very least, the success of our account makes this remaining work worth undertaking.

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